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Role of Mathematical Communication for Learning Mathematics

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Abstract

Mathematical communication is increasingly recognized as a crucial component of effective mathematics learning. This research paper examines the role of mathematical communication in enhancing students' understanding and proficiency in mathematics. The objectives of the study are to explore how communication supports learning in mathematics, identify strategies that teachers can employ to improve students' mathematical communication skills, and assess the impact of these skills on overall student achievement. The research employs a mixed-methods approach, combining quantitative and qualitative data from surveys, classroom observations, and interviews with mathematics teachers and students. A sample of 50 secondary school students and 2 mathematics teachers were selected from various schools. Quantitative data were gathered through surveys assessing students' communication skills and mathematics achievement, while qualitative data were obtained through observations of classroom interactions and interviews with teachers regarding their instructional practices. The findings reveal that students with stronger mathematical communication skills demonstrated a higher level of understanding and problem-solving ability. Teachers who actively promoted mathematical communication through structured tasks, classroom discussions, and opportunities for students to explain their reasoning reported improved student engagement and learning outcomes. Furthermore, the study found that mathematical communication not only facilitated individual learning but also encouraged collaborative problem-solving and peer learning. In conclusion, the study highlights the significant role of mathematical communication in fostering deeper understanding and improving mathematical proficiency. Effective communication allows students to articulate their thinking, engage with mathematical concepts more critically, and collaborate with others. The study recommends that teachers incorporate mathematical communication as a central element of their instructional practices to enhance student learning and success in mathematics.

Key Words: Mathematical communication, mathematics learning, student engagement, problem-solving

Introduction

Mathematics is often understood as involving calculations, figures, and symbols, all of which help establish and connect mathematical meanings. Mathematical communication is a key component in learning mathematics, as outlined by the National Council of Teachers of Mathematics (NCTM, 2000). In classroom settings, both verbal and non-verbal interactions are part of this communication process (Rohmah, 2017). Over the past two decades, communication in mathematics has received considerable attention. Teaching inherently involves communication, and research has shown that students remember only 20% of what they hear, 30% of what they see, and 50% of what they both see and hear. However, when classroom activities emphasize interaction and communication, students can retain up to 90% of what they say and do during discussions (Ezrailson et al., 2006).

The concept of learning with understanding has gained significant attention from both educators and psychologists, and it has become one of the most important goals for students across all subjects. However, achieving this goal has been challenging, particularly in mathematics. One reason for this difficulty may be that while the idea of students learning mathematics with understanding is frequently mentioned in curriculum frameworks, it is often poorly articulated, providing little guidance for curriculum development and policy. The Learning Principle in the *Principles and Standards for School Mathematics*, a key curriculum framework in the U.S., seeks to address this issue by offering a research-based explanation of what it means for students to learn mathematics with understanding

(Stylianides & Berkeley, 2007). This underscores the widespread need for mathematical knowledge and highlights the importance of learning principles and a well-structured curriculum framework in facilitating effective mathematics learning.

Mathematical communication competence was first introduced in Vietnam's Mathematics curriculum in 2018. It encompasses a variety of skills, including listening, reading, presenting, expressing mathematical ideas, and effectively using mathematical language to communicate and interact with others. Students' mathematical communication skills involve the ability to comprehend, interpret, express, respond, and use mathematical symbols to convey ideas both orally and in writing. This skill is linked to both cognitive and psychomotor development. Mathematics is often associated with calculations, figures, and formulas, which has led to the misconception that communication skills cannot be developed through learning mathematics. However, the ability to communicate is crucial as it aids in organizing thoughts and connecting ideas, helping students to complete and refine their understanding of mathematical concepts.

Teachers can help develop students' mathematical communication skills by listening to their ideas, investigating questions, encouraging critical thinking, and prompting students to respond both orally and in writing. They also assess the depth of understanding, present mathematical notations when needed, and motivate student participation. According to NCTM (2003), indicators of students' mathematical communication skills include the ability to express their mathematical thinking clearly and logically, use mathematical language correctly, organize their thoughts through communication, and analyze others' mathematical reasoning. Effective communication in mathematics is crucial for understanding and applying concepts, as mathematics serves as a precise and powerful communication tool.

In recent years, the role of mathematical communication in the learning process has gained significant attention among educators and researchers. The National Council of Teachers of Mathematics (NCTM) underscores the importance of communication as one of the key standards for mathematical proficiency, advocating that students should be able to convey their mathematical thinking coherently and accurately. Effective mathematical communication enables students to not only articulate their own ideas but also engage in discussions, critique the reasoning of others, and refine their own understanding.

Despite its recognized importance, fostering mathematical communication in the classroom remains a challenge. Many students struggle to articulate mathematical concepts or explain their problem-solving strategies, which limits their ability to fully grasp the subject. Teachers, therefore, play a pivotal role in creating opportunities for students to communicate mathematically, through structured tasks, discussions, and assessments that encourage both verbal and written expression.

This paper aims to explore the role of mathematical communication in the learning of mathematics. It will examine how mathematical communication enhances students' understanding, the strategies teachers can employ to develop these skills, and the challenges faced in integrating communication as a central aspect of mathematics instruction. By highlighting the significance of communication in mathematics, this study seeks to offer insights into improving teaching practices and enhancing students' overall mathematical proficiency.

Methodology

This study employs a mixed-methods approach, integrating both quantitative and qualitative data to provide a comprehensive analysis of the role of mathematical communication in learning mathematics. The mixed-methods design was chosen to ensure a deeper understanding of the relationship between mathematical communication skills and student learning outcomes. The study is divided into two phases. The first phase involves the collection of quantitative data to measure students' mathematical communication skills and their academic performance in mathematics. The second phase focuses on gathering qualitative insights from classroom observations and interviews with both teachers and students to explore the instructional strategies used to enhance communication in mathematics learning..

A purposive sampling method was used to select participants for the study. The sample

consists of 50 secondary school students (grades 9-12) and 2 mathematics teachers from various schools. Schools were selected based on their diverse educational settings, which included urban, semi-urban, and rural environments, to capture a broad spectrum of teaching and learning experiences. The student participants were chosen to represent a range of abilities in mathematics, ensuring that both high-achieving and struggling learners were included. Quantitative data were collected through surveys administered to both students and teachers. The student survey assessed their mathematical communication skills, including their ability to express mathematical ideas, use mathematical language, and engage in discussions. Qualitative data were gathered through non-participatory classroom observations. These observations focused on the interactions between teachers and students, particularly how teachers facilitated mathematical discussions and how students communicated their mathematical reasoning. A structured observation checklist was used to capture data on verbal and non-verbal communication, the use of mathematical language, and student participation in problem-solving tasks. Semi-structured interviews were conducted with the 2 participating mathematics teachers to gain deeper insights into their instructional practices. Teachers were asked about the challenges they faced in developing students' mathematical communication skills, the strategies they used to overcome these challenges, and their perceptions of the impact of communication on student learning.

Result and Discussion

The analysis of the results and findings on the role of mathematical communication for learning mathematics sheds light on how students' ability to articulate, represent, and interpret mathematical concepts influences their understanding and problem-solving skills. This section delves into the impact of effective communication in mathematics, highlighting its role in enhancing conceptual clarity, fostering critical thinking, and facilitating collaborative learning. The findings are drawn from both qualitative and quantitative data, providing insights into how various modes of communication—verbal, written, and symbolic—support students in navigating mathematical challenges and developing deeper comprehension of the subject.

Table 1

Mathematical Communication through Questioning

Questioning Activities	Students Class Activities Observation Record	
	Students of private	School of Public (f2)
Question to students after class	13	16
Question to students before class	4	7
Question to students at the time of class	16	22
Students ask question if any confusion	3	2
Ask questions for understanding	19	9
Raise hand for questioning	21	15

From the table 1, more students at institutional school than public were questioned after class, at the time of class and before the class. But at confusion and for understanding students of institutional school had questioned more than public school. More students had raised for questioning at institutional school.

In Institutional school, the students that thirteen were practiced of questioning after class, four students questioning before class and sixteen of them were questioning at the time of class. Among thirty students, three of them were questioning if they were confused, nineteen students asking question for understanding the concept of mathematical content. The majority of students as twenty-one students raised their hand when they practiced to questioning.

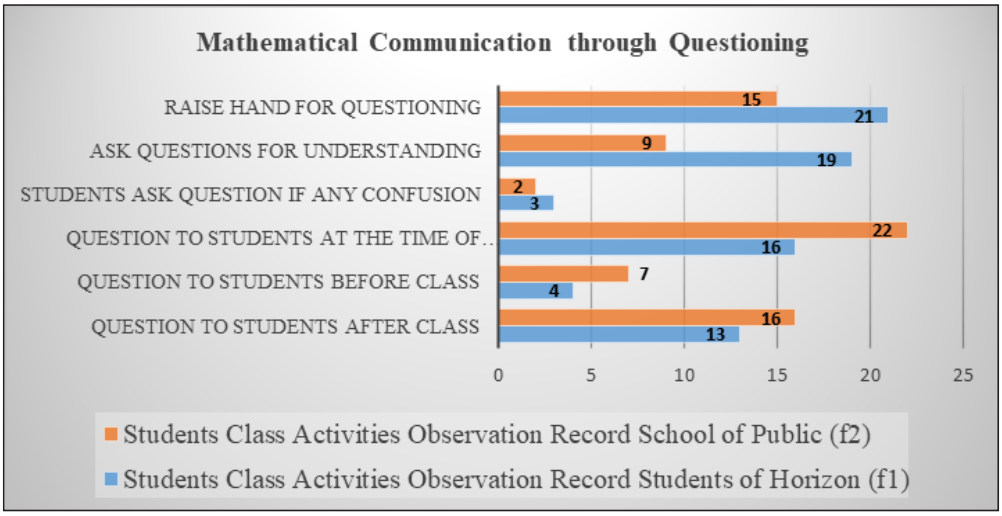
In public school, the students that sixteen were practiced of questioning after class, seven students questioning before class and twenty-two of them were questioning at the time of class. Among two students, three of them were questioning if they were confused, nine students asking question for understanding the concept of mathematical content. The majority of students as fifteen students raised their hand when they practiced to questioning.

The interaction of questioning above indicated that majority of students were engaged on the practice of questioning from total sixty students. But about more students at school were still not participated on mathematical communication. Among sixty students, only 29 students questioned after

class, 11 students questioned before class, 38 students questioned at class time, 5 students questioned if any confusion, 28 students questioned for understanding and 36 raised their hand for questioning. The mathematical communication through questioning practice at case school has figured as: -

Figure 1

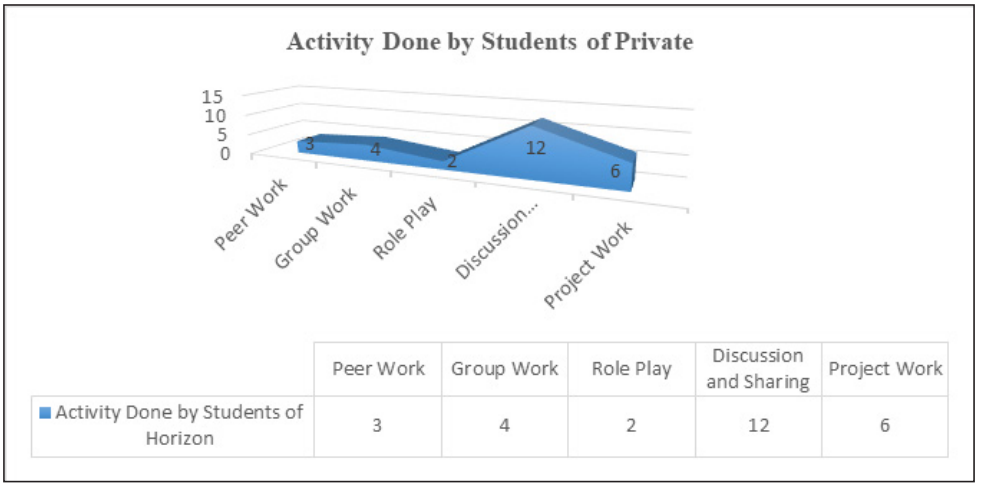
Mathematical Communication through Questioning



Throughout the observation process, as noted in this checklist, the students showed more gender differences than similarities in the way they learnt and participated in mathematics lessons and its related activities. In this checklist the researcher was recording the number of times an indicator occurs in a girl or a boy then makes tallying and later describes it as more, less or equal occurrences. In the table shown above therefore, our results suggest that learners display differences in the way learn and participate in a mathematics lesson.

Mathematical Communication Activities at Classroom

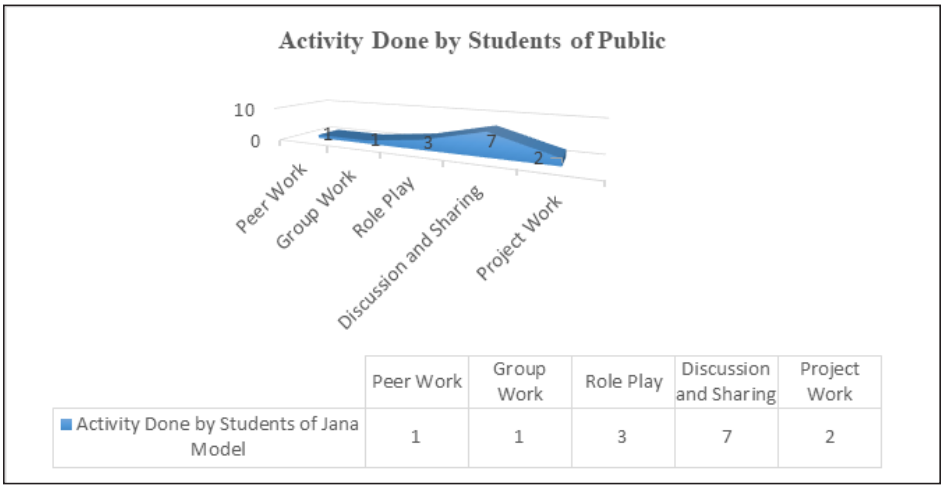
The researcher observed the mathematics classroom of both Horizon Academy and Jana Model and checked the classroom activity based on students pair work, group work, role-play, discussion and sharing and project work. The researcher observed the students classroom activity and checked this activities at the time of fifteen day time duration. The students' engagement of the communication activities has shown graphically on the following pie chart as: -



	Peer Work	Group Work	Role Play	Discussion and Sharing	Project Work
Activity Done by Students of Horizon	3	4	2	12	6

Figure 2

Communication Activity Done By Students at Mathematics Classroom



	Peer Work	Group Work	Role Play	Discussion and Sharing	Project Work
Activity Done by Students of Jana Model	1	1	3	7	2

From the above figure 2, it was shown that the mathematical communication practice at Horizon school had more practiced than Jana Model School. But the practice of mathematical communication ratio at the time of fifteen day, it was much poor communication practice.

Interaction with Peers From observation it was found that students were interacted with their friends about class work, assignment and share their happiness and sorrow with their friends. The researcher concluded that student's interaction with peers was poor. After observing the fifteen days mathematics class it was seen less interaction with peers. They consulted with homework, class work and discussion about subject matter also, they asked question with classmate rather than teacher while they were confused.

From the observations conducted over fifteen days across different classes, it was found that students appeared to be less engaged in learning mathematics. However, several key facts emerged during the observation period. Teachers encouraged proper communication among students, and those who participated in interactions appeared to be more active in class. Despite this many students demonstrated poor participation in classroom activities, with most remaining silent during lessons and some contributing to classroom noise through non-mathematical communication. While students were diligent in completing individual assignments, they struggled with collaborative tasks such as group work, peer collaboration, and project presentations. On a positive note, there was a healthy relationship between boys and girls, which contributed to the enhancement of knowledge. Additionally, students seemed to interact less with male teachers compared to other teachers, although the overall interaction with teachers remained positive.

From the above analysis and interpretation of data obtained from observation checklist, it was found that students' participation in mathematical communication was average. It was found that the environment of class such as teacher's activities of interaction with students, involvement of students in group work, presentation and project work in learning mathematics. Mathematical communication at classroom was practiced through asking questions, given teachers' feedback and motivated to communicate, teachers' explanation, students talk, peer work and group work, role play, discussion and sharing, project work practiced at mathematics classroom.

Impact of Mathematical Communication of Students in Mathematics Learning

The researcher obtained the information of view of mathematical communication and its impact on students' mathematics learning. The students views were categories into five Likert scale and scaling as orderly 5 to 1 as their view as SA to SDA. The weighted mean and statement wise average of the response has presented as below: -

Table 2

Mathematical Communication and Its Impact on Mathematics Learning

S.N.	Statements	Opinion					Weighted Mean
		SA	A	U	D	SDA	
1	I feel easy to share my knowledge, skill, attitude with my teachers	21	3	1	4	1	8.6
2	I discussed in mathematics contents with my classmates	4	14	0	10	2	6.5
3	My teacher understand as I asked	22	5	3	0	0	9.3
4	Questioning practices encourage me to communicate with each other	18	2	0	0	0	6.5
5	Silence classroom is not good for mathematics	13	4	10	3	1	7.9
6	Teachers' feedback and suggestions encourage me to mathematical communication.	24	2	0	1	3	8.9
7	Mathematical communication encourage students to their classroom participation	15	12	0	3	0	8.6
8	Mathematical concept recognition depends upon mathematical communication	2	13	8	2	5	6.3
9	Teacher Taught By Self	5	17	1	3	4	7.1
10	There is provision of Questioning	15	14	0	0	1	8.8
11	Noise disturbed the mathematical communication.	16	14	0	0	0	9.1
12	There is a provision of Pair Work	2	20	1	7	0	7.1
13	Students Project their Assignment on Group	14	16	0	0	0	8.9
14	Teacher Focus the Back bencher to Communicate	1	7	3	16	3	5.1
15	Every class is silence	4	2	1	17	6	4.7
16	No sound is listened rather than teacher	15	10	4	0	1	8.5
17	Every Student have Chance of Questioning	18	10	2	0	0	9.1
18	Students Share their Problems and	14	16	0	0	0	8.9
19	Teacher motivate students to Communicate	2	8	10	6	4	5.9
20	Students asked questions and teacher non-response or avoid	2	17	2	6	3	6.6
	Average Scale	11	10.3	2.3	3.9	1.7	7.6

From the above table 4.5, average 11 students strongly agreed, 10.3 students agreed, 2.3 students undecided, 3.9 disagreed and 1.7 strongly disagreed with statements. The result showed that the average score of 7.6 was shown to total scale calculation of 15 weightage. This indicated that the mathematical communication impact the students' mathematics learning but it was not only the factor of mathematics learning was shown.

The researcher took the interview with two teachers of one private school mathematics teacher (HMT) and another public school's mathematics teacher (JMT). The response of the teachers on the content of mathematical communication of students and its impact on mathematics learning as given below:

HMT: *I focused my mathematical contents towards student based on their active participation. I questioned to students for their pre-knowledge. My students questioning to me before and after the lesson. I give them feedback and motive to their study. In my view, students have better mathematical communication through their peer work, group work, role-play activities, discussion and sharing and*

their project works. But the role of teacher must advisory, facilitate and regular feedback. The students have better GPA than the students who never communicate with each other.

JMT: *I am a teacher of public school and have fifteen years job experience for mathematics teaching at secondary level. Majority of my students now a days are more creative and take a part in mathematical communication to me, to their friends and to their seniors also. Mathematical communication avoids the doubt of fear and assure to promote confidence. They share peer and role play with mathematical communication but the teacher must pay the attention of regular facilitation and feedback.*

The interview data from two mathematics teachers, HMT from a private school and JMT from a public school, provide important insights into the role of mathematical communication in enhancing students' learning. Both teachers stress the significance of active student involvement in mathematical discussions and how communication positively impacts understanding of mathematical concepts.

Active Participation and Student-Centered Learning

HMT focuses on student engagement through questioning before and after lessons, aligning with a student-centered approach where the teacher facilitates rather than simply providing knowledge. Pre-knowledge questioning helps HMT assess students' understanding and adjust lessons accordingly. Similarly, JMT observes increased creativity and participation in mathematical communication, noting that students interact with peers, seniors, and the teacher, promoting a more interactive learning environment.

Peer Collaboration and Group Work. Both teachers recognize the value of peer work, group activities, and role-play in deepening mathematical understanding. Collaborative discussions help students refine their ideas and improve their reasoning. HMT attributes better academic performance, including higher GPA scores, to students who engage more in these communicative activities.

Teacher's Role: Facilitation and Feedback. Both HMT and JMT emphasize the teacher's role as a facilitator who provides regular feedback. Encouraging dialogue and reflection helps students gain confidence and overcome misconceptions. Timely feedback is essential for reinforcing learning and reducing fear of mathematics.

Building Confidence Through Communication. JMT highlights that mathematical communication helps students in public schools overcome fear and build confidence, particularly in environments with fewer resources. Open communication about mathematical concepts fosters a positive learning experience and helps students feel more secure in solving problems.

In summary, both teachers agree that mathematical communication is crucial for improving students' learning and building confidence. Active participation, peer collaboration, and regular feedback from teachers are key factors in creating an environment where students can explore and express mathematical ideas, ultimately enhancing both academic performance and problem-solving skills.

The results suggest that mathematical communication involves students' ability to organize and convey their mathematical thinking clearly to peers, teachers, and others, while also evaluating others' strategies and ideas. It emphasizes using mathematical language accurately and serves as a tool for addressing misconceptions and reflecting on learning challenges. The findings highlight the need for systematic support to help teachers implement the mathematics curriculum effectively. This study shows the importance of developing students' mathematical communication skills through creative activities that enhance both verbal and written communication, benefiting both student learning and teacher decision-making. Classroom discourse fosters a supportive environment for students to explore ideas, take risks, and engage in meaningful dialogue, while also improving teacher-student communication. Additionally, involving parents can strengthen communication around students' education. The research implies that expanding pedagogical approaches in mathematics teaching is essential and can lead to increased self-confidence and motivation in students, ultimately helping teachers and students better connect with mathematical content.

Conclusion

The research underscores the pivotal role of mathematical communication in enhancing students' learning and proficiency in mathematics. Through a combination of quantitative and qualitative data, the study demonstrates that students with stronger mathematical communication skills exhibit a deeper understanding of mathematical concepts and improved problem-solving abilities. These students also engage more actively in classroom discussions, peer collaborations, and individual reflections on their learning.

The study highlights the critical role of teachers in fostering mathematical communication by creating opportunities for students to explain their reasoning, engage in discussions, and participate in structured activities that promote communication. Teachers who adopted these practices reported better student engagement and improved learning outcomes, indicating that mathematical communication is a powerful tool not only for individual learning but also for collaborative problem-solving.

In conclusion, mathematical communication should be seen as a central element of mathematics education. It enables students to articulate their thought processes, engage critically with mathematical content, and collaborate effectively with peers. By prioritizing mathematical communication in the classroom, teachers can significantly enhance student achievement and foster a deeper understanding of mathematics. Therefore, this study recommends that educators integrate mathematical communication strategies into their instructional practices to support student success and develop critical mathematical skills.

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