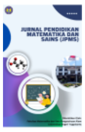

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Jurnal Pendidikan Matematika dan Sains, 13 (1), 2025, 95–102

Implementation of STEM-Integrated Guided Inquiry Learning to Improve Students' Mathematical Communication Skills

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Abstract

Mathematical communication skills are a component of higher-order thinking skills that are important in 21st-century learning and support complex mathematical problem-solving. The purpose of the study was to determine the effect of the implementation of STEM-integrated guided inquiry learning on improving students' mathematical communication skills. his study used a pretest-posttest control group design and a quantitative, quasi-experimental methodology. All eighth-grade students from SMPN in Bandar Lampung, who were divided among eight classes for the 2024/2025 academic year, made up the study's population. Using a purposive sampling strategy, the research sample was chosen from two classes: class 8.1, which had 28 students as the experimental class, and class 8.2, which had 24 students as the control class. Based on the results of statistical analysis with the Mann-Whitney U test, it was concluded that the improvement in mathematical communication skills of students who participated in STEM-integrated guided inquiry learning was higher than the improvement in mathematical communication skills of students who participated in the traditional learning paradigm. Thus, the implementation of STEM-integrated guided inquiry learning can improve students' mathematical communication skills.

Keywords: *Guided inquiry learning, Mathematical communication skills, STEM*

How to Cite: Erviana, N. F., Noer, S. H., & Triana, M. (2025). Implementation of stem-integrated guided inquiry learning to improve students' mathematical communication skills. *Jurnal Pendidikan Matematika dan Sains, 13*(1), 95–102, https://dx.doi.org/10.21831/jpms.v13i1.83157

Permalink/DOI: ***DOI:*** https://dx.doi.org/10.21831/jpms.v13i1.83157

INTRODUCTION

Education continues to develop following the changing times and their demands (Putri et al., 2022). Education is currently in the knowledge age, with information and technology advancing at an unprecedented rate (Mardhiyah et al., 2021). This transformation is aided by the use of digital media and technology, which has a substantial influence on many disciplines, including education (Wijaya et al., 2016). Technology in education supports the implementation of 21st-century learning, which aims to equip students with 21st-century life skills through innovative approaches.

21st-century learning focuses on mastering the 4C skills, namely creative thinking, communication, collaboration, and critical thinking (Septikasari, 2018; Arsanti et al., 2021). These skills enable students to solve problems critically and creatively and work together in groups to develop deep understanding. The use of 4C skills is extremely significant to mathematics learning, which is one of the required courses at various levels of school (Fajriyah, 2022). Mathematics also plays a crucial part in fostering critical thinking, cooperation, and communication skills that are required in modern schooling (Nahdi, 2019). These skills can be pursued by adjusting the learning process with the planned learning outcomes.

The achievement of mathematics learning based on the SK BSKAP Kemdikbudristek (2022) is the development of various skills, such as mathematical understanding, reasoning, problem-solving, communication, connection, and mathematical disposition. This is supported by NCTM (Hafriani, 2021) which directs the focus of learning on communication, connection, mathematical representation, problem-solving, and reasoning. OECD (2019) also underlines the importance of abilities such as communication, representation, strategic problem-solving, and the use of mathematical tools and knowledge in real contexts. This emphasis on 21st-century skills places mathematical communication as an integral part, given its role in supporting effective understanding and application of concepts.

Mathematical communication is an important ability in mathematics learning, which involves conveying mathematical ideas in various forms, such as graphs, tables, and algebraic models (Nurhayati, 2017; Maryati & Suryaningsih, 2021). This ability helps students connect mathematical concepts with everyday life. However, students' mathematical communication skills in Indonesia remain inadequate, as seen by TIMSS and PISA results that reflect pupils' limited mathematical comprehension, application, and reasoning (Prasetyo, 2020).

The issue that students' mathematics communication skills remain relatively inadequate is also seen at SMPN in Bandar Lampung. The supporting evidence for this assertion are the results of tests conducted to determine the degree of students' mathematical communication skill sets, which show that SMPN students in Bandar Lampung have low mathematical communication skills. Where only about 16.6% of students were able to answer correctly, and the remaining 83.33% of students had not given the right answer.

Several factors contribute to students' poor mathematical communication skills, including the prevalence of conventional teacher-centered learning (Triana et al., 2014). This learning often does not involve students actively and does not integrate learning with real life. This is in accordance with the results of interviews with students who gave statements that learning mathematics in class was very boring. Therefore, innovative teaching strategies that let students build on their strengths like the STEM (Science, Technology, Engineering, and Mathematics) approach are needed.

The STEM approach is a learning method that integrates various disciplines to solve real problems (Wells, 2016; Idris & Bacotang, 2023). Through STEM-integrated learning, students are involved in the process of exploration, collaboration, and innovation to connect mathematical concepts with real-world applications. Because STEM subjects encourage students to effectively communicate their ideas, research indicates that they can enhance their mathematical communication skills (Ningtias, 2022; Pujawan et al., 2020). This approach is also relevant to the challenges of 21st-century learning, which prioritizes the all-round development of students' skills (Ardiansyah and Asikin, 2019; Pujawan et al., 2020; Harahap et al., 2021; Khalisah et al., 2022; Saputri and Herman, 2022).

To support its effectiveness, the STEM approach can be integrated with learning models such as guided inquiry, which involves students in active exploration, analysis and communication of ideas (Ningtias, 2022). This model helps students solve contextual problems by applying their knowledge directly. Based on the results of previous research, the combination of STEM and guided inquiry approaches has been shown to improve students' mathematical communication skills while attracting their interest in learning (Pujawan et al., 2020).

Based on this description, the purpose of this project is to investigate the use of STEM-integrated guided inquiry learning in mathematics education to improve students' mathematical communication skills.

METHOD

The study is quantitative, employing a quasi-experimental technique and a pretest-posttest control group design. The study design was designed to produce normalized improvement data (N-gain). The population for this study consisted of all 8th grade students from SMPN in Bandar Lampung, who were divided into eight classes. A purposive selection strategy was used to determine the research sample, which consisted of 28 students from class 8.1 and 24 from class 8.2.

The research was conducted in stages, starting from the preparation, implementation, and final stages. The preparation stage was carried out to find out the condition of the school, such as the population and research samples, student characteristics, and how the teacher teaches in the classroom. At this stage, the learning tools and test instruments to be used were also prepared. At the implementation stage, the research sample was given a pretest to obtain initial data on students' mathematical communication skills. After that, it was given to the sample class, class 8.1 was an experimental class that participated STEM-integrated guided inquiry learning, while class 8.2 was a control class that participated class in the traditional learning paradigm. In order to make inferences, the last stage of this study involves gathering, processing, and analyzing quantitative data pertaining to the pretest and posttest outcomes of students' mathematical communication skills.

The data accumulating method employed was a test of students' mathematical communication skills. A statistical data analysis was performed to assess the improvement that happened. Prior to hypothesis testing, the normalcy test was performed. When it was discovered that the data originated from a population that was not normally distributed, the Mann-Whitney U test was used to evaluate the hypothesis.

RESULT AND DISSCUSION

The Initial Data of Students' Mathematical Communication Skills

Preliminary data on students' mathematics communication skills were acquired via pretest scores in experimental and control classrooms prior to instruction. Based on the data analysis, descriptive data on the first mathematical communication skills of experimental and control class students are obtained, as shown in Table 1.

Table 1. The initial data of students' mathematical communication skills

Class	Students	Mean	Standard Deviation	Lowest Score	Highest Score
Experiment	28	8.04	12.63	0	13
Control	24	4.96	2.3	0	10

Idealized Maximum Score = 32

Table 1 reveals that students' average mathematics communication skills before learning differ between the experimental and control classes. The experimental class's lowest score is the same as the control class's, but its maximum score is greater. Likewise, the experimental class has a greater standard deviation than the control class.

The Final Data of Students' Mathematical Communication Skills

The posttest scores in the experimental and control classes were used to acquire the final data on students' mathematics communication skills after the learning process was completed. Based on the data analysis, descriptive data on the first mathematical communication skills of experimental and control class students are obtained, as shown in Table 2.

Table 2. The final data of students' mathematical communication skills

Class	Mean	Standard Deviation	Lowest Score	Highest Score
Experiment	21.32	1.63	17	24
Control	11.83	5.40	5	23

Table 2 shows that students' average mathematics communication skills before learning vary across experimental and control courses. The lowest score in the experimental class is considerably different from the control class, whereas the highest score in the experimental class is just one point higher than the control class. Although the maximum score only differs by one number, the average value received is significantly different, with a difference of 9.49. It can also be seen that the control class has a higher standard deviation than the experimental class, implying that the distribution of students' mathematical communication skills scores after studying the control class is more diversified than the experimental class.

N-Gain Data of Students' Mathematical Communication Skills

The N-gain index, which is based on the initial and final ability scores of students' mathematical communication skills, provides information on the progress of their scores. Table 3 displays the results of the N-gain data analysis.

Table 3. N-Gain data of students' mathematical communication skills

Class	Mean	Standard Deviation	Lowest Score	Highest Score
Experiment	0.55	0.09	0.32	0.69
Control	0.26	0.18	0.04	0.67

Idealized Maximum Score = 1

Table 3 shows that students in the STEM-integrated guided inquiry learning class had a higher average N-gain score for mathematical communication skills than students class in the traditional learning paradigm. This demonstrates descriptively that the experimental class had a greater growth in mathematical communication skills. The standard deviation of the N-gain score of the class that participated in STEM-integrated guided inquiry learning was similarly greater than that of the class that participated in the traditional learning paradigm. This demonstrates that the distribution of the N-gain score of students' mathematical communication skills in STEM-integrated guided inquiry learning is more diversified than the N-gain score of the class in the traditional learning paradigm.

1. The Achievement of Students' Mathematical Communication Skills

The achievement of mathematical communication skills indicators of students before and after participating in STEM-integrated guided inquiry learning and students who followed class in the traditional learning paradigm can be seen in Table 4.

Table 4. Percentage of achievement of students' mathematical communication skills

Indicators	Experiment Class		Control Class	
	Pre	Post	Pre	Post
Drawing	0%	45.54%	0%	7.81%
Written Text	44.35%	68.45%	30.90%	50.00%
Mathematical Expression	22.62%	78.87%	10.42%	43.40%
Mean	22.32%	64.29%	13.77%	33.74%

Table 4 reveals that the experimental and control courses perform differently on mathematical communication skills markers. The experimental and control classes acquire differing averages for the early data indicators of mathematical communication skills. This demonstrates that students in the experimental and control classes had varying average beginning mathematics communication skills. It is also possible to see that one of the indications of mathematical communication skills, drawing, has a proportion of zero in both the experimental and control classes. However, after receiving therapy in both the experimental and control classes, all percentages of achievement for markers of students' mathematical communication skills rose. Even in the experimental class, indicator accomplishment increased by up to 45.54%.

The increase in the achievement of all indicators of mathematical communication skills was higher in the class that followed STEM-integrated guided inquiry learning. For the drawing indicator, the initial achievement in the experimental class and control class was 0%, but in the final achievement, the achievement of the experimental class increased quite high, namely 45.54%, while in the control class only 7.81%. The indicator that experienced the highest increase in achievement was the mathematical expression indicator, which was 56.25% in the experimental class and 32.98% in the control class. Meanwhile, the lowest increase in indicator achievement was in written text indicators, which amounted to 24.10% in the experimental class, and drawing indicators, which amounted to 7.81% in the control class. The average improvement in the attainment of indices of mathematical communication skills of experimental class students was 41.97%, whereas that of control class students was 19.97%. This demonstrates descriptively that experimental class students perform better on indices of mathematics communication skills than the control class.

Based on the descriptive data of students' mathematical communication skills indicators achievement, it can be concluded that the improvement of the mathematical communication skills of students who participated in STEM-integrated guided inquiry learning is higher than the improvement of the mathematical communication skills of students who participated class in the traditional learning paradigm.

The Research Hypothesis Test Results

Based on the results of the normality test, it is known that the data on the improvement score (N-gain) of students' mathematical communication skills in the class that participated in the STEM-integrated guided inquiry learning and in the class that participated class in the traditional learning paradigm came from a population that was not normally distributed. Therefore, the hypothesis test carried out is a nonparametric test using the Mann-Whitney U test.

The results of data analysis show that at the significance $\alpha = 0.05$ are obtained $Z_{count} = -5.07$ and $Z_{table} = -1.64$, so H_0 is rejected. Based on these results, it can be concluded that the improvement of mathematical communication skills of students who participated in STEM-integrated guided inquiry learning is higher than the improvement of mathematical communication skills of students who participated class in the traditional learning paradigm.

Disscusion

Based on the results of descriptive data analysis and hypothesis testing, this study shows that STEM-integrated guided inquiry learning has a significant impact on students' mathematical communication skills, compared to the traditional learning paradigm. In the experimental class that applied STEM-integrated guided inquiry learning, students' mathematical communication skills experienced a greater improvement. This can be seen from the average increase in each indicator of drawing, written text, and mathematical expression which is much higher than the control class using the traditional learning paradigm.

For example, in the mathematical expression indicator, the experimental class reached 56.25%, while the control class was only 32.98%. This figure shows that students who follow STEM-based learning are better able to organize and convey mathematical ideas in the form of symbols or formulas. A significant increase was also seen in the drawing and written text indicators. In the drawing indicator, the experimental class showed a better understanding in describing mathematical situations visually, while in the written text indicator, students were better able to explain and document the problem-solving process clearly and precisely. This improvement shows that the experimental class students were better able to communicate their thinking in a more complex and diverse form compared to students who followed the traditional learning paradigm.

This research is in line with previous studies that emphasize that STEM-based learning can improve students' mathematical communication skills (Ardiansyah and Asikin, 2019; Pujawan et al., 2020; Harahap et al., 2021; Khalisah et al., 2022; Saputri and Herman, 2022). Specifically, the application of guided inquiry learning models integrated with the STEM approach to develop students' mathematical communication skills has also been widely researched. The results of Jeskova's research, et al (2022) stated that students' mathematical communication skills improved after participating in learning with a guided inquiry learning model integrated with the STEM approach. In addition, Ningtias (2022) stated that in guided inquiry learning students become more active, and students are trained to convey opinions and work together in groups so that students' mathematical communication skills will be honed.

This learning process produces a product in the form of natural soap from lerak fruit, which contains STEM aspects. In making soap, students must adjust the composition of ingredients to their needs, integrating science, technology, engineering, and mathematics. In the problem-solving process, students are also introduced to Desmos software as an implementation of technology. STEM-integrated guided inquiry learning not only improves mathematical communication skills but also encourages students to think critically, analytically, collaboratively, and focus on problem-solving, in accordance with the principles of active learning applied by STEM (California Department of Education, 2015).

The success of STEM learning can be seen from the stages of learning given to students, including observation, data collection, and finding and making solutions that involve an intense communication process. In this context, students are expected to be able to describe mathematical situations in visual form, communicate mathematical solutions in writing, and translate contextual problems into mathematical models. Students' active involvement in this process greatly contributes to the improvement of their mathematical communication skills. This is in accordance with the theory proposed by Nofiansyah et al. (2015), which states that collaborative-based learning, such as that in the STEM approach, can strengthen students' communication skills because they interact and discuss with each other to solve problems together.

Although there are many advantages in this study, there are also challenges that arose during the STEM-integrated guided inquiry learning process. For example, some students faced difficulties in understanding the context of the problem presented or in using technology such as the Desmos application used to draw graphs. Nevertheless, with guidance and assistance from the teacher, students can overcome these obstacles and continue learning well. This shows the importance of the teacher's role in assisting students so that they can optimally utilize technology and the STEM approach. In accordance with Vigotsky's theory which emphasizes the importance of assistance for students who are struggling in order to be able to solve problems (Fitrian and Maemonah, 2022).

This research also shows that the STEM approach not only provides benefits in developing mathematical communication skills, but also improves other skills that support a deeper understanding of mathematical concepts. The problem-based and contextualized learning carried out in the STEM approach helps students to better connect with the material being studied and see the real application of mathematical concepts in everyday life. Thus, the STEM approach is proven to be more effective in improving students' mathematical communication skills compared to the traditional learning paradigm which tends to be more centered on one-way teaching by the teacher (Warsono & Hariyanto, 2013).

Overall, the results of this study confirm the importance of implementing STEM-integrated guided inquiry learning in the context of mathematics education, as it can significantly improve students' mathematical communication skills and prepare them to face real-world challenges with better mathematical skills.

CONCLUSION

Based on the results of the research and discussion, it can be concluded that STEM-integrated guided inquiry learning can improve the mathematical communication skills of Grade 8 students of SMPN in Bandar Lampung Odd Semester 2024/2025 Academic Year. This is based on the results of the study which show that the increase in mathematical communication skills of students who participated in STEM-integrated guided inquiry learning is higher than the increase in mathematical communication skills of students who participated in the traditional learning paradigm.

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