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Ninth-Grade Students' Mathematical Communication Skills in Solving Statistics Problems: An Indicator-Level Analysis

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Abstract

Mathematical communication enables students to express mathematical ideas through explanations, symbols, and representations. In problem solving, however, students may be able to organize mathematical ideas without being equally able to communicate their reasoning coherently and precisely. This study aimed to analyze the mathematical communication skills of ninth-grade students in solving statistics problems. A quantitative descriptive design was employed with 34 ninth-grade students from SMPN 1 Tempuran during the second semester of the 2025/2026 academic year. Data were collected through a four-item written essay test developed based on four mathematical communication indicators. The data were analyzed using descriptive statistics, including mean, standard deviation, percentage, and classification based on the mean and standard deviation. The students' overall mathematical communication performance was moderate, with a mean score of 49.45 (SD = 19.846). Most students (73.53%) were classified in the moderate category, followed by 14.71% in the high category and 11.76% in the low category. Indicator-level analysis revealed an uneven pattern of achievement. The highest achievement was found in organizing and consolidating mathematical thinking through communication (76.47%), whereas the lowest was found in using mathematical language to express mathematical ideas accurately (33.09%). These findings indicate that students were more able to organize mathematical ideas than to communicate those ideas through precise mathematical language and coherent written explanations. The study provides an empirical profile of students' mathematical communication in statistics problem solving and highlights the need for instruction that explicitly develops explanation, justification, and accurate mathematical expression.

INTRODUCTION

Mathematical communication is an important part of students' mathematical learning because mathematical ideas need to be organized, expressed, interpreted, and discussed rather than only obtained through calculation. Communication is closely related to mathematical reasoning and problem solving, particularly when students are required to explain how they obtain an answer and justify the strategies they use. Recent research has shown a relationship between mathematical communication, mathematical reasoning, and problem-solving abilities, indicating that these competencies do not operate independently (Aljura et al., 2025; Izzati et al., 2026). In classroom learning, communication also provides a way for students to make their mathematical thinking visible to teachers and peers. However, communication in mathematics involves more than presenting a final answer. It includes the organization of mathematical ideas, the coherence of explanations, the interpretation of mathematical thinking, and the appropriate use of mathematical language (Planas & Pimm, 2024). Therefore, examining students' mathematical communication requires attention to how they express and develop mathematical ideas during problem solving.

Students may experience difficulties when they have to transform their mathematical thinking into a clear explanation. Research on junior high school students has shown that mathematical communication during problem solving can be examined through the processes students use to develop and express their mathematical ideas (Sumaji et al., 2020). Similar concerns have been reported in studies of written mathematical communication, where students' responses can reveal differences in their ability to communicate mathematical reasoning through written representations and explanations (Susilowati et al., 2025). These difficulties are also related to the language demands of mathematics. Mathematical language is not simply a matter of vocabulary; students need opportunities to use language to construct, explain, and communicate mathematical meanings (Erath et al., 2021). Studies involving mathematics classrooms in different countries further indicate that linguistic challenges can affect students' participation in mathematical learning and their ability to express mathematical ideas (Planas et al., 2025). Consequently, assessing mathematical communication should not be limited to whether students obtain correct answers, but should also consider the quality and form of the mathematical communication used to reach and explain those answers.

The issue becomes particularly relevant in statistics, where students are expected to work with data, representations, calculations, interpretations, and conclusions. Statistical problems require students not only to perform procedures but also to communicate what the data mean and explain the reasoning underlying their conclusions. Evidence from secondary education indicates that statistical literacy can be examined in relation to students' mathematical communication skills, suggesting that communication is relevant to students' engagement with statistical content (Andriani et al., 2024). Mathematical discourse can also support students' conceptual and procedural understanding of probability and statistics, showing the importance of opportunities for students to articulate and discuss mathematical ideas in these topics (Legesse et al., 2020). In this context, students' performance in solving statistical problems provides an opportunity to examine whether they can organize their mathematical thinking, communicate it coherently, evaluate mathematical thinking or strategies, and use mathematical language accurately. These aspects are important because a correct calculation does not necessarily indicate that students can communicate the mathematical meaning of their solution.

Although previous studies have examined mathematical communication in relation to reasoning, problem solving, mathematical discourse, written responses, and language, the findings do not necessarily provide a detailed picture of students' performance across different communication indicators. Research has established the importance of communication for mathematical learning and has examined students' communication processes in problem solving (Aljura et al., 2025), while other studies have investigated written communication and instructional approaches for developing communication skills (Siswantari et al., 2025; Tong et al., 2021). Research on mathematics language has also emphasized the need to distinguish communication from broader language-related issues and to examine how language functions in mathematics learning (Zahner et al., 2021). However, there remains a need for an empirical description that distinguishes students' abilities to organize and consolidate mathematical thinking through communication; communicate mathematical thinking coherently and clearly to peers, teachers, and others; analyze and evaluate the mathematical thinking and strategies of others; and use mathematical language to express mathematical ideas accurately. An indicator-specific analysis is therefore useful for identifying which aspects of mathematical communication have developed and which aspects still require instructional attention.

Based on this consideration, this study aims to analyze ninth-grade students' mathematical communication skills in solving statistics problems based on four indicators: organizing and consolidating mathematical thinking through communication; communicating mathematical thinking coherently and clearly to peers, teachers, and others; analyzing and evaluating the mathematical thinking and strategies of others; and using mathematical language to express mathematical ideas accurately. The study provides an empirical profile of students' overall mathematical communication performance as well as their performance on each indicator. This profile is expected to provide a more specific description of students' mathematical communication in statistical problem solving and to identify aspects that can be addressed through mathematics instruction. The findings may therefore provide a basis for designing learning activities that give students greater opportunities to explain, discuss, evaluate, and express mathematical ideas using appropriate mathematical language.

METHODS

Research Design

This study employed a quantitative descriptive research design to describe ninth-grade students' mathematical communication skills in solving statistics problems. A quantitative descriptive design was appropriate because the study focused on systematically obtaining and describing numerical information about students' performance without manipulating instructional conditions or testing the effect of an intervention. In quantitative research, the quality of a study depends on an appropriate design and the use of reliable and valid measurements to represent the variables under investigation (Duckett, 2021). In mathematics education, a descriptive quantitative design has also been used to obtain an empirical description of students' mathematical abilities based on their observed performance (Putri et al., 2026). Accordingly, the present study analyzed students' scores from written statistics problems to describe their overall mathematical communication performance and achievement across the assessed indicators

Participants

The study was conducted at SMPN 1 Tempuran during the second semester of the 2025/2026 academic year. The participants consisted of 34 ninth-grade students from one class. All students in the selected class participated in the study; therefore, total sampling was used. The participants were assessed individually through written statistics problems. Because the study involved students from one selected class, the findings were interpreted as a description of the participants' mathematical communication performance within the research context and were not intended to represent all ninth-grade students.

Instrument

Data were collected using a written essay test consisting of four statistics problems. The tasks were designed to elicit students' mathematical thinking through written solutions, allowing their mathematical communication to be examined from the way they organized and expressed mathematical ideas (Zulkarnain et al., 2021). Each problem was developed to assess one of the four mathematical communication indicators presented in Table 1.

Table 1. Mathematical Communication Indicators Assessed in the Written Test

No.	Mathematical Communication Indicator	Focus of Assessment	Item
1	Organizing and consolidating mathematical thinking through communication	Students organize and connect relevant mathematical information, ideas, and procedures when constructing a solution.	1
2	Communicating mathematical thinking coherently and clearly to peers, teachers, and others	Students present their mathematical reasoning and solution steps in a logical, understandable, and coherent manner.	2
3	Analyzing and evaluating the mathematical thinking and strategies of others	Students examine, interpret, and evaluate the mathematical reasoning or strategy presented in a solution.	3
4	Using mathematical language to express mathematical ideas accurately	Students use appropriate mathematical terms, symbols, representations, and statements to communicate mathematical ideas accurately.	4

Students were instructed to show their solution processes and provide explanations rather than write only the final answers. The written responses were subsequently scored according to the criteria established for each indicator.

Scoring Procedure

Students' written responses were assessed using a scoring rubric based on the four mathematical communication indicators. The scoring considered the mathematical ideas presented in the response, the clarity and coherence of the explanation, the treatment of mathematical reasoning or strategies, and the accuracy of mathematical expression. The use of indicator-based assessment is consistent with the examination of mathematical communication through students' mathematical reasoning and written work (Pantaleon et al., 2023). Each response was assigned a score according to the established scoring criteria. The scores from the four problems were then summed to obtain each student's overall mathematical communication score.

Data Analysis

The data were analyzed using descriptive statistics to describe students' overall mathematical communication performance and their achievement on each indicator. This approach is appropriate for examining students' mathematical communication in relation to mathematical problem solving and related mathematical competencies (Palinussa et al., 2021). The mean score was calculated using: $\bar{X} = \frac{\sum X_i}{N}$ where $\bar{X}$is the mean score, $\sum X_i$is the total score obtained by all participants, and $N$is the number of participants.

Students' overall scores were classified into three categories based on the mean and standard deviation:

Table 2. Classification Criteria for Students' Mathematical Communication Scores

Category	Criterion
High	$X \geq \bar{X} + SD$
Moderate	$\bar{X} - SD \leq X < \bar{X} + SD$
Low	$X < \bar{X} - SD$

For each mathematical communication indicator, achievement was calculated as a percentage: $P = \frac{S}{S_{\max}} \times 100\%$, where $P$is the percentage of achievement, $S$is the total score obtained by all students for an indicator, and $S_{\max}$is the maximum possible score for that indicator. The resulting percentages were used to describe the level of achievement for each mathematical communication indicator. The use of mathematical communication as an outcome that can be examined alongside problem-solving and reasoning performance is also supported by Pourdavood et al. (2020).

RESULT

Descriptive Statistics

The study involved 34 ninth-grade students who completed a written test consisting of four statistics problems. Students' responses were scored using the predetermined scoring criteria for the four mathematical communication skill indicators. Descriptive statistics were calculated to summarize students' overall performance in the test, including the highest score, lowest score, mean score, and standard deviation.

Table 3. Descriptive Statistics of Students' Mathematical Communication Test Scores

Number of Students	Highest Score	Lowest Score	Mean Score	Standard Deviation
34	81.25	6.25	49.45	19.846

The students' scores ranged from 6.25 to 81.25, with a mean score of 49.45 and a standard deviation of 19.846. The range of scores indicates variation in students' overall mathematical communication performance.

Classification of Students' Mathematical Communication Skills

Students' overall scores were classified into high, moderate, and low categories using the mean and standard deviation. The classification results are presented in Table 4.

Table 4. Classification of Students' Mathematical Communication Test Scores

Category	Score Criterion	Number of Students	Percentage (%)
High	$X \geq 69.30$	5	14.71
Moderate	$29.60 \leq X < 69.30$	25	73.53
Low	$X < 29.60$	4	11.76
Total	—	34	100

Note. X represents the individual student score. The classification limits were derived from the mean score ($\bar{X} = 49.45$) and standard deviation ($SD = 19.846$).

As shown in Table 4, 25 students (73.53%) were classified in the moderate category. Five students (14.71%) were classified in the high category, while four students (11.76%) were classified in the low category. Thus, the largest proportion of participants was in the moderate category.

Achievement by Mathematical Communication Skill Indicator

The students' performance was further examined across the four mathematical communication skill indicators. For each indicator, the total score and percentage of achievement were calculated to identify the distribution of performance across the assessed aspects.

Table 5. Achievement of Mathematical Communication Skill Indicators

Mathematical Communication Skill Indicator	Total Score	Percentage (%)	Category
Organizing and consolidating mathematical thinking through communication	104	76.47	High
Communicating mathematical thinking coherently and clearly to peers, teachers, and others	51	37.50	Low
Analyzing and evaluating the mathematical thinking and strategies of others	69	50.74	Moderate
Using mathematical language to express mathematical ideas accurately	45	33.09	Low

Note. The maximum possible score for each indicator was 136, based on 34 students and a maximum score of 4 per student.

The highest percentage of achievement was obtained for organizing and consolidating mathematical thinking through communication, at 76.47%, which was categorized as high. The achievement for analyzing and evaluating the mathematical thinking and strategies of others was 50.74%, corresponding to the moderate category. The two remaining indicators were categorized as low: communicating mathematical thinking coherently and clearly to peers, teachers, and others at 37.50%, and using mathematical language to express mathematical ideas accurately at 33.09%. Overall, the results show an uneven pattern of achievement across the four mathematical communication skill indicators. Students obtained the highest achievement percentage in organizing and consolidating mathematical thinking through communication (76.47%), whereas the lowest percentage was observed in using mathematical language to express mathematical ideas accurately (33.09%).

DISCUSSION

The findings reveal that students' mathematical communication was not developed uniformly across the four indicators. The most notable pattern was the difference between students' ability to organize and consolidate mathematical thinking and their ability to communicate that thinking clearly and accurately. Achievement in organizing mathematical thinking reached 76.47%, whereas communicating mathematical thinking coherently and clearly reached only 37.50%, and using mathematical language accurately reached 33.09%. The intermediate achievement in analyzing and evaluating mathematical thinking and strategies of others (50.74%)

further indicates that the four aspects did not progress at the same level. This pattern is consistent with the view that mathematical communication comprises several related but distinguishable components that can be assessed through students' mathematical work (Cai et al., 1996). Recent work has likewise examined mathematical communication in relation to students' thinking processes, suggesting that communication is closely connected to how mathematical ideas are constructed, organized, and expressed (Quane, 2026). In the present study, therefore, the overall distribution should not be interpreted simply as evidence of a moderate level of mathematical communication. More importantly, it shows a gap between students' capacity to organize mathematical ideas and their capacity to make those ideas sufficiently explicit for another person to follow.

The relatively high achievement in organizing and consolidating mathematical thinking suggests that students were generally able to establish a mathematical structure when working on the statistics tasks. Their responses could contain relevant information, mathematical procedures, and an identifiable sequence of solution steps, indicating that the students were able to engage with the mathematical content of the problems. This interpretation is supported by studies examining mathematical communication through problem solving, in which students' written mathematical work provides evidence of how they organize and represent their thinking (Zahri et al., 2021; Ata Baran & Kabael, 2021). Mahadini et al. (2025) similarly demonstrate the relevance of examining written mathematical communication through students' problem-solving performance. However, the present findings also show that an organized solution is not necessarily a well-communicated solution. The substantial difference between the 76.47% achievement in organizing mathematical thinking and the 37.50% achievement in communicating it coherently indicates that students may be able to construct a workable solution without fully articulating the reasoning that connects its elements. Thus, the issue identified in this study is not simply whether students can produce mathematical work, but whether they can transform that work into an explanation that makes their reasoning accessible to a reader.

This distinction is particularly evident in the low achievement in communicating mathematical thinking coherently and clearly. A written mathematical response requires students to do more than list calculations or present a final answer; the response must establish connections among mathematical statements and make the reasoning behind the solution understandable. Santos and Semana (2015) demonstrated the importance of written communication in mathematics, particularly when students are required to develop mathematical ideas through written exposition. Riccomini et al. (2024) further showed the instructional importance of enabling students to explain mathematical reasoning through written expression, while Valdés-León et al. (2026) examined the textual characteristics of mathematical explanations in secondary mathematics contexts. These studies help clarify the present finding: students' difficulty may emerge at the point where mathematical thinking has to be externalized as an explicit explanatory sequence. The moderate achievement in analyzing and evaluating the mathematical thinking and strategies of others (50.74%) also fits this interpretation. Evaluating another solution requires students to attend to the logic of mathematical reasoning, rather than merely recognize whether an answer is correct. Classroom discourse and sociomathematical norms can provide an environment in which such reasoning is examined and communicated (Mokwana et al., 2024; Cholily et al., 2026). The moderate result therefore suggests an emerging capacity to engage with mathematical reasoning, but one that is not yet consistently accompanied by clear written explanation.

The lowest achievement, 33.09%, occurred in using mathematical language to express mathematical ideas accurately. This finding is closely related to, but distinct from, the difficulty in producing coherent explanations. A response can contain a recognizable line of reasoning while still being imprecise because mathematical terms, symbols, notation, or expressions are used inconsistently. The importance of mathematical vocabulary in constructing mathematical meaning has been emphasized by Riccomini et al. (2015), while Thinwiangthong et al. (2024) specifically examined symbolic mathematical communication and the ways mathematical ideas are represented through formal symbolic forms. Evidence of errors in students' verbal and written mathematical communication also indicates that difficulties in expressing mathematical meaning can occur even when students are engaged in solving the underlying problem (Maulyda et al., 2020). Azizah et al. (2020) likewise highlight written mathematical communication in students' problem-solving responses. In the present study, the combination of low performance in coherent communication (37.50%) and even lower performance in accurate mathematical language (33.09%) suggests that students' difficulties were concentrated in the process of making mathematical meaning explicit and precise. In statistics problems, this distinction becomes particularly important because a numerical result needs to be communicated in a form that allows its mathematical meaning to be understood rather than merely calculated. The findings therefore point to a specific weakness in the transition from mathematical work to mathematically precise written expression.

Taken together, the findings indicate that mathematical communication should be understood as a process extending from the organization of mathematical ideas to their explanation, evaluation, and precise expression. The relatively high performance in organizing mathematical thinking did not translate into comparable performance in coherent explanation or mathematical language, while the moderate performance in evaluating others' thinking suggests that students' engagement with mathematical reasoning was developing but remained uneven. This pattern reinforces the importance of assessing mathematical communication at the indicator level rather than relying only on an aggregate score (Cai et al., 1996; Yulian et al., 2023). For instruction, the implication is that students need opportunities to explain why a procedure is appropriate, connect successive steps, evaluate alternative solutions, interpret statistical results, and express their reasoning using appropriate mathematical terminology and notation. Written mathematical communication can therefore become an explicit component of assessment rather than an incidental product of problem solving. The relevance of such an approach is supported by research on written communication, mathematical explanation, and mathematical language (Santos & Semana, 2015; Riccomini et al., 2015; Riccomini et al., 2024). At the same time, the findings should be interpreted within the study's scope: the data were obtained from 34 ninth-grade students at one school and from four written statistics problems. The study consequently provides a contextual profile of students' written mathematical communication rather than a basis for broad generalization, and the descriptive design does not establish the causes of the differences among indicators. Further studies could combine written tasks with interviews, classroom discourse, or observations to examine how students move from organizing mathematical ideas toward explaining, evaluating, and expressing those ideas precisely.

CONCLUSIONS

This study examined ninth-grade students' mathematical communication skills in solving statistics problems using a descriptive quantitative approach. The findings from 34 students indicate that their overall performance was at a moderate level, with a mean score of 49.45 (SD = 19.846). Most students (73.53%) were classified in the moderate category, while 14.71% were classified as high and 11.76% as low. More importantly, the indicator-level analysis revealed that mathematical communication was not developed uniformly across the assessed aspects. Students demonstrated their strongest performance in organizing and consolidating mathematical thinking through communication (76.47%). In contrast, their achievement was lower in analyzing and evaluating mathematical thinking and strategies of others (50.74%), communicating mathematical thinking coherently and clearly (37.50%), and using mathematical language to express mathematical ideas accurately (33.09%). The pattern indicates that students were more able to organize mathematical ideas in their solutions than to communicate those ideas through coherent explanations and precise mathematical language. Thus, the main finding is not simply that students' overall mathematical communication was moderate, but that substantial differences existed among the components of the skill assessed in the context of statistics problem solving. These findings suggest that mathematics instruction should give explicit attention to the transition from organizing mathematical ideas to explaining, evaluating, and expressing them precisely. In particular, students should be provided with opportunities to justify solution procedures, explain relationships among steps, evaluate mathematical strategies, interpret statistical results, and use appropriate mathematical terminology and notation. The findings should be interpreted within the scope of the study, which involved 34 ninth-grade students and four written statistics problems at one school. Further research involving larger and more diverse samples and combining written tasks with interviews or classroom discourse analysis could provide a broader account of how students develop mathematical communication in statistics.

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