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A study of mathematical communication ability in writing on real numbers and polynomials of grade 10 students

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Abstract

Background: Mathematical communication is the clear expression of ideas using math language and symbols, either in speech or writing. Without effective writing skill, students may not write steps of problem-solving clearly, and this leads to confusion and ineffective learning. This negatively affects performance in academic work since mathematics is based on logical progression and effective communication can lead to misunderstood problems and incorrect solutions.
Aims: This research aims to study the mathematical communication ability in writing, focusing on their ability to use mathematical language and symbols to express concepts.
Methods: Quantitative survey was conducted by defining research questions, selecting 40 Grade 10 students from Sarakhampittayakhom School, designing a mathematical communication ability test in writing, distributing the test, collecting post-instruction data, analyzing the data using descriptive statistics, and presenting the research results.
Result: Students score an average of 6 out of 16 points (37.50%), with a standard deviation of 2.80. The test focuses on their ability to use mathematical language, symbols, and explanations in problem-solving. While 17.5% have good writing and reasoning ability, 82.5% found it difficult due to limited understanding, low confidence, and insufficient practice, resulting in unclear communication and disorganized thought processes.
Conclusion: Students' mathematical writing ability remains below 50%, with notable score disparities. Developing this skill is essential for effective learning. Teachers enhance mathematical writing through problem-solving explanations, structured writing practices, and precise terminology. Identifying the causes of these disparities supports more effective instruction, while ongoing research explores contributing factors and teaching strategies for skill development.

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INTRODUCTION

Mathematics is an important part of daily life because it improves problem-solving skills, creativity, critical thinking, and reasoning skills, which are all required in many different fields such as science, engineering, economics, and art (Sharma, 2021). Mathematics is deeply embedded in various real-world applications, shaping advancements across multiple disciplines. In engineering, mathematics is applied in various forms such as modeling, optimization, and problem-solving techniques. These applications support the design process, enhance efficiency, and drive innovation across multiple engineering fields, thereby demonstrating the essential role of mathematics in engineering development (Queiruga-Dios et al., 2022). In economics, mathematics is applied through tools such as number sequences, derivatives, and differential equations. These tools assist in creating population models, analyzing investment growth, and evaluating costs. The use of these tools

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enhances financial decision-making processes and long-term predictions in complex economic situations (Turkeshi et al., 2024).

Furthermore, in the context of learning, the Realistic Mathematics Education (RME) approach has been found to improve learners' statistical thinking and problem-solving ability, particularly by making abstract concepts more concrete and relatable to everyday life (Uyen et al., 2021). Teachers play a critical role in improving mathematics instruction by creating student-centered classrooms that promote inquiry, discussion, and creative thinking. Studies indicate that when teachers engage students in meaningful mathematical discussions and encourage the use of mathematical language, students develop a stronger conceptual understanding and improve their language skills (Wachira et al., 2013). Professional development models such as Lesson Study have been proven to effectively enhance teachers' instructional quality, leading to improved student learning outcomes (Lomibao, 2016). Additionally, instructional strategies like open-ended questioning and the creation of engaging learning environments can significantly foster students' creative thinking skills (Mrayyan, 2016). These findings highlight the importance of reflective teaching practices and continuous professional development in mathematics education.

In line with this, the National Council of Teachers of Mathematics (NCTM, 2000) has identified five essential process standards for learning mathematics: (1) Problem Solving, (2) Reasoning and Proof, (3) Communication, (4) Connections, and (5) Representation. These standards are fundamental to secondary school mathematics education. Problem-solving fosters critical thinking as it encourages the application of mathematics to real-world problems, enabling students to analyze and adapt (Al-Mutawah et al., 2019). Reasoning and proof help students construct logical arguments and validate mathematical statements, which are vital for developing a deep understanding of mathematics (Maoto et al., 2018). Communication allows students to articulate ideas, explain their understanding, and collaborate effectively, thereby enhancing overall comprehension (Shodiqin et al., 2020). Connections help learners see relationships among mathematical concepts and their applications in various contexts (Pambudi et al., 2020). Representation supports understanding by enabling students to express ideas through different forms such as graphs, symbols, words, and numbers, which in turn improves their problem-solving and mathematical communication skills (Mainali, 2021). This framework is consistent with the approach adopted in Thailand, where the Institute for the Promotion of Teaching Science and Technology (Education, 2017) emphasizes key mathematical proficiencies (problem-solving, communication, representation and interpretation, connection, reasoning, and creativity) as part of 21st-century learning skills.

Among these proficiencies, mathematical communication is especially important. It involves expressing, explaining, and discussing mathematical ideas clearly and coherently, either orally or in writing (Lomibao et al., 2016). Mathematical communication enhances students' understanding, supports the exchange of ideas, and facilitates conceptual development necessary for advanced mathematics learning (Iman et al., 2024). In particular, written mathematical communication is essential for problem-solving, as it enables students to articulate their reasoning, explain problem-solving processes, and present clear solutions (Ningtyas & Ekawati, 2021). It also promotes logical thinking, reflection, and strategy evaluation—crucial skills for effective mathematics learning. Such communication allows students to verify their methods and develop systematic thinking. Real numbers, which include both irrational (e.g., π and $\sqrt{2}$) and rational numbers (e.g., fractions and integers), form the foundation of arithmetic operations and real-world measurements (Jabbar et al., 2017). Polynomials are algebraic expressions composed of variables, coefficients, and non-negative integer exponents, and are applied widely in physics, engineering, and economics to model various problems. The degree of a polynomial influences its graphical behavior and mathematical application (Bolondi et al., 2020). Understanding and expressing these concepts in writing requires not only logical thinking but also the ability to use correct mathematical language and symbolic representation.

In the context of mathematics education, written communication serves as a crucial tool that reflects students' thinking and understanding. However, observations in a Grade 10 classroom at Sarakhampittayakhom School revealed several challenges students face in written mathematical communication. A key issue is the lack of deep conceptual understanding, which prevents students from expressing their ideas using precise mathematical language. In addition, limited practice in writing and explaining mathematical ideas hinders students from clearly communicating their problem-solving processes. These issues not only impede teachers from accurately assessing students' understanding but also limit students' ability to expand their mathematical reasoning and learning. Although extensive research has highlighted the importance of mathematical communication in enhancing students' understanding and problem-solving skills, most studies have focused on oral communication or general mathematical discussions. There remains limited research that specifically investigates students' written mathematical communication, particularly in the context of foundational topics such as real numbers and polynomials. Furthermore, while several studies have explored students' mathematical writing skills in general, few have examined how students express mathematical reasoning and use appropriate symbols and language in structured written formats at the secondary level. In the context of Thai secondary education, empirical investigations focusing on students' ability to communicate mathematically in writing are especially scarce. This lack of focused research presents a gap that this study seeks to address. Therefore, this study aims to investigate Grade 10 students' written mathematical communication skills, specifically in the context of solving problems involving real numbers and polynomials, by analyzing their ability to use accurate mathematical language, reasoning, and symbolic representation.

METHOD

Research Design

This research was a survey study, which is a quantitative method that involves collecting data from a sample population through standardized instruments (e.g., questionnaires or tests) to describe, compare, or examine relationships among variables (Creswell & Creswell, 2017). In this study, the researcher followed the steps as outlined below (Goodfellow, 2023):

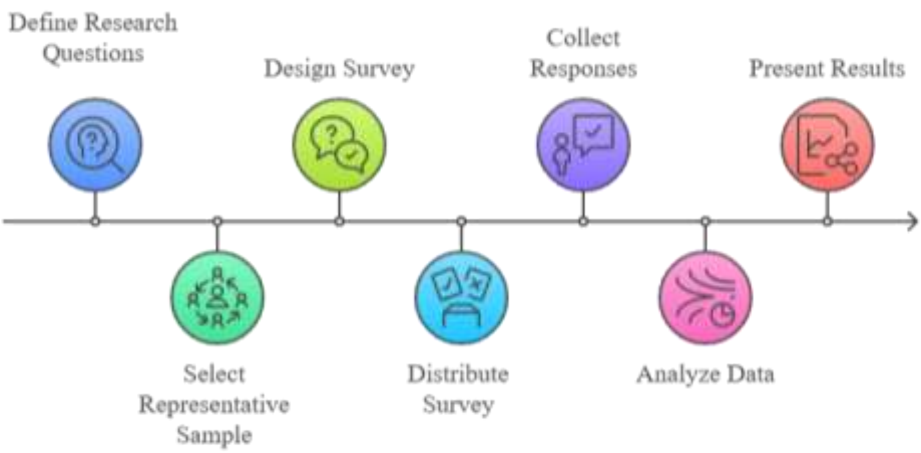

Figure 1. An image of survey study design

1. Define the research questions:
   This study aimed to answer the primary research question: "How do Grade 10 students demonstrate their mathematical communication skills in writing on the topics of real numbers and polynomials?"
2. Select a representative sample:
   The sample in this study consisted of 40 Grade 10 students. These students were selected based on problems encountered in the classroom, rather than through systematic random sampling, as the selection focused on a group directly related to the research problem.
3. Design the survey with clear questions:
   The instrument to be used in this research is a written test. Students will complete this test after the completion of instruction on the topics of real numbers and polynomials. The test will include questions that assess the ability to use mathematical language and symbols to represent statements for conveying meaning, and to present one's own ideas through written explanations that allow others to understand the steps in a correct and complete sequence.
4. Distribute the survey to participants:
   After completing the lessons on the specified topics, all 40 students in the sample group were given the test. This post-instruction assessment was intended to evaluate their mathematical communication skills developed during the learning process.
5. Collect responses:
   The students' responses were collected and reviewed by the researcher. The evaluation focused on the accuracy of mathematical language use and the clarity of the written explanation of processes related to real numbers and polynomials.
6. Analyze the data:
   The data were analyzed using descriptive statistics, such as the mean and standard deviation, to interpret the test results concerning students' mathematical communication skills in writing. These statistics enabled a clear summary of students' ability to express their understanding of real numbers and polynomials through writing.
7. Present results with systematic evidence and clear reporting guidelines:
   The findings were systematically presented using the analyzed statistical data to illustrate the levels of students' mathematical communication skills in writing. The report included suggestions and developmental guidelines aimed at improving students' communication skills, such as instructional adjustments and the use of supportive teaching tools.

Participant

The participants of this study were 40 Grade 10 students (approximately 15–16 years old) from Sarakhampittayakhom School, Thailand. These students were selected using purposive sampling based on preliminary observations indicating difficulties in expressing mathematical ideas through written communication, particularly in the topics of real numbers and polynomials. The group was considered appropriate for this study due to their exposure to relevant mathematical content and the observed challenges in written mathematical expression during prior classroom assessments.

Research Instrument

The research instrument used was a mathematical communication ability test in writing on real numbers and polynomials. It consisted of four subjective questions with a total score of 16 points. The purpose of this test was to assess the ability to use mathematical language and symbols to represent statements for conveying meaning, and to present one's own ideas through written explanations that allow others to understand the steps in a correct and complete sequence.

Scoring Criteria

The Scoring Criteria for the Mathematical Communication Ability Test in Writing are shown in Table 1.

Table 1. The Scoring Criteria for the Mathematical Communication Ability Test in Writing

Score Level / Meaning	Observable Mathematical Communication Ability
4 (Very Good)	Able to use mathematical language and symbols to represent statements for conveying meaning, and present one's own ideas through written explanations that allow others to understand in a sequential manner, which are correct and complete.
3 (Good)	Able to use mathematical language and symbols to represent statements for conveying meaning, and present one's own ideas through written explanations that allow others to understand in a sequential manner, which are correct but not complete.
2 (Fair)	Able to use mathematical language and symbols to represent statements for conveying meaning, and present one's own ideas through written explanations that allow others to understand in a sequential manner, which are complete but not correct.
1 (Needs Improvement)	Able to use mathematical language and symbols to represent statements for conveying meaning, and present one's own ideas through written explanations that allow others to understand in a sequential manner, but which are incomplete and not fully correct.
0 (Requires Correction)	Unable to use mathematical language and symbols to represent statements for conveying meaning, and present one's own ideas through written explanations that allow others to understand in a sequential manner, or shows no evidence of writing.

Examples of questions for the mathematical communication ability test in writing

1. Let a and b be any real numbers. If $a * b = (a + b) - ab$, then what is the value of $10 * 2$

   ………

   ………

   ………

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2. Find the solution set of the inequality $5 - 2x < x - (3 - x)$, and represent the solution set on the number line.

   ………

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   ………

Instrument

Due to time constraints, pilot test of the test was not conducted. However, the test was reviewed for content validity by three mathematics education experts—high school teachers from Sarakhampittayakhom School. The Index of Item-Objective Congruence (IOC) (Poonputta, 2022) was used to assess the alignment between the questions and the research objectives. The analysis revealed that the IOC values ranged from 0.67 to 1.00, which is considered acceptable (greater than 0.50). Based on expert feedback, the researcher revised the assessment to ensure its suitability before using it for actual data collection.

Data Collection

The researcher conducted the study after completing lessons on real numbers and polynomials. Students were asked to complete a mathematical communication ability test in writing, which lasted approximately 55 minutes. The test was administered only once, without any pre-test or post-test. To ensure standardization of the process, the researcher clearly explained the procedures and provided thorough instructions before the test began. The environment was also controlled to be suitable and free from distractions. Subsequently, the tests were examined and scored according to established criteria for further analysis.

Data analysis

The researcher analyzed the results obtained from the mathematical communication ability test on real numbers and polynomials. The scoring criteria included the ability to use mathematical language and symbols to represent statements for conveying meaning, and to present one's own ideas through written explanations that allow others to understand the steps in a correct and complete sequence.

The collected data were then analyzed using descriptive statistics (Gravetter & Wallnau, 2016), including:

1. Mean:

   The mean represents the central value of all scores, calculated by dividing the sum of all students' scores by the total number of students. It is used to show the overall trend of scores within the target group, using the following formula:

$$\bar{X} = \frac{\sum X}{n}$$

   where:

   $\bar{X}$: represents the mean,

   $\sum X$: represents the sum of all data values, and

   n : represents the total number of data values.

2. Percentage:

   The percentage represents the proportion of a student's score relative to the total score. It is calculated by dividing an individual's score by the total test score and multiplying by 100, using the following formula:

$$p = \frac{f}{N}(100)$$

   where:

   p : represents the percentage,

   f : represents the frequency, and

   N : represents the total number of frequencies.

3. Standard Deviation:

   The standard deviation measures the dispersion of scores, indicating how much they vary from the mean. This value helps researchers understand differences among students in the target group. If the standard deviation is low, it indicates that most students' scores are close to the mean. If the standard deviation is high, it indicates a wide spread of scores, using the following formula:

$$S.D. = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}}$$

   where:

   $S.D.$: represents the standard deviation,

   $\sum$: represents the summation,

   x : represents each individual data value,

   $\bar{x}$: represents the mean of the data, and

   n : represents the total number of data values.

RESULTS AND DISCUSSION

The researcher checked and scored the mathematical communication ability test in writing on real numbers and polynomials for Grade 10 students, based on established scoring criteria. The test consisted of 4 questions, each worth 4 points, for a total of 16 points. The researcher analyzed the scores obtained by each student using descriptive statistics. The results are shown in Table 2.

Table 2. The scores of mathematical communication ability test in Writing

Test	Total Score	Average Score	Average Score as a Percentage of Total Score	Standard Deviation
Mathematical communication ability in writing	16	6	37.50	2.80

From Table 1, it was found that the average score for students' mathematical communication ability in writing on real numbers and polynomials was 6 out of 16 points, equivalent to 37.5%, with a standard deviation of 2.80. The test assessed students' ability to use mathematical language and symbols to represent statements for conveying meaning and to present their ideas through written explanations in a correct and understandable sequence. Only 7 students (17.5%) scored 50% or higher, indicating that they were able to express their mathematical understanding clearly and logically using appropriate terminology and structured explanations. Conversely, 33 students (82.5%) scored below 50%, which suggests that the majority of students experienced difficulties in expressing ideas coherently, presenting problem-solving steps systematically, or using proper mathematical language and symbolism. This may be attributed to insufficient conceptual understanding, lack of consistent writing practice, and low confidence in communicating mathematics in written form.

An average score of 37.5% indicates that the overall mathematical communication ability in writing among Grade 10 students remains weak. The relatively high standard deviation (2.80) reflects a significant disparity in students' abilities. Those who scored higher were likely more capable of using mathematical symbols effectively, sequencing ideas logically, and demonstrating understanding through written explanations. In contrast, students with lower scores struggled to connect concepts and present them clearly, often omitting key steps or misusing mathematical terms. This performance disparity suggests the need for differentiated instructional approaches that can cater to students' varied levels of understanding and skill in written communication.

These results are supported by several previous studies. Saironi (2023) emphasized that the selection of appropriate learning strategies has a significant influence on the development of students' mathematical communication abilities. Similarly, Fitriasari et al. (2024) found that student-centered learning can effectively enhance students' written communication skills by encouraging active engagement and reflection. Mitasari et al. (2024) also demonstrated the effectiveness of problem-based learning in improving students' writing performance, with success rates increasing from 16% to 94% following the implementation of targeted strategies. In addition, Sianturi & Sinambela (2024) highlighted the role of technological integration, particularly GeoGebra, in facilitating the written expression of mathematical ideas through visual and symbolic representations. Suharti et al. (2024) also reported that tools such as YouTube, Kahoot, and PhET can foster mathematical communication by allowing students to express concepts in interactive and multimodal ways, leading to clearer understanding and more effective learning experiences.

Several factors may have contributed to the low scores found in this study, including students' limited understanding of fundamental mathematical concepts, lack of proficiency in using mathematical language, and insufficient opportunities for practicing written explanations. This aligns with the findings of Ningtyas & Ekawati (2021), who noted that students' low communication skills are often caused by a lack of practice and weak grasp of basic concepts. Similarly, Putri & Musdi (2020) found that many students are unable to use complete sentences and mathematical representations, such as symbols, tables, and diagrams, in problem-solving, which negatively affects their communication performance. The variability in students' performance observed in this study is consistent with Cai et al. (1996), who emphasized that differences in communication ability can be attributed to the clarity of reasoning, accuracy of representation, and structure of answers. Febriyanti (2018) also highlighted that diverse levels of communication ability influence students' capacity to express opinions and solve problems effectively, thereby stressing the importance of instructional strategies tailored to varied levels of understanding and interpersonal skills.

The findings of this study underline the urgent need for instructional strategies that not only emphasize content delivery but also foster students' ability to express mathematical reasoning through writing. Teachers should be encouraged to provide students with more structured opportunities for written explanations during lessons and assessments, including tasks that require justification, explanation, and reflection. Embedding writing tasks in daily learning routines can improve students' familiarity with mathematical language and develop their expressive competence over time. As suggested by Fitriasari et al. (2024), a shift toward student-centered approaches may bridge the gap between conceptual understanding and written articulation. Moreover, assessment rubrics that explicitly value communication—such as clarity of explanation, logical sequencing, and use of symbols—could help both teachers and students focus on the quality of mathematical writing, not just correctness of answers.

This study, however, had several limitations. The small sample size of only 40 students, selected based on observed classroom challenges in written mathematical communication, limits the generalizability of the findings. Time constraints also restricted the depth of data collection and the ability to monitor students' long-term development. Future research is therefore recommended to involve larger samples using random sampling techniques for broader representation. Further studies should also examine both written and oral forms of mathematical communication to provide a more comprehensive understanding of students' abilities. In addition, future research should explore the use of various instructional strategies and digital tools that offer students ample opportunities to practice and enhance their communication skills. Factors such as mastery of mathematical concepts, the use of appropriate language and symbols, and sufficient time for practice and reflection should also be considered to support the development of effective mathematical communication.

CONCLUSION

The findings of this study revealed that the average score of Grade 10 students on written mathematical communication was 6 out of 16 (37.5%), with a standard deviation of 2.80. Only 17.5% of students scored at or above 50%, indicating a limited ability to use mathematical language and symbols effectively and to communicate problem-solving processes in a clear and structured written form. In contrast, 82.5% of students scored below the threshold, reflecting significant challenges in organizing and articulating their reasoning. These difficulties may be attributed to a lack of conceptual understanding, insufficient practice, and low confidence in written communication. The results highlight the need for more targeted instructional strategies that focus on developing students' written expression in mathematics. This study contributes to the growing body of research emphasizing the importance of written mathematical communication and provides empirical evidence to inform future teaching practices.

AUTHOR CONTRIBUTIONS STATEMENT

WS : Planning the research, collecting and analyzing data, interpreting the results, editing, and communicating with journals

MT : Reviewing, proofreading, and suggestion.

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