Linking Representation and Reasoning: An Analysis of Mathematical Communication in Algebraic Word-Problem Solving

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ABSTRACT

Purpose – Mathematical communication is essential in 21st-century mathematics learning because it enables students to represent, explain, and interpret ideas when solving contextual problems. This study aimed to describe seventh-grade students' mathematical communication in solving algebraic word problems.

Methodology – A qualitative descriptive design was used. Seventh-grade students at SMP Negeri 3 Rambah Hilir were purposively selected to represent high-, middle-, and low-achieving groups based on classroom performance and test results. Data were collected using an algebraic word-problem written test and semi-structured interviews. Analysis followed data reduction, data display, and conclusion drawing. Mathematical communication was examined using three indicators: (1) translating contexts/diagrams into mathematical language or models; (2) explaining mathematical ideas and relationships in writing; and (3) reading and interpreting written mathematical representations.

Findings – Students' mathematical communication was low. High-achieving students met all indicators, producing accurate representations and coherent written reasoning. Middle-achieving students generally met indicators (1) and (3), but their written explanations (indicator 2) were incomplete or unclear. Low-achieving students struggled across indicators, particularly in forming algebraic models and interpreting representations, leading to incorrect or incomplete solutions. The results highlight the need for explicit scaffolding of representation, written explanation, and interpretation in algebraic word-problem instruction.

Novelty – This study offers an indicator-based profile of mathematical communication in algebraic word-problem solving across achievement levels using combined test and interview evidence.

Significance – The findings support teachers and curriculum developers in designing learning activities and assessments that strengthen communication, representation, and reasoning in junior secondary algebra.

1. Introduction

21st-century education demands that students have a wide range of skills to compete and adapt to global developments. 21st century skills known as 6C include: critical thinking, collaboration/cooperation, communication, creativity, culture, and connectivity (Islamiyah, Nasrullah, Yendra, Ratnasari & Khan, 2024; Rahayu, Cahyani, Herlina & Kumar, 2024; Loska, Ayuni & Ainirohmah, 2024; Fadilah, Nurhayati & Hermanto, 2024; Putri, Riyanti, Saputri, Wahyuni & Ullah, 2024). In line with this, Munthe & Karim (2021) also argues that one of the abilities that students must develop is mathematical communication skills. Students' mathematical communication skills are important and can be the foundation for understanding, conveying, and discussing ideas effectively (Lomibao et al., 2016).

There are two important reasons why communication in mathematics learning needs to be the focus of attention: 1) mathematics as language and 2) mathematics learning as social activity. According to the National Council of Teachers of Mathematics yalso emphasizes that communication skills are an important part of mathematics and mathematics education. Communication is closely related to daily problems presented in the form of story questions. Story questions can be used to assess students' mathematical communication skills (Hodiyanto, 2017). This is in line with the opinion Zulfa et al. (2024) which says that Story problems are often found in mathematics learning in the classroom and are closely related to mathematical communication skills. Algebra is one of the materials that must be mastered by students in learning mathematics, because it has a crucial role in solving contextual story problems (Maharani et al., 2019; Hayu & Angraini, 2024; Santika, Nisa, Nasrullah, Alfiyanti, Aminah & Dwiyanti, 2025; Cahayanik & Nurrahmawati, 2025; Parindang, Ramlan, Wahyuni & Salman, 2025; Dhani, Nurrahmawati, Afri & Khan, 2025; Devan, Angraini & Sadiq, 2025). In research Faizah & Sugandi (2022) also said that algebra is a very important material because implicitly or explicitly it needs to be mastered in daily life activities.

However, a preliminary study conducted by researchers at SMP Negeri 3 Rambah Hilir showed that the average score of students' mathematical communication ability tests based on three indicators of mathematical communication ability tested obtained an average score of 14.2 out of a maximum score of 100, which is in the low category. Isfayani (2023) said that grade VII students of Mutiara Junior High School experienced four mistakes in working on algebra problems, namely lack of understanding of positive and negative operations, lack of understanding of reading problems, errors in calculations, and incorrect use of processes. Septikayanti et al. (2022) Stating that students tend to have difficulties when solving story problems or everyday events into mathematical symbols, students are less able to connect pictures into mathematical ideas, students are still not used to writing down what is known and what is asked from the problem before solving it, so students often misinterpret the meaning of the problem. Based on this, the researcher feels the need to conduct a deeper analysis of how the mathematical communication skills possessed by grade VII students of SMP Negeri 3 Rambah Hilir.

2. Methods

This study uses a qualitative approach with a descriptive method. The subjects in this study are grade VII students of SMP Negeri 3 Rambah Hilir. The location and time of the research

were conducted at SMP Negeri 3 Rambah Hilir in the 2024/2025 school year. The data collection techniques used were written tests and interviews. The research instrument used was a mathematical communication ability test sheet in the form of story questions in the form of a description of algebraic form material consisting of 6 questions. The indicators of mathematical communication ability used, namely: 1) Stating a situation, picture, diagram, or real object into a mathematical language, symbol, idea or model; 2) Explain mathematical ideas, situations, and relationships orally or in writing; and 3) Reading with an understanding of written mathematical representations. The indicators of mathematical communication ability used as follows:

Table 1 - Indicators of Mathematical Communication Ability

Aspects	Indicator
Mathematical expression	Declaring a situation, picture, diagram, or real object into a mathematical language, symbol, idea or model
Written text	Explain mathematical ideas, situations, and relationships orally or in writing.
Reading	Reading with an understanding of written mathematical representations.

The data analysis techniques used in this study are analyzed namely data reduction, data presentation, and drawing conclusions. The story question instrument used by the researcher has been validated for content and construct validation. In content validation, the researcher asked for expert assessments related to the relevance of the question items prepared with basic competencies, indicators of mathematical communication skills. Content validation is carried out by discussing with experts. This validation is carried out to determine the feasibility of the test questions used by revising them according to the direction of the validator. The validators are 2 lecturers. Then an analysis of the validation sheet was carried out using the Aiken's V formula as follows:

$$V = \frac{\sum S}{n(c-1)}$$

Description :
V   : Index of validator agreement regarding the validation of question items
S   : Validator score minus lowest score
n   : Number of validators
c   : The number of categories that validators can choose from

Table 2 - Expert Validation Assessment Criteria

Interval	Criteria
$0.00 < V \leq 0.4$	Less
$0.4 < V \leq 0.8$	Medium
$0.8 < V$	Sangar Valid

(Aiken, 2010)

The results of the expert assessment were analyzed using the Aiken's V approach as follows:

Table 3 - Validation sheet analysis results by validators

Item	S1	S2	V	Criteria
1	3	3	0,67	Medium
2	3	4	0,83	Highly Valid

Item	S1	S2	V	Criteria
3	3	3	0,67	Medium
4	3	3	0,67	Medium
5	3	4	0,83	Highly Valid
6	3	4	0,83	Highly Valid

Based on Table 3, it can be seen that question items number 1, 3, and 4 get moderate criteria. Meanwhile, question items number 2, 5, 6 get very valid criteria.

Then, after the content validation, the researcher validates the construct using validity, differentiation, difficulty, and reliability tests. Most of the questions are declared valid and can be used even with variations in DP (good/adequate) and kindergarten (easy/difficult). Question number 5 was declared invalid, bad in DP, medium in kindergarten, and therefore could not be used. Based on the reliability of the test instrument of the test questions determined using Cronbach's Alpha (α) formula on the r11 table with a significance level of 5%, the results of the test reliability calculation were obtained, which was r11 = 0.77. Based on the classification of the reliability coefficient of the instrument, $0.60 \leq r < 0.80$, so that the test instrument is declared to have a high level of reliability.

3. Results and Discussion

3.1 Results

The results of the data research were presented in the description of the test results and the interviews conducted. The data obtained in this study are of two types: the first is a written test, and the second is interview data.

Table 4 - Description of Students' Mathematical Communication Abilities Per Individual

Categories	Number of Students	Percentage of students	Average MOH
Height	5	19%	68,3
Medium	10	38%	45,8
Low	11	42%	32,6
Average score			44,5

The results showed that students' overall mathematical communication skills had an average score of 44.5, which was in the low category. Of the 26 students studied, 5 (19%) were in the high category, 10 (38%) in the medium category, and 11 (42%) in the low category.

Table 5 - Description of Students' Mathematical Communication Skills Indicator

Indicator	Total Scores by Category			Total Score	Introduce yourself	Categories
	Height	Medium	Low			
Expressing situations, pictures, diagrams, or real things into mathematical language, symbols, ideas, or models	17	23	18	58	56%	Medium
Explain mathematical ideas, situations and relationships in writing	12	10	6	28	27%	Low

Indicator	Total Scores by Category			Total Score	Introduce yourself	Categories
	Height	Medium	Low			
Reading with an understanding of written mathematical representations	12	22	19	53	51%	Medium

Indicator Declares the situation into a mathematical model: This indicator has a medium category with a percentage of 56%. Although some students are able to write algebraic equations correctly, there are students who are unable to understand the problem well and are unable to translate the situation into mathematical models. Indicator Explain mathematical ideas, situations and relationships in writing: This indicator is in the low category with a percentage of 27%. Many students are unable to explain mathematical ideas and relationships in writing, even after successfully simplifying algebraic expressions. Reading Indicator with understanding of written mathematical representations: This indicator has a medium category with a percentage of 51%. Students with high categories are able to understand the problem well and give reasons for the answers, while students with low categories have difficulty interpreting the questions.

3.1.1 Analysis of Students' Answers to Medium Subject (ISM)

Figure 1. Answer Number 1 of The Ism Subject

Figure 1 presents ISM's written response to Problem 1. A detailed examination of the solution indicates that the student systematically followed key stages of mathematical problem solving. In Box 1, ISM explicitly identified the known information and the quantity being asked. This step reflects the student's ability to interpret the problem context and reorganize it into structured mathematical statements, which is consistent with the first phase of problem comprehension.

In Box 2, ISM determined the side length of the new cube by appropriately translating the contextual information into an algebraic representation. This demonstrates the student's capacity to construct a mathematical model from a verbal description. The modeling process suggests that ISM was able to abstract relevant quantitative relationships from the problem situation.

Box 3 shows that ISM correctly formulated the mathematical expression for the volume of a cube. The use of the formula ($V = s^3$) indicates conceptual understanding of geometric principles rather than mere procedural recall. Subsequently, in Box 4, ISM performed the algebraic manipulation accurately and arrived at a logically consistent conclusion. The computational steps were coherent, sequential, and free from arithmetic errors.

To triangulate the written data, an in-depth interview was conducted with ISM. The interview findings confirm that the student had a clear understanding of the problem structure and could articulate the reasoning underlying each procedural step. ISM explained the transformation from the contextual scenario into algebraic form with confidence and conceptual clarity. This indicates that the written performance was not coincidental but grounded in meaningful understanding.

However, a minor inconsistency was identified in the student's final written response, specifically in the statement of the requested rank (or classification) in the problem. This error appears to stem from inattention rather than a conceptual misunderstanding, as the reasoning leading to the solution was mathematically sound. Thus, the error can be categorized as a representational oversight rather than a deficiency in conceptual or procedural competence. ISM demonstrates fulfillment of key mathematical communication indicators, including:

a. Expressing real-world situations in mathematical language and symbolic form.
b. Constructing appropriate mathematical models.
c. Applying relevant formulas accurately.
d. Executing algebraic operations systematically.

These findings position ISM within the medium-ability category, characterized by adequate conceptual understanding, coherent procedural execution, and minor representational inaccuracies. The data suggest that the student's mathematical competence is structurally sound, though carefulness in final representation remains an area for improvement.

3.1.2 Analysis of Student Answers on Medium Subject (ISM)
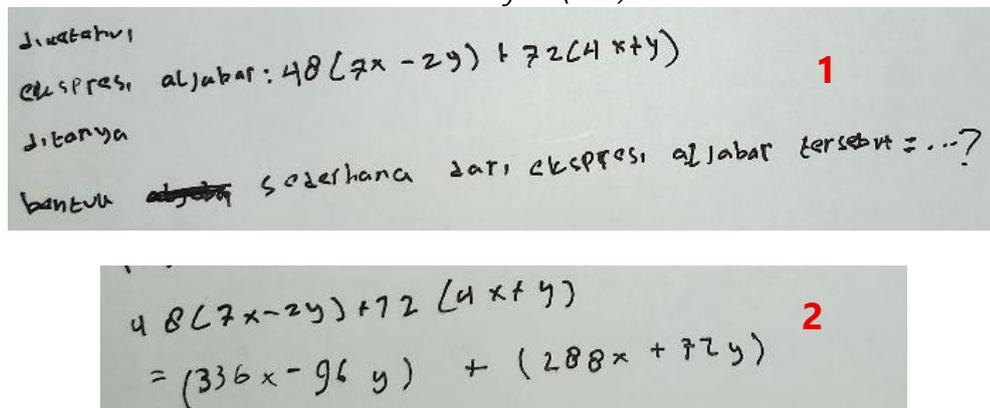
Figure 2. Answer to question number 2 ISM subject

Figure 2 presents ISM's written response to Problem 2. A close examination of the solution reveals a partial fulfillment of the expected problem-solving indicators.

In Box 1, ISM explicitly stated the known information and identified the quantity being asked. This indicates that the student was able to comprehend the problem context and restate it in mathematical terms. Such performance reflects adequate problem interpretation

skills and suggests that ISM successfully engaged in the initial stage of mathematical problem solving, namely understanding and organizing given information.

Box 2 demonstrates that ISM attempted to manipulate algebraic expressions. The written work shows that the student applied relevant algebraic operations, indicating familiarity with symbolic procedures. Furthermore, the structure of the expressions suggests that ISM recognized the operational relationships embedded in the problem. This procedural attempt reflects an emerging ability to work within formal algebraic systems.

To triangulate the written response, an in-depth interview was conducted. The interview findings reveal that ISM was able to verbally explain the properties of the operations involved, including the rules governing algebraic manipulation. This suggests that the student possesses declarative knowledge of operational properties and understands the theoretical basis underlying the procedures used.

However, despite demonstrating conceptual awareness and procedural initiation, ISM was unable to complete the solution correctly. The difficulty appeared during the transformation stage, where multiple algebraic steps required sustained logical coordination. The student's reasoning became fragmented, leading to an incomplete or incorrect final result. This indicates a gap between conceptual recognition and procedural execution, particularly in maintaining consistency across sequential algebraic operations.

From a cognitive perspective, this pattern suggests that ISM operates at an intermediate level of mathematical competence. The student demonstrates adequate comprehension and partial procedural fluency but experiences difficulty integrating multiple algebraic processes into a coherent solution pathway. The obstacle is therefore not rooted in misunderstanding fundamental concepts, but rather in limited strategic control and procedural endurance during complex manipulation. ISM fulfills several indicators of mathematical communication and reasoning, including:

a. Identifying and restating known and unknown quantities.
b. Translating contextual information into algebraic form.
c. Recognizing and explaining relevant operational properties.

Nevertheless, the inability to complete the problem highlights a need for strengthening procedural coherence, strategic monitoring, and error-checking mechanisms. These findings reinforce the classification of ISM as a medium-ability student, characterized by adequate conceptual understanding but inconsistent procedural consolidation when confronted with higher cognitive demands.

3.1.3 Low-category subjects (FAL)

Figure 3. Answer to question number 2 FAL subject

Figure 3 illustrates FAL's written response to Problem 2. An analysis of the student's work reveals limited but identifiable engagement with the problem-solving process.

In Boxes 1 and 2, FAL correctly performed individual algebraic operations on the given expressions. This indicates that the student possesses basic procedural knowledge related to algebraic manipulation at a local level. The accuracy of these isolated operations suggests that FAL is familiar with elementary algebraic rules and can apply them in straightforward contexts.

However, FAL did not proceed to recombine the two algebraic expressions into a unified mathematical form, which was a critical step required to complete the problem. This omission reflects a breakdown in integrative reasoning, where separate algebraic components must be coordinated into a coherent solution. The student's work therefore remains fragmentary and incomplete, despite the correctness of the individual steps performed.

To validate the written data, an in-depth interview was conducted with FAL. The interview findings indicate that FAL was able to explain the meaning of the problem and articulate the intended solution in general terms. This suggests that the student understood the problem context and the overall goal of the task. Nevertheless, FAL encountered difficulty in translating this understanding into a complete and accurate mathematical solution.

The discrepancy between conceptual understanding and written execution points to a weakness in procedural integration rather than in problem comprehension. FAL appears to struggle with connecting sequential algebraic steps and maintaining logical continuity throughout the solution process. This limitation is characteristic of low-ability students, who may demonstrate partial procedural competence but lack strategic control and structural coherence in problem solving. FAL demonstrates partial fulfillment of mathematical communication indicators, including:
a. Understanding the problem context.
b. Performing basic algebraic operations correctly.
c. Expressing an initial mathematical response.

However, the failure to integrate and complete the algebraic process indicates insufficient procedural consolidation. These findings support classifying FAL within the low-ability category, characterized by fragmented procedural knowledge and limited capacity to synthesize multiple algebraic elements into a complete solution.

3.2 Discussion

The findings of this study reveal clear qualitative distinctions in mathematical communication skills across high-, medium-, and low-ability students. The integration of written test results and in-depth interviews demonstrates that mathematical communication is not merely a matter of procedural accuracy but involves a complex interaction between conceptual understanding, symbolic representation, and the ability to articulate reasoning coherently.

Students in the high-ability category consistently demonstrated comprehensive mastery across multiple indicators of mathematical communication. They were able to (1) interpret and restate problem situations accurately, (2) construct appropriate mathematical models, (3) use symbolic representations correctly and consistently, and (4) provide logically structured conclusions. Importantly, interview data confirmed that their written responses were grounded in conceptual understanding rather than mechanical execution. These findings align with those of Ma'rifah et al. (2020), who reported that students with high mathematical communication skills excel at representing story problems mathematically and at articulating problem structures using formal symbols. The present study extends these findings by

showing that high-ability students also exhibit metacognitive control, evidenced by coherent sequencing and error minimization throughout the solution process.

In contrast, students in the medium-ability category partially met the communication indicators. They were generally able to identify known and unknown quantities and apply relevant formulas or operations. However, their work often revealed inconsistencies in representation, fragmented reasoning, or incomplete procedural integration. Although symbolic expressions were appropriately used in isolated steps, maintaining logical coherence across multiple operations proved challenging. This pattern corroborates the findings of Faizah and Sugandi (2022), who observed that medium-ability students demonstrate adequate written communication but lack consistency in meeting all established indicators. The present findings suggest that the limitation lies not in basic conceptual knowledge, but in the integration and coordination of symbolic, procedural, and explanatory components.

Students in the low-ability category exhibited substantial difficulties across nearly all indicators of mathematical communication. They struggled to accurately restate the given information, inconsistently used mathematical symbols, and frequently failed to complete the solution process. Interview data indicated that while some students had a partial intuitive understanding, they encountered significant barriers in translating it into a formal mathematical representation. These results are consistent with Dewanti and Muna (2023), who reported that low-ability students often fail to meet core communication indicators and require targeted instructional intervention. The present study reinforces this conclusion by demonstrating that deficiencies at this level are structural rather than incidental, involving weaknesses in conceptual grounding, symbolic fluency, and procedural synthesis.

Collectively, these findings suggest that mathematical communication develops hierarchically. High-ability students demonstrate integrated competence across interpretation, representation, symbolic manipulation, and justification. Medium-ability students exhibit foundational competence but lack structural coherence. Low-ability students show fragmented understanding and limited representational control. The differences observed across categories, therefore, reflect not only variations in performance level but also differences in the organization and coordination of mathematical knowledge.

From a pedagogical perspective, these results imply that instructional strategies should be differentiated according to students' communicative profiles. For medium-ability students, emphasis should be placed on strengthening procedural integration and reflective monitoring. For low-ability students, instruction should prioritize conceptual reconstruction and explicit modeling of mathematical representation. Enhancing opportunities for structured mathematical discourse may also serve as a bridge between conceptual understanding and symbolic expression.

This study confirms and extends previous research by demonstrating that mathematical communication skills are multidimensional and stratified across ability levels. The triangulation of written and interview data provides robust evidence that the quality of mathematical communication reflects deeper cognitive organization, underscoring its central role in mathematical problem-solving.

4. Conclusions

Based on the description and analysis of the research results, it can be concluded that, of the 26 students studied. The average score of students' mathematical communication skills is 44.5, which is in the low category. Students who have mathematical communication skills in the

high category (5 people) represent only 19% of 26 students; students in the medium category (10 people) represent only 38% of 26 students; and students in the low category (11 people) represent only 42% of 26 students. Students with high categories can express situations in mathematical models, perform algebraic operations, and draw conclusions effectively. Students in the medium category can write down the solution steps and explain mathematical ideas, but they make errors in writing the ranks, are unable to describe the nature of algebraic calculation operations, and can read and understand written mathematical representations. Students in low categories are unable to write down problem-solving steps, have difficulty explaining mathematical ideas and situations, and are less able to understand mathematical problems and representations.

Acknowledgments

Conflict of Interest

The authors declare no conflicts of interest.

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