Kognitif
Jurnal Riset HOTS Pendidikan Matematika
Volume- 5 No- 3 Halaman 1132 – 1145
ISSN 2776-9704 P-ISSN 2776-9984
https://doi.org/10.51574/kognitif.v5i3.3210

Analysis of Students’ Mathematical Communication Skills in Project-Based Learning

Khaerani, Rahmawati, Syamsuriyawati, Rahmat Kamaruddin, Nuraeni Handang Mamara

How to cite : Khaerani, K., Rahmawati, R., Syamsuriyawati, S., Kamaruddin, R., & Mamara, N. H. (2025). Analysis of Students’ Mathematical Communication Skills in Project-Based Learning. *Kognitif: Jurnal Riset HOTS Pendidikan Matematika*, *5*(3), 1132–1145. https://doi.org/10.51574/kognitif.v5i3.3210

To link to this artcle : https://doi.org/10.51574/kognitif.v5i3.3210

Opened Access Article

Published Online on 10 August 2025

Submit your paper to this journal

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v5i3.3210 Volume 5, No 3, Juli - September 2025, pp. 1132– 1145

Analysis of Students' Mathematical Communication Skills in Project-Based Learning

Khaerani[1*], Rahmawati[2], Syamsuriyawati[3], Rahmat Kamaruddin[4], Nuraeni Handang Mamara[5]

[1,2,3]Department of Mathematics Education, Faculty Teacher Training and Education, Universitas Muslim Maros
[4]Department of Mathematics Education, STKIP Andi Matappa
[5]Education Department, Faculty of Arts and Social Science, The University of Sydney

Article Info

Article history:

Received Jun 25, 2025
Accepted Jul 28, 2025
Published Online Aug 10, 2025

Keywords:

Mathematical Communication
Project Based Learning
21st Century Skills
Mathematics Education

ABSTRACT

Mathematical communication ability is an essential 21st century skill that needs to be possessed by mathematics education students. However, initial studies show that students often experience difficulties in conveying mathematical ideas in writing and visually, which is partly due to the use of conventional learning models that do not support interaction and exploration. This study aims to analyze students' mathematical communication skills in the context of project-based learning, as well as to identify the forms of mathematical communication that emerge and the factors that influence them. This research used descriptive qualitative approach with case study method. The subjects consisted of 9 students of Mathematics Education Study Program of Maros Muslim University who were selected purposively. Data were collected through participatory observation, in-depth interviews, and project documentation, then analyzed through the stages of reduction, presentation, and conclusion drawing. The results showed that students' oral communication and visual representation developed significantly through group discussions and project presentations. However, aspects of written communication were still weak, especially in the use of logical structure and consistency of mathematical symbols. The implication of this finding indicates the need to strengthen the written communication aspect through the integration of mathematical writing exercises in the curriculum, as well as the provision of learning spaces that support students' courage in communicating reflectively and structurally.

Corresponding Author:

Khaerani,
Department of Mathematics Education,
Faculty Teacher Training and Education,
Universitas Muslim Maros,
Dr. Ratulangi Street No. 62, Taroda Village, Turikale District, Maros Regency, South Sulawesi, 90512,,
Indonesia
Email: khaerani@umma.ac.id

Introduction

One of the 21st century skills that must be possessed by students, especially from mathematics education majors, is the ability in mathematical communication (Jahro, 2022). Mathematical communication skills are essential competencies for mathematics education students, especially for those who prepare themselves as prospective educators (Asmara & Asnawati, 2020). Mathematical communication consists of the ability to convey ideas, concepts, and mathematical solutions both orally, in writing, and visual representations (Melissa et al., 2023). Mathematical communication not only includes the ability to convey answers, but also the ability to explain the thinking process logically through writing, graphics, and symbols (Maryati et al., 2022). However, the facts in the field show that this ability is still in the low category. One of the causes of students' low mathematical communication skills is the learning method used by lecturers. Although there are various cooperative learning models, some lecturers still use conventional methods that are one-way, so that students have limited opportunities to develop mathematical communication skills (Fadhelina, 2021). Until now, the role of lecturers in building students' mathematical communication skills, especially in mathematics, is still very limited (Suhenda & Munandar, 2023) .

The problem of students' mathematical communication skills can also be seen based on the results of the 2018 PISA study, Indonesia is ranked 73 out of 79 countries in mathematical literacy with an average score of 379, while the OECD average is 489, this shows that mathematical understanding and communication skills at the basic education level (OECD, 2019) are still in the weak category. Alumni tracer results from the Indonesian Mathematics Educators Forum (2022) also revealed that 62% of mathematics education graduates had difficulty in conveying mathematical concepts in a written and structured manner in teaching activities. In addition, preliminary observations at Maros Muslim University show that most students have not been able to express mathematical arguments completely in their project reports or final project presentations.

One of the learning models that can improve mathematical communication skills is project-based learning (PjBL). The right learning model and is considered capable of meeting the demands of learning in the current era, namely the industrial revolution 4.0 is a project learning model (Dewi et al., 2022). PjBL emphasizes solving real problems through projects that involve research, collaboration, and presentation of results (Farida et al., 2024). This model provides opportunities for students to develop mathematical communication skills actively. The application of STEM-integrated PjBL can improve students' mathematical communication skills in connecting mathematical ideas, using mathematical representations, and conveying ideas verbally and in writing (Mawaddah & Mahmudi, 2021). Previous research shows that project-based learning can improve students' mathematical communication skills. For example, a study shows that project-based learning innovation can improve students' mathematical communication skills in transformation geometry courses (Putri et al., 2019). Another study shows that students with high mathematical ability tend to have good mathematical communication skills, while students with low mathematical ability show limited mathematical communication skills (Yuntawati, 2016). With a practical and contextual approach applied to the PjBL model helps students become more active in the learning process (Yuliani et al., 2024).

The problem of weak written mathematical communication is not only a problem in Indonesia, especially in Maros, but also relevant globally, where many international reports emphasize the importance of strengthening mathematical communication in teacher education (OECD, 2021). Although project-based learning has been widely studied and proven effective in improving concept understanding and collaborative skills, the literature still shows a research gap in this area. Not many previous studies have specifically linked PjBL to improved written mathematical communication, especially among student teachers. Furthermore, most studies

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v5i3.3210 Volume 5, No 3, Juli - September 2025, pp. 1132– 1145

tend to focus on primary and secondary level learners, so studies involving mathematics education students are still rare. In addition, the approach used is generally quantitative, whereas a qualitative approach can provide a deeper understanding of students' mathematical thinking and communication processes in the context of PjBL.

Maros Muslim University as a higher education institution has a strategic role in improving students' mathematical communication skills. The curriculum currently implemented at Maros Muslim University is the implementation of a project-based learning model. However, there is currently no research that specifically analyzes the mathematical communication skills of Mathematics Education study program students at Maros Muslim University, especially in the context of project-based learning. Therefore, this study aims to analyze the mathematical communication skills of mathematics education students at Universitas Muslim Maros in project-based learning. The results of this study are expected to provide insight into the role of project-based learning in improving students' mathematical communication skills, as well as offering recommendations for the development of more effective learning approaches.

Methods

Type of Research

This research applied a qualitative approach with descriptive method, which was chosen to explore in-depth understanding of students' mathematical communication skills during project-based learning. Qualitative research allows researchers to explore the process, communication patterns, and student responses naturally without rigid variable intervention.

Research Subjects

The subjects in this study consisted of 9 fourth semester students of the Mathematics Education Study Program at Maros Muslim University, who were taking the Mathematics Teaching and Learning Strategy course with the application of a project-based learning model for six lecture sessions. The project developed in the form of developing teaching media based on local contexts and preparing LKPD based on real problems around elementary school students. Subject selection was carried out through several stages using purposive sampling technique. The first stage was an initial observation of all students taking the course, which amounted to 24 people. Furthermore, participatory observation and recording of student activeness in the first two meetings of the lecture were conducted to identify potential relevant participants. Based on the observation, 12 students were selected who met the criteria, namely: (1) had attended at least two sessions of project-based learning, (2) showed activeness in group discussions and project work, and (3) had a minimum Grade Point Average (GPA) of 3.00 as an indicator of basic academic ability. Students who met the criteria were then asked to participate in interviews and follow-up observations. After considering the consistency of attendance, the quality of project contributions, and readiness to participate in the entire series of research, 9 students were selected as the final research subjects. All participants agreed to participate voluntarily. The identity of the participants was kept confidential to protect privacy and research ethics. This research has also obtained ethical approval from the Research Ethics Committee of the Faculty of Teacher Training and Education, Maros Muslim University.

Instrument

The instruments in this study were developed to reveal students' mathematical communication skills as a whole based on three main aspects: oral communication, written communication, and visual representation. The instrument model used includes observation guidelines, interview guidelines, and student project document assessment sheets. The observation guideline was developed based on the mathematical communication indicators formulated by the National Council of Teachers of Mathematics (NCTM, 2000), which includes the ability to: (a) organize and clarify mathematical ideas, (b) express ideas in writing, orally, and visually, and (c) use mathematical symbols and representations appropriately. This instrument contains an observation rubric that records student activities in group discussions, project presentations, and interactions with lecturers. The interview guideline was developed to dig deeper into the perceptions, difficulties, and mathematical communication strategies experienced by students during the project. The questions were designed based on mathematical communication theory (Sfard, 2008; Vygotsky, 1978), and were semi-structured to allow for flexibility and in-depth exploration. We also used a student project document assessment sheet, which was used to assess written and visual communication skills through student project products, such as written reports, presentations, and graphical representations. The assessment criteria included clarity of mathematical argument, integration between narrative and visual representation, and appropriate use of symbols. The assessment was conducted using a customized rubric from Sumarmo (2010) and NCTM indicators.

Procedure/Data Collection

Data collection in this study was conducted through three main approaches: participatory observation, in-depth interviews, and collection of supporting documents. Participatory observation was conducted during four meetings in the project-based learning process. Researchers were directly involved to observe students' mathematical communication behavior when they discussed in groups, presented project results, and compiled written reports. The focus of observation was directed at how students convey ideas, use mathematical symbols or notations, and represent concepts in the form of graphs, tables, or other visual diagrams. In addition to observation, in-depth interviews were conducted to obtain more reflective information about students' experiences during project activities. Interviews were conducted with six students and one lecturer, with questions exploring their perceptions of the mathematical communication process, challenges faced, and strategies used to effectively communicate mathematical ideas. The interviews were semi-structured, allowing flexibility in exploring responses in depth according to the direction of the conversation. The documentation technique was used to complement the data from the observations and interviews. The documents collected included three student projects in the form of written reports, presentation materials (slides), notes on the results of group discussions, as well as audio and video recordings during presentation activities. The documentation was analyzed to identify mathematical communication patterns that emerged in the product and learning process, and was used as data triangulation material to increase the validity of the findings. The entire data collection process was conducted systematically and continuously throughout the duration of the project.

Data Analysis

Data analysis in this study was conducted using the interactive model approach of Miles and Huberman (2014), which consists of three main stages: data reduction, data presentation, and conclusion drawing. Data reduction is done by sorting, selecting, and simplifying raw data

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v5i3.3210 Volume 5, No 3, Juli - September 2025, pp. 1132– 1145

from observations, interviews, and documentation, in order to focus on information that is relevant to the indicators of mathematical communication. In this stage, data that did not fit the focus of the research was eliminated, while the main data were grouped based on aspects of oral, written, and visual communication. Determination of the classification of mathematical communication ability refers to the score interval that has been developed by Utami et al. (2020) seen in Table 1.

Table 1. Criteria for Mathematical Communication Ability

Score/Category	Oral Communication Criteria	Written Communication Criteria	Visual Representation Criteria
Good	Able to explain mathematical concepts and strategies clearly, coherently, and use appropriate mathematical terms.	Compose written arguments with a complete structure (thesis, reasoning, and conclusion), using mathematical notation correctly.	Uses appropriate graphs, tables, or diagrams with explanations or logical connections to the context.
Sufficient	Explains ideas with common language that can be understood, but the use of mathematical terms is not yet consistent.	Conveys ideas in writing with incomplete structure or less logical reasoning; there are minor errors.	Uses relevant visual representations but incomplete or without narrative explanation.
Less	Explanations are unsystematic, stilted or out of context; minimal use of mathematical terms.	Writing does not show logical reasoning or structure; predominantly end result answers with no explanation of process.	Does not use visual representations or uses them inappropriately and without relevance to the content.

Once reduced, the data was presented through narrative descriptions, matrix tables, and direct participant quotes, making it easier to analyze patterns and trends. This presentation also facilitated the process of reading and interpreting the meaning in the context of students' mathematical communication during project activities. The last stage is conclusion drawing, which is formulating the main findings related to students' mathematical communication skills based on the trends found, as well as identifying the relationship between supporting and inhibiting factors. During the analysis process, open and thematic coding was conducted to identify the main indicators in each communication category. In addition, a triangulation process was carried out on both sources and methods by checking the compatibility between the results of observations, interviews, and documentation, thus strengthening the reliability of the research findings.

Research Results

Observation Data Results

Table 2 shows the observation data of good, sufficient, and insufficient mathematical communication skills determined based on the criteria in Table 1. Observation data was obtained during four sessions of project-based learning. Researchers recorded student interactions during group discussions, presentations, and preparation of project products.

Table 2. Observation of Mathematical Communication Ability

No.	Student's Initial Name	Oral Communication	Written Communication	Visual Representation
1	MHS-1	Good	Less	Good
2	MHS-2	Fair	Fair	Good
3	MHS-3	Good	Less	Fair
4	MHS-4	Less	Less	Enough
5	MHS-5	Enough	Less	Good
6	MHS-6	Good	Fair	Good
7	MHS-7	Fair	Enough	Enough
8	MHS-8	Good	Enough	Good
9	MHS-9	Fair	Less	Fair

The observation results showed that most students were verbally active, especially in explaining the steps of solving problems or when asked to explain their part of the project. A total of 6 out of 9 students showed good oral communication, characterized by the use of basic mathematical terms and the ability to explain concepts to group colleagues. However, in the aspect of written communication, students tended to be passive. When assigned to write an explanation of the project results, only a small number were able to compose coherent written reasoning. Observations also noted that the use of visual representations (graphs, tables, diagrams) was often not accompanied by written explanations explaining the meaning or interrelationships between elements. Group discussions helped to strengthen oral and visual communication, but did not automatically improve students' written communication skills.

Document Analysis Results

The documents analyzed in this study consisted of written project reports, digital presentation slides, and group work notes from three groups of students taking the Mathematics Learning Strategies course. The analysis was conducted to assess the quality of mathematical communication in written and visual form. The results of the analysis showed that all groups presented project results with a logical solution structure, but mathematical explanations in the form of written narratives were still minimal. For example, in Group 1's report, a comparison graph of household water consumption was presented, but the graph was not accompanied by a narrative explaining the relationship between variables or the reasons for choosing the graph form. In contrast, Group 2 compiled a project report "Using Circle Diagrams for Plastic Waste Data" that included problem formulation, stages of solution, and justification for choosing mathematical strategies. They included sentences such as: "We chose to use pie charts because we wanted to show the proportion of waste categories as a whole, according to the context of management in the household environment." However, the narrative was not fully consistent throughout the report. Group 3, in their report on "Energy Consumption Efficiency", presented attractive tables and bar graphs, but the descriptive section only listed numerical results without any explanation of the calculation procedure or quantitative meaning. From these results, it can be concluded that only two of the nine reports showed a strong written communication structure, while most of the others only presented the final results without any explanation of the process or in-depth mathematical arguments. Visual representations such as graphs and tables were used quite frequently, but their integration with the mathematical narrative is still a challenge that needs further attention.

Interview Results

The results of in-depth interviews with six students and one lecturer showed that students tend to feel more confident when conveying ideas verbally than in written form. Students

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v5i3.3210 Volume 5, No 3, Juli - September 2025, pp. 1132– 1145

admitted that verbal communication allows them to explain spontaneously and is aided by the use of visual media such as pictures and graphs. One student stated: "When I present, I can be more fluent because I can explain directly using pictures or graphs, but when I am told to write, I am confused about where to start and afraid of being wrong." (MHS-3). Another student added that writing mathematical explanations requires precision in choosing the right terms, and this is often an obstacle: "I know the answer, but I am confused about writing it in the correct mathematical language." (MHS-6). However, there are also students who still have doubts and insecurities when explaining the problem solving process logically in public. The student stated: ""I actually understand how to do it, but if I am told to explain it to friends, I am afraid of the wrong terms..." (MHS-1). The lecturer in charge of the course confirmed this condition and stated that so far, project evaluation has focused more on the final results and group presentations, without a special rubric that evaluates the quality of written mathematical arguments. "We do assess the project report, but so far we have not specifically distinguished aspects of written mathematical narrative or argument structure." (Lecturer A).

Discussion

Students' Mathematical Communication Ability Level

Based on the triangulation of observation data, document analysis, and interviews, a quantitative picture is obtained as shown in Figure 1

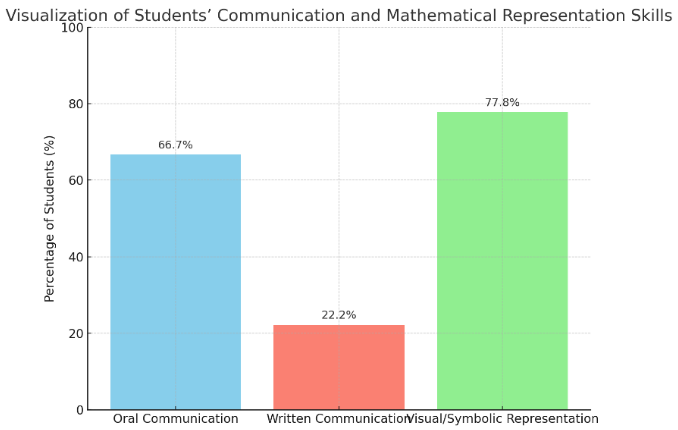

Figure 1. Visualization of Studentss Communication and Mathematical Skills

From Figure 1 it was found that oral communication skills: 6 out of 9 students (66.7%) showed oral skills at the 'adequate' to 'good' level in project presentations and group discussions. In addition, written communication skills: 2 out of 9 students (22.2%) were able to compose coherent and systematic written mathematical arguments in the project report. Then, visual/symbolic representation ability: 7 out of 9 students (77.8%) used relevant visual representations (graphs, diagrams, tables) in the presentation, although not all were accompanied by adequate written explanations.

In general, the results showed that students' mathematical communication skills in project-based learning were in the moderate category. They were also less trained in writing mathematical narratives because the project tasks emphasized visual products and final results. Students are quite capable of communicating mathematical ideas through oral and visual representations, but still experience obstacles in building mathematical arguments in writing. Based on observation and interview findings, students tend to feel insecure in writing because they are worried about using the wrong terms or notations. This discrepancy is in line with Sfard's (2008) view that mathematical communication involves two main metaphors: participation (oral/visual) and acquisition (written), where the participatory form is more developed in social contexts such as group discussions. This phenomenon is consistent with previous research which states that students' mathematical communication in the context of project-based learning is indeed often limited to oral and visual communication, while written communication is often neglected (Muliawati & Aldin, 2024). In addition, another study also concluded that the lowest mathematical communication possessed by students is interpreting ideas in writing (Wulandari & Astutiningtyas, 2020).

Most students showed good performance in conveying ideas orally during presentations and discussions, in accordance with Vygotsky's (1978) sociocultural framework that emphasizes the role of social interaction in cognitive development. However, the ability to compose coherent mathematical writing is not yet strong, suggesting that internal representation and written articulation are still weak. This gap needs to be examined more deeply as an aspect that requires appropriate pedagogical intervention. In line with previous research which revealed that logical and systematic mathematical writing, as an important aspect of mathematical communication, is still underdeveloped among students (Purwaningsih et al., 2020). Thus, it can be concluded that students' mathematical communication skills are still not fully developed. Systematic intervention is needed through learning approaches that emphasize mathematical writing, as well as explicit feedback on the quality of communication in written form.

Dominant and Weak Aspects of Mathematical Communication.

From the analysis of the research results, it is revealed that oral communication and visual representation are the two most dominant aspects in project-based learning. Students showed relatively good ability in explaining ideas verbally and utilizing graphs, diagrams, and tables in explaining mathematical concepts. Visual representation is a strength of students in solving mathematical problems and presenting solutions. The use of visual representations in mathematics is very effective in facilitating understanding of concepts (Sipayung et al., 2024). According to Rahmatika et al. (2022) visual communication facilitates understanding of abstract concepts and becomes a bridge between concrete and formal representations. This is reinforced by the statement Lubis et al. (2023) that visual representations can improve spatial reasoning and the ability to explain mathematical relationships intuitively. However, written communication skills showed clear weaknesses. Most of the project reports only contained final results without a complete explanation of the solution process, justification of steps, or relationships between concepts. In interviews, students admitted to lack of confidence, confusion in using mathematical terms, and lack of habituation in writing mathematical arguments explicitly. This finding is in line with the results of Panadero et al. (2024) who emphasized the importance of explicit rubrics in project-based learning to improve the quality of students' written communication. Without clear guidelines or rubrics, students tend to ignore aspects of mathematical argumentation in written reports (Karaman, 2024). This is due to several factors, including the lack of experience in preparing good mathematical reports and the habit of focusing more on the end result than the in-depth thought process (Maryati et al., 2022). Therefore, to strengthen students' written communication aspects, learning strategies that not only focus on project outcomes, but also provide explicit space for the writing process, reflection, and formative feedback are needed. Interventions through writing guidance, the use of mathematical communication rubrics, and the integration of written argumentation tasks can be relevant solutions.

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v5i3.3210 Volume 5, No 3, Juli - September 2025, pp. 1132– 1145

Factors Affecting Mathematical Communication Skills

The results of the study identified several factors that influence students' mathematical communication skills, both supporting and inhibiting. Project-based learning provides a space for students to develop active and contextualized communication during the learning process. Project-based assignments based on real problems increase students' motivation to explore mathematical concepts and explain their ideas more effectively. Project-based learning can deepen mathematical understanding and communication because students are exposed to situations that require direct application of concepts (Maysuri & Sopacua, 2024). Collaboration in groups: group work is an important factor that supports students' mathematical communication. Group discussion enriches ideas, improves understanding, and accelerates the process of conveying ideas verbally and visually. Group collaboration in the context of project-based learning strengthens students' ability to explain mathematical ideas and work together in solving problems (Dewi et al., 2024) .

We also found the inhibiting factor of lack of training in mathematical writing: logical and systematic mathematical writing is a major obstacle in written communication. Students often only focus on the technical solution of the problem without explaining their thought process in a structured way. The ability to write mathematics clearly and structurally requires continuous practice, as well as awareness of the importance of communication in the problem solving process (Nurhasanah et al., 2019). Students are unable to write down the information known and asked in the problem, lack of focus in learning so that they do not understand the material taught, the level of difficulty of the problem, and calmness in working on problems (Suryawati et al., 2023). This is in line with research Munthe & Karim (2021) which states that the low communication skills of students can be influenced by several factors, including focus and enthusiasm, students do not understand the material, are not careful, do not understand the meaning of the problem well, and learning conditions that are less supportive. Furthermore, lack of confidence in presentation: although most students were able to communicate well orally in group discussions, lack of confidence became an obstacle when they had to present the results in front of the class. Students' discomfort in public speaking can reduce their ability to convey knowledge clearly (Juta & Van Wyk, 2020).

Contribution of Project-Based Learning to Mathematical Communication Skills

Project-based learning is proven to have a positive contribution to the development of students' oral and visual communication. Through projects, students are encouraged to work together, solve problems contextually, and convey the results of their thinking creatively and collaboratively. Project-based learning provides opportunities to hone public speaking skills as well as use visual aids such as graphs and diagrams in conveying mathematical ideas. This is in line with previous research which concluded that there is a positive and significant relationship between mathematical problem solving ability and students' mathematical communication ability (La'ia & Harefa, 2021). However, the contribution to written communication skills is still limited. Although students were able to communicate ideas verbally and visually, their ability to organize mathematical reasoning in a written and structured manner still needs improvement. This suggests the need for a more balanced approach between verbal, visual and written communication in project-based learning.

Implications for Learning in Mathematics Education

Based on the results of the study, there are a number of implications that can be used to improve mathematics learning in higher education, especially in the Mathematics Education Study Program. First, the expansion of emphasis on mathematical writing: in project-based learning, it is very important to give greater emphasis on the logical and systematic aspects of mathematical writing (Lowaer et al., 2025). Lecturers need to introduce effective writing techniques, including the appropriate use of mathematical symbols and notations. Second, strengthening the use of visual media: given that students show good ability in visual representation, developing project-based learning that integrates more visual aids, such as GeoGebra, Desmos, or other mathematical software, can further improve their mathematical understanding and communication. Strengthening the use of visual media is needed because the visual representation aspect is a prominent strength in students (Melati et al., 2023). Third, increased confidence in oral communication: lecturers can provide more opportunities for students to practice public speaking through structured discussions, seminars, and group presentations. This will improve students' oral communication skills more effectively (Wariani & Hayon, 2023).

Conclusion

Based on the results of the analysis, the mathematical communication skills of Mathematics Education Study Program students at Maros Muslim University in the context of project-based learning show strength in the aspects of oral communication and visual representation. Students are able to express mathematical ideas verbally through discussions and project presentations, and utilize visual media such as graphs, tables, and diagrams to support concept explanations. This indicates that the project-based approach plays an effective role in increasing active participation, collaboration, and the ability to express ideas visually to support the understanding and delivery of mathematical concepts in a real context. However, students' written communication still showed significant weaknesses. Irregularity in argument structure, inconsistent use of mathematical symbols, and lack of elaboration of reasoning are the main obstacles. Supporting factors for successful mathematical communication include the challenging and collaborative context of the project, as well as technological support. In contrast, the main obstacles stemmed from lack of experience in systematic mathematical writing and low confidence in conveying ideas formally. Therefore, strategic interventions are needed in the form of strengthening mathematical writing exercises, developing written communication evaluation rubrics, and formal presentation training to build confidence. With continuous and planned implementation, project-based learning has great potential to improve students' mathematical communication holistically, including verbal, visual, and written aspects.

Conflict of Interest

The authors declare that there is no conflict of interest.

Author Contributions

K. conceptualized the research idea presented and collected the data. The other fourth authors (R., S., R.K., and N.H.M.) actively contributed to the development of the theory, methodology, data organization and analysis, discussion of results, and approval of the final version of the work. All authors confirm that they have read and approved the final version of this manuscript.

https://doi.org/10.51574/kognitif.v5i3.3210 Volume 5, No 3, Juli - September 2025, pp. 1132– 1145

The percentage contributions to the conceptualization, drafting, and revision of this paper are as follows: K.: 60%, R.: 10%, S.: 10%, R.K.: 10%, and N.H.M.: 10%.

Data Availability Statement

The authors state that the data supporting the findings of this study are available from the corresponding author, [K.], upon reasonable request.

References

Asmara, R. balada, & Asnawati, S. (2020). Kemampuan Komunikasi Matematis Siswa Melalui Model Pembelajaran Diskursus Multy Reprecentasy Pada Materi Bilangan Bulat. *IndoMath: Indonesia Mathematics Education*, *3*(1), 52. https://doi.org/10.30738/indomath.v3i1.6100

Dewi, A. C., Yahya, M., & Darmawang. (2022). Efektifitas model pembelajaran perbasis proyek pada mata kuliah perencanaan pembelajaran kejuruan. *Jurnal Konsepsi*, *11*(2), 373–379. https://p3i.my.id/index.php/konsepsi/article/view/226

Dewi, I., Siregar, H., Agustia, A., & Dewantara, K. H. (2024). Implementasi Case Method Berbasis Pembelajaran Proyek Kolaboratif terhadap Kemampuan Kolaborasi Mahasiswa Pendidikan Matematika. *Teorema: Teori Dan Riset Matematika*, *09*(September), 261–276.

Fadhelina, N. (2021). Analisis Kemampuan Komunikasi Matematis Mahasiswa Melalui Penerapan Blended Learning Pada Mata Kuliah Geometri. *JIIP - Jurnal Ilmiah Ilmu Pendidikan*, *4*(2), 119–123. https://doi.org/10.54371/jiip.v4i2.217

Farida, M. K., Setyosari, P., & Aulia, F. (2024). Analisis Keterlibatan Mahasiswa Dalam Pembelajaran Berbasis Proyek. *JKTP: Jurnal Kajian Teknologi Pendidikan*, *7*(3), 172. https://doi.org/10.17977/um038v7i32024p172

Jahro, S. M. (2022). The Effectiveness of the Susan Loucks-Horsley Model and the Small Group Discussion Method on Collaboration Skill. *Annual International COnference on Islamic Education for Students*, *1*(1), 173–186. https://doi.org/10.18326/aicoies.v1i1.316

Juta, A., & Van Wyk, C. (2020). Classroom Management as a Response to Challenges in Mathematics Education: Experiences from a Province in South Africa. *African Journal of Research in Mathematics, Science and Technology Education*, *24*(1), 21–30. https://doi.org/10.1080/18117295.2020.1731646

Karaman, P. (2024). Effects of using rubrics in self-assessment with instructor feedback on pre-service teachers' academic performance, self-regulated learning and perceptions of self-assessment. *European Journal of Psychology of Education*, *39*(3), 2551–2574. https://doi.org/10.1007/s10212-024-00867-w

La'ia, H. T., & Harefa, D. (2021). Hubungan Kemampuan Pemecahan Masalah Matematis dengan Kemampuan Komunikasi Matematik Siswa. *Aksara: Jurnal Ilmu Pendidikan Nonformal*, *7*(2), 463. https://doi.org/10.37905/aksara.7.2.463-474.2021

Lowaer, D., Ruyana, N. A., Luthfiyyah, R., & Nurafifah, S. (2025). *Pembelajaran Berbasis Proyek (PBL) Sebagai Strategi Untuk Meningkatkan Kemampuan Pemecahan Masalah Matematika Siswa SD*. *2*(April), 30–37. https://doi.org/10.62387/ep.v1i2.240

Lubis, R. N., Meiliasari, & Rahayu, W. (2023). Kemampuan Komunikasi Matematis Siswa pada Pembelajaran Matematika. *Jurnal Riset Pembelajaran Matematika Sekolah*, *7*(2), 23–34. https://doi.org/10.21009/jrpms.072.03

Maryati, I., Suzana, Y., Harefa, D., & Maulana, I. T. (2022). Analisis Kemampuan Komunikasi Matematis dalam Materi Aljabar Linier. *Prisma*, *11*(1), 210.

https://doi.org/10.35194/jp.v11i1.2044
Mawaddah, S., & Mahmudi, A. (2021). Analisis Kemampuan Komunikasi Matematika Siswa Melalui Penggunaan Project-Based Learning Terintegrasi Stem. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *10*(1), 167. https://doi.org/10.24127/ajpm.v10i1.3179
Maysuri, T., & Sopacua, J. (2024). Pengaruh Penerapan Model Pembelajaran Project Based Learning dalam Upaya Meningkatkan Hasil Belajar pada SMA Negeri 3 Maluku Tengah. *JIMPS*, 566–580.
Melati, E., Fayola, A. D., Hita, I. P. A. D., Saputra, A. M. A., Zamzami, & Ninasari, A. (2023). The Use of animation as technology-based learning media to encourage learning motivation. *Journal on Education*, *6*(1), 732–741.
Melissa, M. M., Susanto, L. A. W., Yudanti, E., & Salsabila, D. (2023). Profile of mathematical communication skills of prospective mathematics teachers. *AIP Conference Proceedings*, *2569*(1), 40018. https://doi.org/10.1063/5.0112854
Muliawati, I., & Aldin, A. (2024). The Effectiveness of the Problem Based Learning Model on Elementary School Students' Mathematics Learning Outcomes. *Journal of Indonesian Primary School*, *1*(2), 27–31. https://doi.org/10.62945/jips.v1i2.91
Munthe, V. F., & Karim, A. (2021). Analisis Kemampuan Komunikasi Matematis Peserta Didik SMP Pada Materi Relasi dan Fungsi. *Prosiding Diskusi Panel Pendidikan Matematika*, *17*, 325–340. https://didikpos.com/2020/02/pakai-sistem-kuno-kualitas-pendidikan-indonesia-
Nurhasanah, R. A., Waluya, S. B., & Kharisudin, I. (2019). Kemampuan Komunikasi Matematis dalam Menyelesaikan Masalah Soal Cerita. *Seminar Nasional Pascasarjana 2019*, *2017*, 769–775.
Purwaningsih, E., Sari, S. P., Sari, A. M., & Suryadi, A. (2020). The effect of stem-pjbl and discovery learning on improving students' problem-solving skills of the impulse and momentum topic. *Jurnal Pendidikan IPA Indonesia*, *9*(4), 465–476. https://doi.org/10.15294/jpii.v9i4.26432
Putri, A. D., Syutaridho, S., Paradesa, R., & Afgani, M. W. (2019). Peningkatan Kemampuan Komunikasi Matematis Mahasiswa Melalui Inovasi Pembelajaran Berbasis Proyek. *JNPM (Jurnal Nasional Pendidikan Matematika)*, *3*(1), 135. https://doi.org/10.33603/jnpm.v3i1.1884
Rahmatika, A., Batubara, I. H., Sari, I. P., Muhammadiyah, U., Utara, S., Muhammadiyah, U., Utara, S., & Matematis, K. K. (2022). Penerapan Software GeoGebra Dalam Kemampuan Komunikasi Matematis Mahasiswa Pada Mata Kuliah Trigonometri. *EduTech: Jurnal Ilmu Pendidikan Dan Ilmu Sosial*, *8*(2), 162–167. https://doi.org/10.30596/edutech.v8i2.10581
Sipayung, N. F., Dalimunte, N. A., Wandini, R. R., Pendidikan, S., Madrasah, G., Tarbiyah, F. I., Keguruan, D., Islam, U., Sumatra, N., & Medan, U. (2024). Efektivitas Penggunaan Representasi Matematika pada Pembelajaran Matematika di SD. *Jurnal Pendidikan Tambusai*, *8*, 668–673.
Suhenda, L. L. A., & Munandar, D. R. (2023). Kemampuan Komunikasi Matematis Siswa Dalam Pembelajaran Matematika. *Jurnal Educatio FKIP UNMA*, *9*(2), 1100–1107. https://doi.org/10.31949/educatio.v9i2.5049
Suryawati, S., Hasbi, M., Suri, M., & Kurniawati, S. (2023). Faktor Yang Mempengaruhi Kemampuan Komunikasi Matematis Siswa Smp. *Journal of Education Science*, *9*(1), 7. https://doi.org/10.33143/jes.v9i1.2849
Utami, L. F., Pramudya, I., & Slamet, I. (2020). Students' Mathematical Communication Skills in Terms of Concrete and Abstract Sequential Thinking Styles. *Al-Jabar : Jurnal Pendidikan Matematika*, *11*(2), 371–381. https://doi.org/10.24042/ajpm.v11i2.7486

Kognitif: Jurnal Riset HOTS Pendidikan Matematika
https://doi.org/10.51574/kognitif.v5i3.3210 Volume 5, No 3, Juli - September 2025, pp. 1132– 1145

Wariani, T., & Hayon, V. H. B. (2023). Kajian Tentang Keaktifan, Hasil Belajar, dan Produk yang Dihasilkan Mahasiswa Pada Perkuliahan yang Menerapkan Pembelajaran Berbasis Proyek. *Indonesian Journal of Educational Science (IJES)*, *5*(2), 134–142. https://doi.org/10.31605/ijes.v5i2.2371

Wulandari, A. A., & Astutiningtyas, E. L. (2020). Analisis kemampuan komunikasi matematis mahasiswa dalam pembelajaran relasi rekurensi. *Jurnal Math Educator Nusantara: Wahana Publikasi Karya Tulis Ilmiah Di Bidang Pendidikan Matematika*, *6*(1), 54–64. https://doi.org/10.29407/jmen.v6i1.14263

Yuliani, A., Nugraha, Y., & Samura, A. O. (2024). Pengaruh Penggunaan Pembelajaran Berbasis Proyek terhadap Kemampuan Pemecahan Masalah Matematika pada Siswa Sekolah Menengah Atas. *Jurnal Ulul Albab*, *28*(1), 15. https://doi.org/10.31764/jua.v28i1.23326

Yuntawati. (2016). Analisis kemampuan komunikasi matematis mahasiswa dalam menyelesaikan masalah matematika. *Prosiding Seminar Nasional Lembaga Penelitian Dan Pendidikan (LPP) Mandala*, *September*, 1–23..

Author Biographies

	**Khaerani,** is a lecturer and researcher at the Mathematics Education Study Program, Maros Muslim University, South Sulawesi, Indonesia. His research interests are Innovation in Mathematics Learning, Ethnomathematics, and Meta-analysis. Affiliation: Maros Muslim University, Email: khaerani@umma.ac.id
	**Rahmawati** is a lecturer and researcher at the Mathematics Education Study Program, Maros Muslim University, South Sulawesi, Indonesia. His research interests are Innovation in Mathematics Learning, Ethnomathematics, and Meta-analysis. Affiliation: Maros Muslim University, Email: nyoled@umma.ac.id
	**Syamsuriyawati** is a lecturer and researcher at the Mathematics Education Study Program, Maros Muslim University, South Sulawesi, Indonesia. His research interests are Innovation in Mathematics Learning, Ethnomathematics, and Meta-analysis. Affiliation: Maros Muslim University, Email: wathy@umma.ac.id

	**Rahmat Kamaruddin** is a lecturer in the Mathematics Education Study Program at the Andi Matappa Pangkep Teacher Training and Education College (STKIP). He earned his Bachelor's degree at the Makassar State University in the Faculty of Mathematics in the Department of Mathematics Education and completed a postgraduate program in the Department of Mathematics Education, Makassar State University. His research interests are Mathematics Education, Learning Media, Realistic Mathematics, Email: rahmat@stkip-andi-matappa.ac.id
	**Nuraeni Handang Mamara** is a researcher who is pursuing her PhD in Education at The University of Sydney. Her research interests are teaching approaches for varied learning needs and multimodalities to foster effective and engaging learning environment. Email: nmam0656@uni.sydney.edu.au