International Journal of Research in Education Humanities and Commerce

Volume 06, Issue 05 "September - October 2025"

ISSN 2583-0333

USING PROBLEM-SOLVING IN THE JUNIOR MATHEMATICS COURSE: EXPLORING STUDENTS' WRITTEN MATHEMATICAL COMMUNICATION SKILLS THROUGH A LEARNING PROJECT

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https://doi.org/10.37602/IJREHC.2025.6525

ABSTRACT

Mathematical communication skills are essential for connecting students' understanding of mathematical concepts with their ability to apply these concepts in problem-solving tasks. To support students in mastering these skills, an effective learning activity is needed. A learning project was designed to enhance problem-solving abilities while concentrating on developing students' mathematical communication skills. The objective of this research is to explore the various aspects of mathematical communication and problem-solving and to analyse pedagogical approaches that can improve students' communication abilities in mathematics.

The research utilised a quantitative method, involving 132 Year 7 students who participated in the project. The study focused on aspects of mathematical communication and problem-solving, and students' progress was evaluated within groups of 2-3. Additionally, a qualitative approach was used to gather deeper insights into the research. As part of the project implementation, four mathematics teachers were interviewed to provide further context and understanding. After data collection, SPSS was used to address the research objectives. The analysis highlighted the pedagogical approaches that foster the development of students' communication skills following the implementation of the learning project.

Keywords: mathematical communication skills, mathematical pedagogical approach, problem-solving, problem-based learning project

1.0 INTRODUCTION

Mathematics learning goals include the ability to express ideas using symbols, diagrams, graphs, or mathematical terms to explain situations or problems (Aulia, Rohati, & Marlina, 2021). Mathematical communication plays a critical role in secondary school mathematics education (Hendriana, Rohaeti, & Sumarmo, 2017, as cited in Aulia, Rohati, & Marlina, 2021). According to the National Council of Teachers of Mathematics (NCTM, 2000; 2020), communication is a fundamental component of mathematics and mathematics education. The NCTM framework articulates five essential goals of mathematics learning: the development of communication, reasoning, problem-solving skills, and connections, alongside cultivating a positive disposition toward the subject.

Aini, ZAyyadi, and Saleh (2020) further explained that mathematical communication skills including the ability to express mathematical ideas through oral, written, and demonstrate and describe them visually; the ability to understand, interpret, and evaluate mathematical ideas both verbally and in other visual forms; the ability to use terms, mathematical notations, and

structural structures to present ideas, describe relationships and model situations. Ansari (2003) defined written mathematical communication as the ability and skills of students to use appropriate vocabulary, notation, and mathematical structures to logically and thoroughly express relationships and ideas during the problem-solving process. Similarly, Qohar (2011) emphasised that written mathematical communication involves the ability to represent and convey mathematical ideas through mathematical models. In essence, written mathematical communication skills refer to the capacity to articulate mathematical thinking using the language of mathematics.

Therefore, strong mathematical communication skills are essential for students to solve mathematical problems and internalise mathematical concepts effectively.

2.0 LITERATURE REVIEW

Research emphasises the importance of communication skills in mathematics learning, highlighting that mathematical communication skills influence academic performance, self-efficacy, proofreading skills, and mathematics resilience (Ellis, 2019; Sumartini, Maryati, & Sritresna, 2021; Priatna, 2020). Developing the ability to think critically, reason logically, solve problems, and communicate ideas—both orally and in writing—is crucial for improving students' mathematical communication skills (Widiatmoko, 2020). Numerous studies have examined various aspects of communication in mathematics, including mathematical reasoning (Williams et al., 2003), planned behavior and inquiry (Komatsu, 2021), and communication learning activities. With strong mathematical communication skills, students are expected to justify their reasoning in problem-solving, transform descriptions into mathematical models, and present mathematical ideas clearly. Students who can express mathematical ideas both orally and in writing demonstrate strong mathematical thinking abilities (Aziz & Suprayitno, 2021), illustrating the close relationship between mathematical communication and mathematical thinking. Researchers have primarily focused on verbal and written communication (Kosko & Wilkins, 2010; Lim & Chew, 2007; Lomibao et al., 2016). However, evidence suggests that many students have not yet mastered these skills (Sumartini, 2019; Putri & Sundayana, 2021). The limited expression of students' ideas, both orally and in written form, is evident in their work (Aini, Zayyadi & Saleh, 2020). Many students still show relatively low communication skills (Luritawaty, 2016; Nuraeni & Afriansyah, 2021), and their mathematical communication abilities remain inadequate (Noviyana, Rochmad, & Dewi, 2020; Paruntu, Sukestiyarno, Priyono, & Prasetyo, 2018; Rizqi et al., 2016; Rustam, 2018). High school students, in particular, need to improve these skills (Aulia, Rohati & Marlina, 2021; Liu, Osmond & Affas, 2023). Research conducted by Farokhah et al. (2019) focuses on the ability to represent mathematical problems using symbols, diagrams, manipulatives, and other mathematical concepts. The findings indicate that a significant number of students struggle to use mathematical objects effectively, with many failing to engage with them adequately. Consequently, a large proportion of students are unable to apply these tools proficiently. This highlights the importance of training students in mathematical representation skills, as many students face difficulties in solving problems and writing equations correctly (Utami et al., 2019; Nasrullah, Alimuddin, et al., 2021).

Several factors may contribute to students' lack of mathematical communication skills. One significant factor is the reliance on traditional teaching methods, which often encourage passive

learning and limit students to accepting information solely from the instructor (Li & Schoenfeld, 2019; Raj Acharya, 2017; Liu, 2023a, 2023b). This approach hinders students' ability to develop their mathematical communication skills. Furthermore, students are typically not accustomed to solving mathematical problems through comprehensive and logical problem-solving processes (Liu, Osmond & Affas, 2023). Often, they solve problems mechanically, without clearly articulating each step. Additionally, mathematics instructors have noted that students' lack of confidence in their abilities contributes to their difficulties in mathematical communication. Many students are hesitant to share their mathematical reasoning due to the fear of making mistakes, making it even more challenging for them to enhance their communication skills through problem-solving.

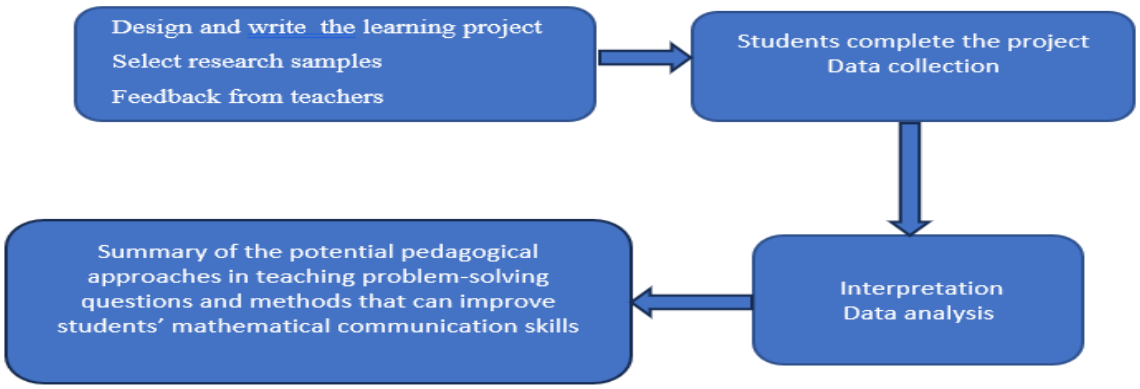
According to the findings of Liu, Osmond, and Affas (2023), mathematical communication skills in Australia are often lower than expected. In a senior investigation project, students' mathematical communication skills were notably concerning compared to other mathematical competencies. This prompted the researchers to explore ways to improve and develop students' communication skills, which have been incorporated into the curriculum. Providing junior students with opportunities to explore and strengthen these skills helps ensure their confidence in demonstrating mathematical abilities during the transition to senior-level mathematics. Therefore, investigating pedagogical approaches and assessment strategies that can effectively integrate these elements into a learning project is a worthwhile area of research.

3.0 MATERIAL & METHODS

3.1 Research design

To systematically examine and describe the mathematical communication skills of Grade 7 students, a learning project was developed and written, with initial interviews and feedback collected from mathematics teachers before finalising the project draft. In group work, students are expected to be quick, active, responsive, and creative in solving mathematical problems using the learning project-- a shopping list for preparing a BBQ party. This approach is well-suited to the students' environment, allowing them to engage with real-world problems and fostering opportunities for mathematical communication. By utilising available resources effectively, students can showcase their creativity and develop solutions based on mathematical analysis (Ahmand, S., 2017).

3.2 Research flowchart



3.3 Participant

132 Year 7 students from a Christian college participated in the task, working in groups of 2-3.

3.4 Instrument and data collection

This paper is based on quantitative and qualitative research methods with a descriptive approach. The data collection techniques used in this study include learning projects and semi-structured interviews.

The analysis process involved four key stages: data reduction, data presentation, data interpretation, and conclusion. A total of 132 students participated in the learning project, and 121 of them submitted completed work. One submission was excluded from the data analysis due to the majority of questions being left blank. Semi-structured interview data were collected from math teachers, mainly used in highlighting pedagogical approaches in lesson planning and practice.

The purpose of this study is to explore students' mathematical communication abilities, problem-solving skills, and their capacity to demonstrate mathematical understanding through the learning project. It further aims to explore pedagogical approaches that support the development of these skills, with a specific focus on informing secondary mathematics teaching and planning.

4.0 RESULTS

In this study, students were given a task that involved designing a shopping list based on provided materials, covering items needed for a BBQ. They were expected to compare unit costs, evaluate the quality and nutritional value of the items that they chose, consider health factors, manage a set budget, account for the number of guests invited, and consider the required number of servings. Students' work was evaluated using tables, graphs, and written discussions and analyses.

Data was grouped based on students' results from the learning project. After consulting with other mathematics teachers, achievement levels were classified into four categories: above average, average, below average, and unsatisfactory (as shown in Table 1).

Table 1. Student Ability Category Scale

Indicators	Achievements							
	Above average (≥85%)		Average (≥ 70%)		Below average (≥ 40%)		Unsatisfactory (≤ 40%)	
	N	%	N	%	N	%	N	%
Mathematical expression	47	39.2	58	48.3	8	6.7	7	5.8
Graph/table	60	50	50	41.6	6	5	4	3.3
Mathematical analysis	12	10	39	32.5	37	30.8	32	26.7
Written text	31	25.8	42	35	33	27.5	14	11.7

According to the table, over 88% of students demonstrate strong mathematical expression skills, and approximately 92% can present data in the form of a graph or table. Additionally, 60% of students can clearly explain their solutions in written form. However, the data also reveal a weakness in mathematical analysis, with only 42% of students demonstrating proficiency in this area. 11.7% of students did not provide solutions or gave insufficient information when explaining their reasoning for making reasonable purchasing decisions. Additionally, 14% of students thought clearly, even when given hints related to the question. Students classified in the average category were generally able to provide solutions but often failed to support their responses with adequate data or evidence. A small number of students categorised as unsatisfactory were absent for multiple lessons during the project's implementation; consequently, the reasons for their lack of responses could not be identified. The assessment criteria based on Teledahl (2017), Khomsyatun, Asnawati and Noto (2023) are outlined in Table 2.

Table 2. Mathematical communication skills and students' communication abilities

Criteria: Mathematical Communication Skills	Number of students	Percentage
The ability to understand the scenario and the questions	126	95.5%
The ability to write down the formula correctly	108	81.8%
The ability to show work and provide correct solutions	112	84.9%
The ability to analyse the results and to make sure the final answers are correct	105	79.6%
The ability to use the given information to complete drawings, tables and graphs	58(table only) 74(table and graph)	43.9% 56.1%
The ability to analyse and evaluate findings	94	71.2%
The ability to clearly explain mathematical concepts and relationships.	41	31.1%

During the learning project, students discussed with each other inside the group. They were expected to demonstrate ability in expressing, explaining, describing, listening, asking, and collaborating to gain a deeper understanding of the mathematics questions. When analysing the results, the language and symbols of mathematical conventions (Güçler, 2014) are the criteria used to assess students' mathematical understanding. The data showed that the majority of students (above 80%) understand the questions, demonstrating the ability to interpret and apply mathematical knowledge into practice. Through collaboration, students can develop a deeper understanding of the mathematical concepts they investigate. Furthermore, students' mathematical communication skills were generally assessed based on their ability to present mathematical concepts visually through tools such as value tables, drawings, diagrams, and graphs. The students demonstrate the ability to interpret given information and solve problems effectively. Over 80 % of students can write down what is known, use the formula correctly, and, further, according to the formula, they can draw a bar graph or a line graph to visualise their results. Additionally, 76 % of the students can analyse the data correctly, justify their choices and propose reasonable solutions. However, about 70% of students struggled to provide clear evidence of their mathematical understanding and were unable to demonstrate satisfactory communication skills.

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ISSN 2583-0333

5.0 DISCUSSION

Several factors contribute to this phenomenon. First, students lack adequate training and have limited opportunities to practice these skills. As a result, many fail to demonstrate strong analytical skills or have a deep understanding of how to apply mathematical knowledge and terminology effectively. Additionally, students often struggle to connect school-based mathematics with real-life applications. This disconnect may hinder their appreciation of the relevance and integration of mathematics into their daily lives (Liu, Osmond, & Affas, 2023). Students need to develop the ability to represent and understand mathematical notation through everyday events, the ability to relate real objects to mathematical ideas, and the ability to evaluate mathematical thinking by observing the strategies used when solving problems in daily life (Bastian, Nindiasari & Syamsuri, 2024). When this connection is made, and when students are encouraged to express their ideas, explain their approaches to solving problems, participate in group work and discussions, and learn through teacher demonstrations, mathematical communication skills are more likely to develop.

Based on these findings, assessing mathematical communication skills is challenging. Students need guidance on how to respond to open-ended questions, use feedback effectively, and engage in self-assessment to develop and demonstrate these skills. Methods like instructional approaches include a variety of reading resources, such as historical context, real-world mathematical applications, mathematical modelling, and scientific materials, or carefully designed problems, tasks, and learning projects, can help students consolidate prior knowledge, deepen their understanding, and develop essential mathematical skills (Liu, Osmond, & Affas, 2023; Bastian, Nindiasari & Syamsuri, 2024). This is particularly important when addressing problems that do not require mastery by all students (Aini, Zayyadi, Saleh, 2020); a differentiated approach needs to be considered.

As mathematical communication reflects learners' conceptual understanding, it is regarded as a critical component of mathematical proficiency. Participation in discussion and written explanation can further position students as active agents in the learning process. Through critical analysis, dialogue, and attentive listening, students exchange strategies, solutions, and insights. Writing about mathematics encourages learners to reflect on and clarify their ideas, which in turn deepens their conceptual understanding of the problems they engage with. Therefore, by providing students with opportunities to explore and engage in such a learning environment, teachers play a crucial role in facilitating this process. Teachers can support students by showing examples on the board and making their thinking visible, for instance, by verbalising their reasoning process as they work through problems. This helps students understand not just the steps, but the logic behind them. Additionally, encouraging students to explain their work aloud provides valuable insight into their cognitive processes, making it easier for teachers to identify and address misunderstandings. A simple and effective approach could be that each week, students may be invited to present one of their homework solutions on the whiteboard at the front of the classroom, with each presentation lasting approximately five minutes. While this practice can enhance learning and communication skills, it may not be necessary for every student each week, particularly for those who find math challenging. However, consistent participation in these presentations may still be expected over time.

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Just as students are taught to construct graphs to represent their reasoning or solutions, they can also be guided to engage in the discussion and critique of graphical representations. Such as teaching students how to convert written questions into visual texts. Nunokawa (2004) and Bremigan (2005) stated that a graphical representation can support students to better 'see" both the mathematical problems and reasoning skills required to solve the problem. Visual texts can be used to complement written language, numerical data, and mathematical concepts (Armstrong, Ming & Helf, 2018). To help students develop the ability to interpret a data graph and decide whether it contains all the necessary information for the question, teachers can provide students with opportunities to discuss and evaluate different graph options (Quinnell, 2014). Within this context, students are engaged in interpreting text rather than generating solutions (Bastian, Nindiasari & Syamsuri, 2024).

Taken together, this study summarised that the above pedagogical approaches support students in applying effective problem-solving strategies and in enhancing their mathematical written communication skills as follows:

OBSERVE:

a) Read the problem once to get a general idea of what it is about.
b) Read it again to understand the details more thoroughly.
c) Review it a third time and highlight the specific questions being asked.

PLAN:

a) List the relevant facts or information provided in the problem that you will use.
b) Decide on and describe the strategy or method you will apply to solve the problem.

DO:

a) Draw a blank diagram to represent the problem visually.
b) Fill in the diagram with the given information.
c) Identify any missing or unknown information needed to solve the problem.
d) Determine a strategy and solve the problem.
e) Show all working clearly and accurately.
f) Discuss and evaluate the visual representation, considering how effectively it communicates the solution.

CHECK:

a) Does your answer make sense and seem reasonable?
b) Is your work shown clearly and correctly?

6.0 CONCLUSION

This study aimed to explore junior high school students' mathematical written communication skills by analysing their abilities to demonstrate understanding, analysis, and discussion, to inform more comprehensive and effective approaches to teaching communication skills in mathematics. The study highlights the urgent need for students to improve their analytical

skills, especially in summarising data and gaining a deeper understanding of mathematical concepts. Although many students were able to perform calculations and present data visually, they still struggle to interpret information, express reasoning clearly, and apply mathematical knowledge to real-life contexts. The findings suggest that targeted instructional approaches can promote the development of these skills. Strategies such as encouraging mathematical discussion, using visual representations, incorporating real-life problem-solving tasks, modelling effective communication, and promoting group work have been shown to improve students' mathematical thinking and written communication skills.

Future research should focus on evaluating the effectiveness of specific instructional methods aimed at improving mathematical communication and cognitive understanding. In particular, it should investigate how curriculum-based instructional design impacts learning outcomes, supports students' problem-solving processes, and strengthens their ability to express mathematical ideas clearly and accurately.

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