EXPLORING STUDENTS' MATHEMATICAL COMMUNICATION IN GUIDED INQUIRY AND STAD COOPERATIVE LEARNING MODELS

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ABSTRACT This study aims to investigate the effect of guided inquiry and Student Teams Achievement Division (STAD)-type cooperative learning models on students' mathematical communication ability. A quasi-experimental method with a pretest-posttest control group design was employed. The sample consisted of two eighth-grade classes selected through cluster random sampling from a junior high school in Bandar Lampung. Students in the experimental class received instruction using the guided inquiry model, while those in the control class were taught using the STAD-type cooperative model. A mathematical communication test, consisting of items aligned with three key indicators—written explanations, symbolic expressions, and visual representations—was administered before and after the intervention. Data were analyzed using an Independent Samples t-test. The results revealed a statistically significant difference in posttest scores between the two groups ($t = 2.844$, $p < 0.05$), favoring the guided inquiry model. Additionally, students taught through guided inquiry demonstrated greater improvements across all indicators of mathematical communication, particularly in their ability to explain reasoning through structured written responses and to use appropriate mathematical symbols.

Keywords: Mathematical communication, guided inquiry, STAD, cooperative learning

ABSTRAK Penelitian ini bertujuan untuk menyelidiki pengaruh model pembelajaran inkuiri terbimbing dan kooperatif tipe Student Teams Achievement Division (STAD) terhadap kemampuan komunikasi matematis siswa. Metode yang digunakan adalah kuasi-eksperimen dengan desain pretest-posttest kelompok kontrol. Sampel terdiri atas dua kelas siswa kelas VIII yang dipilih melalui teknik cluster random sampling dari salah satu SMP di Bandar Lampung. Siswa dalam kelas eksperimen mendapatkan pembelajaran menggunakan model inkuiri terbimbing, sementara kelas kontrol menggunakan model kooperatif tipe STAD. Instrumen tes komunikasi matematis mencakup tiga indikator utama, yaitu penjelasan tertulis, ekspresi simbolik, dan representasi visual, yang diberikan sebelum dan sesudah perlakuan. Analisis data dilakukan menggunakan uji Independent Samples t-test. Hasil menunjukkan terdapat perbedaan yang signifikan secara statistik pada skor posttest antara

 https://doi.org/10.30606/absis.v8i1.3180

kedua kelompok ($t = 2,844$, $p < 0,05$), dengan keunggulan pada model inkuiri terbimbing. Selain itu, siswa yang dibelajarkan melalui model inkuiri terbimbing menunjukkan peningkatan lebih besar pada semua indikator komunikasi matematis, khususnya dalam menjelaskan alasan melalui penulisan yang terstruktur serta penggunaan simbol matematika yang tepat.

Kata-kata kunci: Kemampuan komunikasi matematis, inkuiri terbimbing, STAD, pembelajaran kooperatif

INTRODUCTION

Mathematics is a subject taught at every level of school that can develop human thinking and serves as a basis for various advances in modern technology and science (Sarini, 2019). In addition, according to Hendriana (2018), mathematics has formed the foundation for the development of contemporary technology and is the basis for other fields of science. According to Hikmawati et al. (2019), mathematics plays a role in making things easier, so it becomes an important aspect in other fields such as science and technology. Therefore, to help students who have low mathematical abilities in using mathematics orally and in writing, special attention must be given (Andriani, 2020).

One of the objectives of learning mathematics, as stated in the Decree of the Standards, Curriculum, Assessment, and Education Agency Number 33 of 2022, is to develop students' ability to communicate mathematical ideas. The goal is not only to equip them with problem-solving skills but also to teach them how to express their reasoning and solutions effectively. Therefore, students must be given opportunities to share their thoughts throughout the learning process. Teaching mathematics from the elementary level is essential to support the gradual development of this skill (Sarini, 2019). Based on these objectives, it is clear that enhancing students' capacity to communicate mathematically is a vital aspect of mathematics education.

Students must develop control over their mathematical communication skills, as this is a crucial aspect of the mathematics learning process. The ability to think mathematically is closely tied to effectively communicating mathematical ideas. Therefore, it is essential for learners to express their understanding clearly in both oral and written forms (Ismayanti & Sofyan, 2021). Strong communication skills significantly influence success in learning mathematics. Learners who can articulate mathematical ideas clearly are better able to understand, convey, and build upon concepts from others in an accurate, scientific, and evaluative manner (Asyinandani & Elniati, 2023).

Some important aspects of mathematical communication include: (1) conveying ideas through actions, writing, dialogue, and various forms of meaningful visual expression; (2) understanding, interpreting, and evaluating ideas in text and visual communication; (3) designing, interpreting, and connecting ideas in communication;

and (4) seeing and estimating, formulating questions, and talking about the ideas he thinks (Yuniarti et al., 2018). According to Yanti (2019), regarding the role of mathematics in everyday life, mathematical communication must be taught in schools so that students can read and understand the instructions contained in the problem. Everyone knows that mathematics is a complex communication tool. Because communication is the main way students interact with teachers in the school environment, this statement emphasizes that communication abilities are very important for students to understand and have.

Students in Indonesia are still considered to have low mathematical communication abilities. This is evidenced by the results of the 2022 Programme for International Student Assessment (PISA) study of 15-year-old students in Indonesia. PISA shows that Indonesian students still have poor mathematics scores (OECD, 2023). In addition, the results of PISA 2022 show that Indonesian students only reach 0 to 5% of students who can reach level 6 mathematics, down from the OECD average, with a score of 366 compared to 472. The results of PISA 2022 also show that Indonesian students descriptively get lower scores than the OECD average (OECD, 2023).

Based on an interview with a mathematics teacher on May 16, 2024, at SMP Negeri 8 Bandar Lampung, it was found that the mathematical communication of class VIII students was still relatively low. Students tend to be passive in discussions, have difficulty expressing their thoughts verbally and in writing, and cannot explain in a way coherent and logical the necessary steps to finish questions. This fact is shown from the answers of class VIII-E students, which show the lack of students' ability to solve descriptive questions containing indicators of mathematical communication ability in the material on relations and functions.

Apart from student test results, which contain indicators of mathematical communication ability, the results of interviews with students also showed that several factors can contribute to the failure of students in mathematical communication. First, many students have difficulty understanding word problems because they are not used to connecting mathematical concepts to real-life situations. Second, the lack of practice in converting information from narrative form into mathematical communication, such as pictures, tables, and diagrams, makes them feel confused and unsure about how to visualize the problem. In addition, many students have difficulty explaining mathematical concepts and solutions in writing because they are not used to organizing their thoughts systematically and clearly. The lack of habit of writing structured mathematical explanations or arguments, as well as limitations in mathematical literacy ability, also contribute to these difficulties. As a result, students tend to prefer to just work on problems without trying to understand or explain their thought processes.

Teacher-focused learning also contributes to low mathematical communication ability. One of the causes of students' low mathematical communication skills is that the dominant learning method is led by teachers without allowing students to

 https://doi.org/10.30606/absis.v8i1.3180

develop and convey their ideas (Mahmuzah et al., 2016). Students only observe learning activities and do not explore them actively (Noviyana et al., 2019). This kind of learning tends to be giving or handing over knowledge so that students become passive, and learning tends to be monotonous. As a result, students' ability to communicate mathematically is less developed.

According to Ningtias & Soraya (2022), Learning requires more than just the delivery of information from teachers to students. By using the right model, students can learn in an atmosphere that activates them and helps them express mathematical concepts through symbols and other mathematical models (Rahmalia et al., 2020). One learning model that can help students communicate better mathematically and improve students' mathematical communication ability is the guided inquiry learning model.

Few studies have compared the guided inquiry and STAD models specifically in the context of students' mathematical communication in Indonesian schools. According to Pasaribu and Prastyo (2022), guided inquiry learning is a learning model that encourages students to actively participate in the learning process. This model provides students with the opportunity to explore mathematical concepts in depth through the guidance of a teacher who acts as a facilitator (Adiputra, 2017). In this model, the teacher functions as a guide and facilitator, giving students the freedom to maximize their abilities and supporting them in problem-solving.

On the other hand, the Student Teams Achievement Divisions (STAD) type of cooperative learning model has also been widely used in mathematics learning (Ngalimun, 2016). This model emphasizes cooperation in small groups, where students work together to understand the material and complete tasks collaboratively. Although the STAD model can improve social interaction and cooperation, its effectiveness in developing mathematical communication is still debated (Putra, 2023).

SMP Negeri 8 Bandar Lampung is one of the schools that strives to improve the quality of mathematics learning, including the aspect of students' mathematical communication. Therefore, further research is needed to determine how these two models contribute to students' mathematical communication in junior high schools, especially in SMP Negeri 8 Bandar Lampung. Therefore, this study aims to explore the mathematical communication of grade VIII students in applying the guided inquiry learning model and the STAD-type cooperative model in the odd semester of the 2024/2025 academic year.

METHODS

This study employed a quasi-experimental method with a quantitative approach, specifically using a pretest-posttest control group design. The independent variable in this research was the learning model, which included the guided inquiry and

Student Teams Achievement Division (STAD)-type cooperative models. The dependent variable was students' mathematical communication ability.

The population comprised all eighth-grade students at SMP Negeri 8 Bandar Lampung during the 2024/2025 academic year, totaling 266 students across nine classes. It was assumed that students' mathematics abilities across classes were relatively equal. Two classes were selected using a cluster random sampling technique. A spinner method was used to randomly assign class VIII-I as the experimental group (guided inquiry model) and class VIII-G as the control group (STAD-type cooperative model).

Before the intervention, a pretest was administered to assess students' initial mathematical communication ability. After instruction, a posttest was conducted using the same instrument. The test consisted of four essay items that measured three key indicators: written explanations, symbolic expressions, and visual representations. Both groups received the same test items. A scoring rubric was developed to evaluate student responses based on these indicators.

Instrument development involved two stages: (1) constructing a test blueprint aligned with mathematical communication indicators and the subject matter; and (2) creating test items and answer keys based on the blueprint. To ensure validity and reliability, the instrument was piloted with grade IX-A students, who had previously studied the material. The instrument was found to be valid, reliable, moderately difficult, and sufficiently discriminating (Sugiyono, 2022).

Prior to hypothesis testing, the gain scores of students' mathematical communication ability were calculated and subjected to normality and homogeneity tests to confirm the assumptions for parametric analysis. The data were determined to be normally distributed and homogeneous. Consequently, an Independent Samples t-test was conducted to compare the mean gain scores between the experimental and control groups.

The research hypotheses were stated as follows:

H_0: There is no significant difference in the average gain scores of mathematical communication ability between students taught using the guided inquiry model and those taught using the STAD-type cooperative model.
H_1: Students taught using the guided inquiry model have significantly higher gain scores in mathematical communication ability than those taught using the STAD-type cooperative model.

The Independent Samples t-test was conducted using the formula proposed by Sugiyono (2022):

$$t = \frac{\bar{x}_1 - \bar{x}_2}{s\sqrt{\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

 https://doi.org/10.30606/absis.v8i1.3180

with pooled standard deviation:

$$s = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}}$$

Where:

$\bar{x}_1$: average score of students' communication ability in the experimental class

$\bar{x}_2$: average score of students' communication ability in the control class

n_1 : number of students in the experimental class

n_2 : number of students in the control class

s_1^2 : variance in the experimental class

s_2^2 : variance in the control class

The null hypothesis was accepted if the calculated t-value was less than the critical t-value at a 0.05 significance level with degrees of freedom df=n1+n2−2; otherwise, the null hypothesis was rejected.

FINDING AND DISCUSSION

The results of this study are presented based on the analysis of students' mathematical communication ability before and after the implementation of the learning models. To measure students' initial abilities, a pretest was administered prior to the intervention. The data obtained from the pretest provided baseline information regarding students' mathematical communication skills in both the experimental and control classes. This initial comparison is essential for determining whether the two groups were comparable before the treatment was applied.

Table 1. Summary of Pretest Scores of Students' Mathematical Communication Ability

Class	N	Mean	Standard Deviation	Lowest Score	Highest Score
Experimental	30	4.37	3.24	0	12
Control	30	4.50	4.65	0	14

The pretest scores indicate that the average mathematical communication ability in the control group was slightly higher than that of the experimental group. However, the difference in means was not statistically significant. The standard deviation in the control group was greater than in the experimental group, suggesting that student performance in the control class was more varied.

Following the implementation of the learning models, a posttest was administered to measure the students' mathematical communication ability after treatment. The results are summarized in Table 2.

Table 2. Summary of Posttest Scores of Students' Mathematical Communication Ability

Class	N	Mean	Standard Deviation	Lowest Score	Highest Score
Experimental	30	25.20	4.17	16	31
Control	30	22.23	4.57	14	31

The posttest results show that the experimental group, which received instruction using the guided inquiry learning model, achieved a higher average score than the control group, which was taught using the STAD-type cooperative model. The experimental group also demonstrated a higher minimum score, indicating more consistent performance. Although the maximum score was the same for both groups, the control group displayed greater score variability, as indicated by a larger standard deviation.

To assess the improvement in students' mathematical communication ability, gain scores were calculated by comparing pretest and posttest results. The normalized gain (N-gain) was used to reflect the extent of improvement across both groups, as shown in Table 3.

Table 3. Summary of Gain Scores of Students' Mathematical Communication Ability

Class	N	Mean	Standard Deviation	Lowest Gain	Highest Gain
Experimental	30	0.7869	0.1480	0.48	1.00
Control	30	0.6821	0.1523	0.35	1.00

The gain score analysis reveals that the guided inquiry group showed greater improvement in mathematical communication ability compared to the STAD-type cooperative group. Both the average and minimum gain scores were higher in the experimental group, indicating not only better overall improvement but also greater consistency among students.

To determine whether the observed differences were statistically significant, a hypothesis test was conducted using an Independent Samples t-test. Prior to testing, the assumptions of normality and homogeneity were verified and met.

The hypotheses tested were as follows:

https://doi.org/10.30606/absis.v8i1.3180

H_0: There is no significant difference in the average gain scores between students taught using the guided inquiry learning model and those taught using the STAD-type cooperative learning model.

H_1: Students taught using the guided inquiry learning model demonstrate significantly higher gain scores than those taught using the STAD-type cooperative model.

Using a significance level of $\alpha = 0.05$ and degrees of freedom $df = n1+n2-2$, the results showed that the calculated t-value exceeded the critical value ($t = 2.844 > t_{0.05} = 1.672$). Therefore, the null hypothesis (H_0) was rejected, indicating a statistically significant difference in favor of the guided inquiry model.

These results confirm that the guided inquiry learning model was more effective in enhancing students' mathematical communication ability than the STAD-type cooperative model.

To determine whether the improvement in students' mathematical communication ability differed significantly between the two learning models, a hypothesis test was conducted using an Independent Samples t-test. The results of the test are summarized in Table 4.

Table 4. Hypothesis Test Results

$t_{calculated}$	$t_{critical}$	Decision
2.844	1.672	H_0 Rejected

The result shows that the calculated t-value (2.844) is greater than the critical t-value (1.672) at a significance level of $\alpha = 0.05$. Therefore, the null hypothesis (H_0) is rejected. This indicates that the average gain score in mathematical communication ability among students taught using the guided inquiry model is significantly higher than that of students taught using the STAD-type cooperative learning model.

To gain further insight into student performance, an analysis of achievement was conducted for each indicator of mathematical communication ability. This analysis compared the percentage of students' mastery of each indicator before and after the intervention in both the experimental and control classes. The results are shown in Table 5.

Table 5. Percentage of Students' Achievement on Mathematical Communication Indicator

Indicator	Experimental Class		Control Class	
	Pretest (%)	Posttest (%)	Pretest (%)	Posttest (%)
Written Explanation	19%	88%	18%	77%

https://doi.org/10.30606/absis.v8i1.3180

Indicator	Experimental Class		Control Class	
	Pretest (%)	Posttest (%)	Pretest (%)	Posttest (%)
Mathematical Expression	13%	89%	15%	80%
Drawing / Visualization	0%	24%	0%	8%
Average	**10.7%**	**67%**	**11%**	**55%**

The pretest and posttest data reveal that both groups showed improvement across all indicators. However, the experimental class consistently outperformed the control class on each indicator. For the written explanation indicator, the experimental group increased by 69%, compared to 59% in the control group. In the mathematical expression indicator, the experimental class showed a 76% improvement, while the control group showed a 65% gain. The most notable difference was observed in the drawing or visualization indicator, where the experimental group improved by 24%, compared to only 8% in the control group.

These results demonstrate that the guided inquiry learning model is more effective in enhancing students' mathematical communication ability across all measured indicators. The structured inquiry process and emphasis on active engagement in the guided inquiry model likely contributed to students' deeper understanding and improved ability to express mathematical ideas through various forms.

The findings of this study reveal that students taught using the guided inquiry learning model exhibited significantly better mathematical communication ability compared to those taught using the STAD-type cooperative model. This superiority can be attributed to the structure of the guided inquiry model, which emphasizes active student participation throughout the learning process. Each phase of the model is designed to foster critical thinking, problem-solving, and mathematical discourse, thereby enhancing students' capacity to express mathematical ideas clearly and accurately. These results align with previous studies. Ningtias and Soraya (2022) found that guided inquiry promotes engagement through exploration and collaborative learning. Similarly, Rizki et al. (2021) reported significant improvements in students' mathematical expression and active discussion when taught using this model. Samsidar et al. (2019) also noted that guided inquiry supports peer communication and conceptual understanding by encouraging learners to articulate their thinking processes.

The improvement was evident across all indicators of mathematical communication—written explanation, symbolic expression, and visual representation—with the experimental group consistently outperforming the control group. Students in the guided inquiry group demonstrated the ability to explain their reasoning systematically and to use mathematical symbols and models

https://doi.org/10.30606/absis.v8i1.3180

effectively. These outcomes are closely linked to the learning stages embedded in the guided inquiry process, which guide students to construct knowledge collaboratively and express it through multiple mathematical representations.

The implementation process showed that students in the guided inquiry model were actively engaged in every learning stage. Beginning with orientation, teachers connected the new material to students' prior knowledge and real-life contexts. Students were then grouped and provided with student worksheets (LKPD) containing contextual problems. In groups, they analyzed the problems, designed strategies for solving them, and explored various sources to support their understanding. This process fostered independent learning, discussion, and deeper conceptual engagement.

Despite these advantages, several challenges were encountered during implementation. Some students struggled to understand the LKPD due to complex instructions or unfamiliar numerical contexts. Students with low literacy skills tended to avoid reading lengthy questions or interpreting large numbers. To address this, teachers simplified language, adjusted context to be more relatable, and provided concrete examples prior to task execution.

Another challenge involved group formation. Although heterogeneous groups were initially established, some students expressed discomfort with their assigned peers. To foster a more collaborative atmosphere, teachers allowed flexibility in group formation. As a result, student participation and interaction increased significantly in subsequent lessons, indicating improved adaptation to the inquiry-based structure.

In contrast, students in the STAD-type cooperative model had fewer opportunities to explore diverse strategies and express their thinking freely. The learning process was more teacher-centered, with limited emphasis on student discourse or problem analysis. Consequently, students in this group were often passive, and the classroom environment became less dynamic. If group work was not well facilitated, stronger students dominated discussions while weaker students remained disengaged. Moreover, some students lacked the confidence to express their ideas verbally, leading to low participation in class discussions and a reduced sense of ownership over their learning.

These conditions contributed to the lower overall achievement across mathematical communication indicators in the STAD group, particularly in the visual and symbolic dimensions. The dependence among group members, limited autonomy, and lack of individualized reflection restricted students' opportunities to develop their mathematical communication skills fully.

In conclusion, the guided inquiry learning model offers a more effective and comprehensive approach to developing students' mathematical communication ability than the STAD-type cooperative model. This study reinforces the importance of learning strategies that encourage student autonomy, interaction, and the use of multiple representations in mathematics education.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this study, it can be concluded that the guided inquiry learning model is more effective in improving students' mathematical communication ability compared to the STAD-type cooperative model. Students taught through guided inquiry were more actively engaged in the learning process, demonstrated deeper conceptual understanding, and were better able to express mathematical ideas through written explanations, symbolic expressions, and visual representations. While the STAD model also provided opportunities for collaboration, its impact was less pronounced in supporting individual communication skills, particularly in aspects that require independent reasoning and representation. Therefore, the guided inquiry model is recommended as an alternative instructional approach that supports meaningful mathematical learning and enhances students' ability to communicate their understanding clearly and systematically. In applying this model, teachers are encouraged to pay greater attention to strengthening students' skills in visual representation, which remains the weakest indicator compared to others. Moreover, future researchers and practitioners planning to use or adapt the learning tools developed in this study—particularly student worksheets (LKPD)—are advised to simplify the language, adjust numerical content to be more accessible, and ensure the contextual relevance of tasks, so that students with varying levels of literacy and numeracy can benefit optimally from the learning experience.

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