UJMER Volume 1 No 1 2025

Unnes Journal of Mathematics Education Research

http://journal.unnes.ac.id/sju/index.php/ujmer

Students' Mathematical Communication Skills Viewed from the Perspective of Mathematical Linguistics in Ethnomathematics-Infused Problem-Based Learning Based on Bima Culture

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Article Info

Article History:
Received 30 January 2025
Accepted 18 April 2025
Published 13 Juni 2025

Keywords:
Ethnomathematics, Mathematical Communication, Mathematical Linguistics, Problem-Based Learning.

Abstract

Mathematical communication ability is a competency considered essential for all students to master. The indicators of mathematical communication ability addressed in this study are: (1) presenting problems using objects; (2) constructing arguments for solving mathematical problems; and (3) applying mathematical formulas to solve problems. Mathematical linguistics is an approach that can link mathematical abilities, particularly in the realm of mathematical communication. Students' mathematical communication ability levels can be influenced by their mathematical linguistics proficiency. One learning model capable of enhancing students' mathematical communication abilities is the PBL model infused with Bima cultural ethnomathematics. This study aims to: (1) analyze the quality of implementation following the use of the Bima cultural ethnomathematics-infused PBL model in helping to improve students' mathematical communication abilities; and (2) analyze students' mathematical abilities in relation to their mathematical linguistics proficiency when using this model. A mixed-methods approach with an explanatory sequential design was employed. The study was conducted at MTs Negeri 3 Bima, with Class VIII A serving as the experimental group and Class VIII B as the control group. Qualitative research subjects were selected based on students' mathematical linguistics proficiency. Data analysis involved t-tests and z-tests, while qualitative data analysis utilized data validity checks, data reduction, data presentation, and conclusion drawing. The results indicate that the instruction was of high quality, supported by excellent learning materials and instruments. Assessments showed that learning outcomes using the Bima cultural ethnomathematics-infused PBL model exceeded the Minimum Mastery Criteria (KKM) of 75, with a classical mastery rate of over 75%. Furthermore, the experimental class demonstrated higher average mathematical communication abilities and mastery proportions compared to the control class, and an improvement in mathematical communication abilities was observed in the experimental class. Students with low and moderate mathematical linguistics proficiency mastered only two indicators of mathematical communication ability, whereas students with high mathematical linguistics proficiency mastered all indicators.

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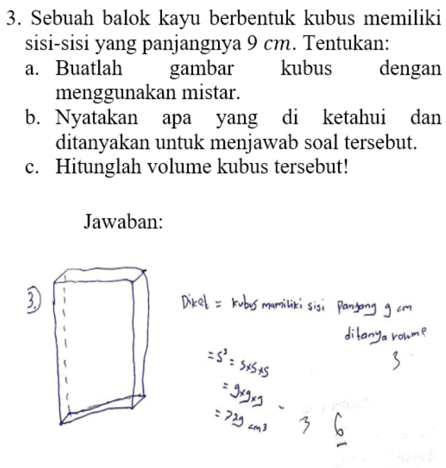
p-ISSN 2252-6455
e-ISSN 2502-4507

INTRODUCTION

Communication is a key competency required of students; according to the Decree of the Minister of Education, Culture, Research, and Technology No. 033/H/KR/2022, one of the objectives of mathematics education in Indonesia is for students to communicate ideas using diagrams, tables, symbols, or other means to explain problems or situations and to represent these situations through mathematical symbols. Communication is dynamic, evolving over time through a series of procedures and changes that foster the continuous growth and development of individual knowledge and relationships (Afikah et al., 2023). It is a process that provides students with visual elements to assist them in explaining required statements and justifications using empirical or deductive arguments (Rico et al., 2023). Therefore, developing mathematical communication skills is essential in mathematics education (Setiyawati, Junaedi, Nugroho, et al., 2020). The indicators of mathematical communication skills proposed by the NCTM (2000) that will be examined here focus on written communication: (1) presenting mathematical problems using objects (images, diagrams, tables); (2) constructing arguments and solutions for mathematical problems; and (3) applying mathematical formulas to solve problems. The student learning process inevitably involves thinking; an individual is considered to be thinking when they engage in mental activity. Through thinking, one can easily establish connections between pieces of information stored in the mind, thereby influencing intelligence levels; thus, a clear link exists between intelligence specifically mathematical-linguistic intelligence and the mathematical learning process experienced by students (Setiyawati, Junaedi, Sunyoto, et al., 2020). Mathematical linguistics is an approach that can bridge mathematical abilities, particularly in the realm of mathematical communication.

This study is based on research conducted by Mohammad Nabil Nurfaizi (2021) titled "High School Students' Mathematical Communication Skills in Solving Linear Programming Word Problems Viewed from the Perspective of Linguistic Intelligence." The results of this study indicate that students with high linguistic intelligence are able to meet the indicators of mathematical communication. In contrast, students with moderate or low linguistic intelligence have not yet met all the indicators. Consequently, this study suggests that teachers should select appropriate learning models and activities to enhance students' mathematical communication skills.

A preliminary study was conducted to assess the mathematical communication skills of eighth-grade students at MTs Negeri 3 Bima, Bima Regency. The results from this preliminary study reveal that the students' mathematical communication skills regarding the topic of polyhedra (solids with flat faces) were very low; when faced with problems, few could accurately express their solutions, and they struggled to communicate mathematical concepts or convey their ideas, understanding, and opinions to teachers, peers, and group members. This is illustrated in Figures 1 and 2 below.

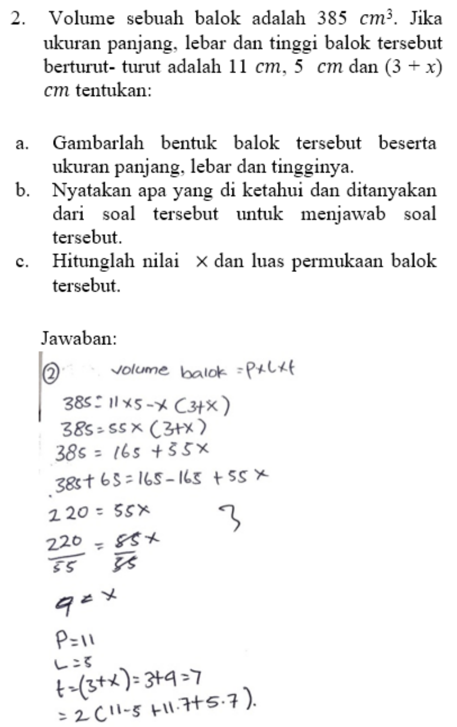

3. Sebuah balok kayu berbentuk kubus memiliki sisi-sisi yang panjangnya 9 cm. Tentukan:
a. Buatlah gambar kubus dengan menggunakan mistar.
b. Nyatakan apa yang di ketahui dan ditanyakan untuk menjawab soal tersebut.
c. Hitunglah volume kubus tersebut!

Jawaban:

3) Dikel = kubus memiliki sisi panjang 9 cm
ditanya volume
$= S^3 = 5 \times 5 \times 5$
$= 9 \times 9 \times 9$
$= 729\ cm^3$

Figure 1. Questions and Answers for the Mathematical Communication Skills Pre-test

Figure 1 shows that regarding indicator 1, the student was unable to draw accurately, making a mistake by drawing a rectangular prism instead of the requested cube. Regarding indicator 2, the student failed to construct a sound argument or problem-solving process; the answer was incomplete, failing to properly state what the question asked for. Regarding indicator 3, the student did not write the formula correctly, omitting the formula symbol and simply writing s³ directly. Thus, as shown in Figure 1, the student failed to meet indicators 1, 2, and 3 concerning mathematical communication skills.


2. Volume sebuah balok adalah 385 cm^3. Jika ukuran panjang, lebar dan tinggi balok tersebut berturut- turut adalah 11 cm, 5 cm dan $(3+x)$ cm tentukan:

a. Gambarlah bentuk balok tersebut beserta ukuran panjang, lebar dan tingginya.
b. Nyatakan apa yang di ketahui dan ditanyakan dari soal tersebut untuk menjawab soal tersebut.
c. Hitunglah nilai x dan luas permukaan balok tersebut.

Jawaban:

2. volume balok = p×l×t
385 = 11×5-x (3+x)
385 = 55×(3+x)
385 = 165 + 55x
385+65 = 165-165 + 55x
220 = 55x
220/55 = 55x/55
4 = x
p=11
l=5
t=(3+x)=3+4=7
=2(11·5+11·7+5·7).

Figure 2. Questions and Answers for the Mathematical Communication Skills Pre-test

Meanwhile, regarding Figure 2 (Question No. 2), it is evident that while the student was required to draw the geometric shape specified in the problem, they failed to provide such a drawing. Furthermore, the student did not state the given information or what was being asked before proceeding to the solution; instead, they immediately applied the formula for the volume of a rectangular prism. Consequently, the student has not yet met indicators 1 and 2 of mathematical communication ability for this problem.

Based on the analysis of a preliminary study regarding students' mathematical communication skills, it was found that students most frequently made errors related to indicators 1 and 2. This was largely due to a lack of understanding regarding the problems and concepts associated with 3D shapes with flat surfaces particularly in word problems. Consequently, there is a need for student-centered mathematics learning innovations that provide opportunities for students to enhance their learning activities and develop their ability to communicate mathematically. This indicates that students' mathematical communication skills represent a significant issue requiring an urgent solution. The situation stems from the use of conventional teaching models and methods characterized by a repetitive sequence: 1) presenting material, 2) providing example problems, 3) working on textbook exercises, 4) students solving problems on the board, and 5) assigning homework. This monotonous routine was applied to all mathematics topics throughout the semester or even the entire academic year. It is evident that the teacher focused primarily on classroom instruction without taking the initiative to alter teaching patterns, employ alternative learning models, or create a different learning atmosphere for the students.

One learning model that facilitates increased student learning activity and the development of mathematical communication skills is Problem-Based Learning (PBL). A literature review titled "Literature Study: Ethnomathematics-Based Problem-Based Learning Model to Enhance Students' Mathematical Communication Skills and Curiosity in Mathematics Learning" indicates that using an ethnomathematics-based PBL model can improve these skills and foster curiosity, thereby serving as a reference for future research (Noriza, 2023). Problem-Based Learning is an instructional process designed to help students improve their cognitive strategies and learning performance (Marthaliakirana et al., 2022a). It is a teaching approach that successfully provides a learning environment where students can practice constructing arguments regarding unstructured problems (Marthaliakirana et al., 2022b). Students can share their thoughts on what they have learned through the scientific method, thereby deepening their understanding and enhancing their scientific literacy (Hernández-Ramos et al., 2021). PBL can be more effective than conventional instruction in improving problem-solving skills (Argaw et al., 2017). PBL serves as a pedagogical approach in pre-service teacher training, allowing for the exploration of integrating PBL theory and practice into secondary school curricula (He & Qi, 2022). PBL is an instructional model categorized under inquiry-based learning, case-based learning, project-based learning, discovery learning, and just-in-time teaching (Shongwe, 2024). Naturally, the use of an instructional model should be complemented by learning media to foster a superior, high-quality learning process; one such example is the use of handouts featuring a Problem-Based Learning model infused with Bima cultural ethnomathematics.

Ethnomathematics represents the intersection of mathematics with its historical, cultural, and social roots; the term itself derives from the combination of "ethno" referring to socio-cultural contexts and "mathematics." It encompasses mathematical knowledge manifested in activities such as counting, weighing, measuring, comparing, ordering, classifying, designing, and playing. Ethnomathematics embraces ideas, procedures, processes, methods, and practices rooted in diverse cultural environments. An individual's mathematical ability can be influenced by their cultural background (Turmuzi, Suharta, & Tengah, 2023). The ethnomathematical approach allows for the contextualization of culture-based learning (Umbara et al., 2021). Ethnomathematics connects socio-cultural contexts with mathematics (Rodríguez-Nieto & Alsina, 2022); consequently, it is deeply linked to the mathematics and culture of a nation (Marleny et al., 2020). Previous research advocates for the application of ethnomathematics in mathematics instruction (Turmuzi et al., 2023).

Implementing ethnomathematics as a pedagogical approach enables learning material to be linked to students' cultures, thereby facilitating comprehension; students find the material easier to grasp because it relates directly to their own cultures and everyday activities (Masruroh et al., 2022). Researchers support integrating ethnomathematics incorporating elements of cultural values into mathematics instruction, as this can help enhance students' skills and talents, foster more meaningful understanding of the material, and improve mathematical achievement (Fouze & Amit, 2018). Based on the facts presented above, the researcher deems it necessary to further investigate "Mathematical Communication Ability Viewed from Students' Mathematical Linguistics within the Context of Ethnomathematics-Infused Problem-Based Learning Based on Bima Culture."

METHOD

This study employs a mixed-methods approach using a sequential explanatory design. This design is characterized by a quantitative component that outweighs the qualitative one, with a stronger emphasis on the quantitative aspect. The study consists of two phases: the first involves quantitative data collection, the results of which inform the second phase the collection of qualitative data.

The study population comprises Grade VIII students at MTs Negeri 3 Bima, Bima Regency. A random sampling technique was used to select the participants, resulting in a sample of 50 Grade VIII students. Class VIII A was designated as the experimental group, while Class VIII B served as the control group. The experimental group received instruction using a Problem-Based Learning (PBL) model infused with Bima cultural ethnomathematics, supported by specific handouts on this approach, to enhance students' mathematical communication skills regarding the topic of polyhedra (3D shapes with flat faces). The control group received conventional instruction using standard teaching materials provided by the school.

Data collection techniques included tests to assess students' mathematical communication skills, observation sheets to monitor student activity, and interviews. The data were analyzed using both quantitative and qualitative methods. Quantitative data were analyzed using t-tests and z-tests, while qualitative data were analyzed through descriptive synthesis to draw conclusions.

RESULTS AND DISCUSSIONS

This study presents findings regarding mathematical communication skills before and after the intervention. The research aimed to analyze the improvement in mathematical communication skills in both the experimental and control classes. An analysis of pretest and posttest scores was conducted to determine the extent of improvement in students' mathematical communication skills in both groups. During the preparation and planning phase, the researcher developed a lesson plan (RPP), a syllabus, and handouts based on the Problem-Based Learning (PBL) model incorporating Bima cultural ethnomathematics and focusing on the topic of polyhedra (geometric shapes with flat faces) as well as learning activity observation sheets, pretest and posttest questions, interview guidelines, and documentation materials. The study began by administering a pretest to students in both the experimental and control classes. The pretest was conducted prior to instruction to assess students' initial competence regarding the subject matter. Subsequently, the two classes received different treatments. The experimental class utilized the PBL-based handouts incorporating Bima cultural ethnomathematics for the topic of polyhedra, while the control class used standard teaching materials available at the school.

PBL is an instructional model that approaches learning through authentic and meaningful problems; these serve as a foundation for student inquiry and investigation, enabling students to construct their own knowledge, develop higher-order inquiry skills and independence, and boost their self-confidence (Suparman et al., 2022). The first stage involved problem orientation: students were divided into four groups and provided with the PBL handouts (incorporating Bima cultural ethnomathematics and the topic of polyhedra) to observe; the teacher encouraged students to ask questions and guided them in formulating answers. The second stage involved organizing students to understand the material on polyhedra using the PBL handouts, identifying the shapes, creating drawings, and constructing arguments. The third stage involved guiding individual or group experiences, which included discussing appropriate formulas for the given problems and engaging in discussions about the polyhedra. The teacher provided assistance whenever students encountered difficulties while solving problems in their groups. The fourth stage involves developing and presenting the work by having students present the results of their discussions to the class. The fifth stage entails analyzing and evaluating the problem-solving process through a lesson reflection conducted by the teacher. Subsequently, a post-test is administered to the experimental class. The results regarding student mastery of the learning material are as follows:

Table 1. Average Test Results

$\bar{x}$	n	μ_0	s	t_{value}	t_{table}
87	30	75	10	6.59	1.69

Based on Table 1, the calculated t-value (6.59) is greater than or equal to the t-table value (1.69); this means H_0 is rejected and H_1 is accepted. Thus, the average mathematical communication ability of students in the class using the Problem-Based Learning model infused with Bima ethnomathematics reached 75.

Table 2. Classical Mastery Test Results

x	n	π_0	z_{value}	z_{table}
27	30	0.75	1.94	1.64

Based on Table 2, the calculated z-value is 1.94 greater than or equal to the z-table value 1.64; this means H_0 is rejected and H_1 is accepted. Thus, the proportion of student mastery in the class using the Problem-Based Learning model infused with Bima cultural ethnomathematics is greater than 75%.

Table 3. Results of the Mean Difference Test

$\bar{x}_1$	$\bar{x}_2$	n_1	n_2	s	t_{value}	t_{table}
87	51	30	20	28.768	4.33	1.67

Based on Table 3, the calculated t-value (4.33) is greater than or equal to the t-table value (1.67), meaning H_0 and H_1 are accepted. Thus, the mean score for mathematical communication skills in the class using the Problem-Based Learning model infused with Bima cultural ethnomathematics is higher than that of the class using the conventional learning model.

Table 4. Results of the Test for Difference in Proportions

π_1	π_2	$\hat{p}$	$\hat{q}$	z_{value}	z_{table}
0.9	0.1	0.58	0.42	6.38	1.64

Based on Table 4, the calculated z-value is 6.38, which is greater than or equal to z-table (1.64); this means H_0 is rejected and H_1 is accepted. Thus, the proportion of mathematical communication ability among students in the class using the Problem-Based Learning model infused with Bima cultural ethnomathematics is higher than that of the class using the conventional learning model.

Table 5. Results of the Test on the Average Improvement in Students' Mathematical Communication Skills Using N-Gain

	Experimental Class	
	Average Pretest Score	**Average Posttest Score**
	52	87
N-Gain Index	62.27	
Category	Moderate	

Based on Table 5, the average pre-test score for students in the experimental class was 52, while the average post-test score was 87; this indicates an improvement following the intervention using the Problem-Based Learning model infused with Bima cultural ethnomathematics. The experimental class's N-Gain index was 62.27, placing it within the moderate category. These results demonstrate that the Problem-Based Learning model handout, incorporating Bima cultural ethnomathematics, enhanced the students' mathematical communication skills. The improvement observed in the experimental class using the Problem-Based Learning model infused with Bima cultural ethnomathematics can be attributed to the researcher's efforts to actively engage students during instruction. Students were given opportunities to identify various objects or elements of Bima culture and relate them to the material being studied, such as the topic of polyhedra (solid shapes with flat faces). The Bima community possesses several structures with geometric forms; for instance, the geometric shape of the Ro Woha (central room) framework element in the Uma Jompa structure resembles a cube, as illustrated in Figure 3.

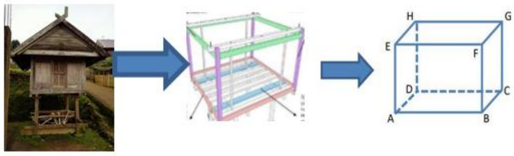


Figure 3. The geometric shape of the structural elements of the RoWahu (central space) frame in the Uma Jompa is a cube

Next, the geometric shape of the lower space of the Uma Lengge is identified as a cuboid, as shown in Figure 4.

Figure 4. The geometric shape of the space beneath the Uma Lengge is a cuboid

The geometric shape of the traditional Bima weaving loom is identified as a prism, as shown in the figure below.

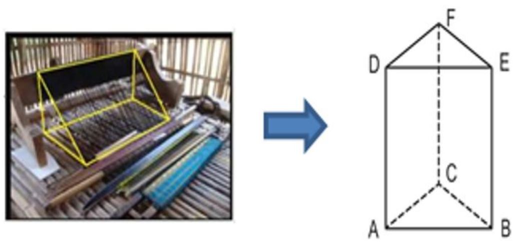


Figure 5. The geometric shape of the distinctive Bima weaving tool is called a prism

The geometric shape of the Doko-Doko cake is identified as a pyramid, as shown in the figure below.

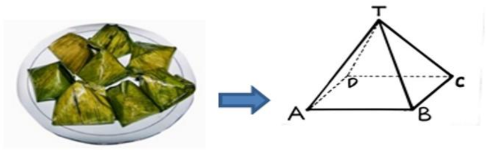


Figure 6. The geometric shape of the Doko-Doko cake from Bima is called a pyramid

These objects and structures help bring students closer to understanding the concepts of polyhedra (solid shapes with flat faces). Students are taught to identify the number of faces, edges, and vertices of these polyhedra. Subsequently, students are presented with problems contextualized around Bima's cultural buildings and objects, requiring them to calculate the surface area and volume of these shapes. Each group is given the opportunity to present their findings, with one or two representatives sharing the results of their discussion with the class. Previous research has successfully improved students' mathematical abilities through an ethnomathematics approach specifically, the study by Didin Nur Rahmawati (2023) titled "Mathematical Communication Skills and Self-Efficacy of 8th-Grade Junior High School Students in Problem-Based Learning Assisted by Blora Cultural Ethnomathematics Modules." The study's results demonstrated the effectiveness of Problem-Based Learning assisted by Blora cultural ethnomathematics modules; this was evidenced by the fact that the class using this method achieved a 75% classical mastery rate in mathematical communication skills tests.

Meanwhile, the qualitative aspect of this study focuses on analyzing students' mathematical communication skills specifically their mathematical language within a class utilizing a problem-based learning model infused with Bima cultural ethnomathematics. Six research subjects were selected and classified based on their mathematical linguistics: two subjects with low mathematical linguistics (A-1 and A-3), two with moderate mathematical linguistics (A-8 and A-20), and two with high mathematical linguistics (A-14 and A-15). The research results are presented in Table 6 below.

Table 6. Students' Mathematical Communication Skills Viewed from the Perspective of Mathematical Linguistics

Mathematical Communication Ability Indicators	**Mathematical Linguistics**		
	Low	**Moderate**	**High**
Presenting mathematical problems in object forms (pictures, diagrams, and tables)	Both subjects are not yet able to present mathematical problems in object forms (pictures, diagrams, and tables).	Subject A-8 made an error in drawing, where they drew a rectangular prism (balok) instead of a cube as required, whereas Subject A-20 was able to draw well.	Both subjects are able to present mathematical problems in object forms (pictures, diagrams, and tables) well.
Constructing arguments and problem solving	Subject A-1 is able to construct arguments and solve problems fairly well, but Subject A-3 has not presented them correctly.	Both subjects are able to construct arguments and solve problems well.	Both subjects are able to construct arguments and solve problems well.
Applying formulas in problem solving	Both subjects are able to apply formulas in solving problems.	Both subjects are able to apply formulas fairly well to solve the problems given in the questions.	Both subjects are able to apply formulas well to solve the problems given in the questions.

CONCLUSION

Based on the research findings and discussion, it can be concluded that instruction using the Problem-Based Learning model infused with Bima cultural ethnomathematics improved learning outcomes regarding 3D shapes with flat surfaces; meanwhile, students with low and moderate mathematical linguistic ability mastered only two indicators of mathematical communication skills, whereas students with high mathematical linguistic ability mastered all indicators.

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