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THE EFFECTIVENESS OF GUIDED INQUIRY LEARNING AND PROBLEM-BASED LEARNING MODELS ON MATHEMATICAL COMMUNICATION ABILITY

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Abstract

The development of students' mathematical communication ability has become one of the key objectives of mathematics education in the 21st century. Nevertheless, many senior high school students continue to experience difficulties in expressing mathematical ideas effectively. In response to this issue, this research aimed to compare the effectiveness of the Problem-Based Learning (PBL) and Guided Inquiry Learning (GIL) models in improving students' mathematical communication ability. A quantitative method employing a quasi-experimental non-equivalent control group design was implemented at SMA Negeri 50 Jakarta on the topic of Three-Variable Linear Equation Systems (SPLTV). Students' mathematical communication ability was measured using a validated test instrument, and the collected data were analyzed through an independent samples t-test. The findings revealed that students taught using the PBL model achieved greater learning gains, obtaining a moderate normalized gain (N-Gain) score of 0.486. Meanwhile, the GIL group obtained an N-Gain score of 0.289, which fell into the low category. Statistical analysis produced a significance value of 0.000, indicating that the PBL model was significantly more effective than GIL in enhancing students' mathematical communication ability.

Keywords: Guided Inquiry Learning, Mathematical Communication Ability, Problem-Based Learning.

INTRODUCTION

Mathematical communication is the ability to use mathematical language to articulate opinions clearly and accurately (Monariska et al., 2021). This ability serves as a vital tool for students to explain mathematical concepts to teachers and peers in both oral and written forms, including the use of symbols, algebraic formulas, and visual diagrams (Suhenda & Munandar, 2023; Zaditania & Ruli, 2022). Ultimately, this ability reflects students' ability to share their mathematical reasoning and perspectives effectively using correct technical language.

In the landscape of modern mathematics education, mathematical communication ability is a fundamental 21st-century competency that students must master, as mandated by the Indonesian Ministry of Education and Culture Regulation (Permendikbud) No. 21 of 2016 (Febriana & Pujiastuti, 2022; Revita & Sari, 2024). Dewi & Nuraeni (2022) emphasized that this ability is the key to training students to explain ideas and solve math problems through various strategies. In line with this, the National Council of Teachers of Mathematics (NCTM, 2000) emphasized that this ability allows students to organize thoughts systematically, articulate ideas accurately, and build strong mathematical justifications through social discourse. Therefore, strengthening these abilities is essential to achieving optimal learning outcomes.

However, empirical evidence suggests that students' mathematical communication ability in Indonesia is still at a suboptimal level. The findings of the 2022 Program for International Student Assessment (PISA) indicate that the majority of Indonesian students have difficulty presenting mathematical reasoning in writing. Specifically, 88% of students are below level 3 in mathematical reasoning, 68% have not been able to construct structured arguments, and 81% tend to solve problems using purely procedural methods (OECD, 2023). These conditions are consistent with Une et al. (2023), identifying the existence of persistent barriers to systematic documentation of ideas and weak coherence of logical arguments. Furthermore, Na et al. (2025) reported that 55% of high school class XI students showed low levels of mathematical communication ability.

The low ability to communicate mathematically is influenced by various factors, including the learning process, students' attitude, and assignment culture (Hikmawati et al., 2019). Furthermore, Fuada et al. (2017) added that the development of this ability is greatly influenced by the learning model applied by educators. Riyanti & Mardiani (2021) explained that the application of a learning model that integrates active participation has the potential to increase communication competency because it facilitates students to formulate and articulate ideas independently. Therefore, there is a need for learning strategies capable of encouraging active involvement in math classes.

One relevant model is Guided Inquiry Learning (GIL), which positions students as the center of the entire learning process Samsidar et al., 2018). Pramana et al. (2024) and Rohana et al. (2024) state that GIL integrates students' active participation through the activities of asking questions, conducting investigations, and gaining knowledge through directed inquiry processes with the guidance of educators.

In its implementation, educators provide intensive guidance in the early stages, which is then gradually reduced as the independence of students increases (Musyawir et al., 2022). Teacher intervention through questions and dialogue is deliberately designed to guide students to discover their own concepts, although this process remains structured (Umairah, 2022). Thus, the GIL model not only supports the development of conceptual understanding but also systematically hones students' mathematical communication ability (Samsidar et al., 2018).

Another learning model that has the potential to improve students' mathematical communication ability is Problem-Based Learning (PBL) (Agustina et al., 2024). As a contextual learning model, PBL enables students to construct knowledge by solving authentic real-world problems, both individually and collaboratively (Losi et al., 2021; Ramadiani & Fauzi, 2022). Solikhin (2022) and Rasmuin & Khatima (2023) assert that the use of real problems in PBL serves as a starting point for acquiring new knowledge. Thus, PBL places real-world problems as the main instrument that triggers the process of acquiring knowledge and constructing students' mathematical ideas.

Through active social interaction, PBL allows students to present ideas, discuss with peers, and reflect on their problem-solving strategies (Salsabilla et al., 2023). This model has been shown to improve students' critical thinking ability and foster sustainable learning independence (Hanipah & Sumartini, 2021; Yuniar & Nurhasanah, 2022). In short, the implementation of PBL encourages a communicative learning environment, which not only sharpens thinking but also builds students' independence in articulating solutions.

Several previous studies have proven the positive effects of GIL and PBL on mathematical communication (Mirna et al., 2023; Ningtias & Soraya, 2022; Sopari et al., 2022; Wahyuni & Swastika, 2024). However, studies comparing the effectiveness of the two models are still very limited. Most studies focus only on a single model, so they have not provided a clear comparative picture of which strategy is more effective on a given material. To fill this gap, this study directly compares the effectiveness of GIL and PBL, with a particular focus on the topic of the Three Variable Linear Equation System (SPLTV) at SMA Negeri 50 Jakarta.

The novelty of research lies in its focus on different learning mechanisms in influencing indicators of mathematical communication ability. These include the ability to relate real objects to mathematical ideas, expressing everyday activities through mathematical symbols in written form, explaining mathematical ideas and relations in writing, evaluating mathematical ideas to solve real-world problems, and communicating conclusions that align precisely with the given questions. Thus, this study aims to identify significant effectiveness between the GIL and PBL models in students' mathematical communication ability.

METHOD

This study adopted a quantitative approach with a quasi-experimental design, specifically the non-equivalent control group design. This methodology was selected to determine the comparative effectiveness of Guided Inquiry Learning (GIL) and Problem-Based Learning (PBL) models. By involving two distinct experimental groups, this study provides an empirical analysis of how these treatments influence students' mathematical communication ability through a systematic sequence of pre and post-treatment measurements.

Purposive sampling was employed to select 67 tenth-grade students from SMA Negeri 50 Jakarta as the research participants. The research procedure followed a structured progression, beginning with a pre-test to establish the initial baseline of mathematical communication ability. Following this, the groups received their respective treatments (one group using GIL and the other using PBL), and the process concluded with a post-test (Nugraha et al., 2025).

Research data were collected using essay tests designed to measure students' mathematical communication ability, adapted from Nuraini (2023), then modified according to research needs. Before primary data collection, the instrument was retested to ensure its validity and reliability.

Table 1. Result of Validity Test

Item	r_{count}	r_{table}	Remark
1	0.886	0.361	Accepted
2	0.788	0.361	Accepted
3	0.825	0.361	Accepted

Instrument validity was examined using SPSS, and the findings are presented in Table 1. Referring to the Indartini & Mutmainah (2024) criteria, the validity of the instrument items is satisfied if the $r_{count} > r_{table}$ is significant at 0.05. The analysis indicated that every item satisfied this requirement because all r_{count} values exceeded the corresponding r_{table} value.

Following the confirmation of instrument validity, reliability testing was conducted to evaluate the consistency of the measurement instrument. Cronbach's Alpha coefficient was calculated using SPSS for this purpose.

The reliability analysis of the test instrument yielded a Cronbach's Alpha value of 0.766. According to the criteria established by Indartini & Mutmainah (2024), this value confirms the reliability of the mathematical communication ability test instrument. Therefore, the instrument is declared reliable, consistent, and fully capable of serving as a data collection tool for this research.

RESULTS AND DISCUSSION

The study began with an initial assessment in the first session to establish a baseline for students' mathematical communication ability. Subsequently, a three-session instructional phase was conducted. The first experimental group received instruction through the Guided Inquiry Learning (GIL) model, whereas the second experimental group was taught using the Problem-Based Learning (PBL) model.

Upon concluding the intervention, a final evaluation was performed during the fifth session to determine each model's effectiveness and measure the resulting progress in communication proficiency. The following table presents a descriptive summary of students' mathematical communication performance recorded during the initial and final assessment sessions.

Descriptive Analysis of Mathematical Communication Ability

Data processing begins with a descriptive statistical analysis to map the distribution of scores and observe performance shifts before and after pedagogical intervention. The pre-test data summarized in Table 2 showed that the two classes had similar initial levels of mathematical communication ability, which were generally low. The low initial achievement was proven with a minimum score of 0 in the GIL class and 5.00 in the PBL class. These findings indicate that students' mathematical communication ability was still limited before the implementation of the learning models.

The implementation of the three-session PBL model proved to trigger progressive growth in students' abilities, reflected in the average score increase to 64.44 with a score range of 16.67 to 91.67. These results show that the PBL model demonstrates superior effectiveness in improving students' mathematical communication ability. This is in contrast to the GIL group, which only recorded an average of 49.12, with its highest achievement being limited to 75.00 and its lowest score still 0.

Table 2. Descriptive calculation of pretest and posttest results

Group	Mean		Maximum Score		Minimum Score	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
GIL	26.57	49.12	68.33	75.00	0.00	0.00
PBL	30.78	64.44	61.67	91.67	5.00	16.67

Normalized Gain (N-Gain) Analysis

A common method that measures the effectiveness of learning or intervention in improving student outcomes is normalized gain (N-Gain) (Sukarelawa et al., 2024). The N-Gain data presented in Table 3 demonstrate that the two learning models produced different degrees of improvement in students' mathematical communication ability.

The group implementing the Guided Inquiry Learning (GIL) model received an average N-Gain of 0.289, which placed it in a low-level category. Students in the GIL group achieved only limited improvement in mathematical communication ability, as reflected by the average N-Gain score, which remained within the low category despite opportunities for guided investigation. In contrast, the PBL group attained an average N-Gain score of 0.486, placing their improvement in the moderate category. This shift suggests that problem-based models result in more consistent and robust contributions to driving the development of learners' mathematical communication ability. Once a descriptive description of the quality of these improvements is obtained, the next step is to conduct an assumption test that includes a normality test and an N-Gain data homogeneity test to determine the next hypothesis test step.

Table 3. Descriptive calculation of N-Gain

Group	Mean	Category
GIL	0.289	Low
PBL	0.486	Moderate

Statistical Prerequisite Verification

Before executing the formal hypothesis evaluation for final empirical deductions, the underlying statistical assumptions must be verified to confirm that the collected dataset complies with parametric criteria. This diagnostic procedure was strictly administered to the Normalized Gain (N-gain) scores across both experimental cohorts, ensuring the methodological soundness and precision of the subsequent inferences.

To ascertain whether the compiled research data originates from a normally distributed population, a normality test was implemented (Nuryadi et al., 2017). The selection of the specific testing framework is contingent upon the sample size utilized within the study. Consequently, the Kolmogorov-Smirnov method was deployed for this evaluation, with the comprehensive outcomes summarized in Table 4.

Data from Table 4 confirms that the significance values generated by both the GIL and PBL learning models are uniform at 0.200. Following the statistical decision rule, if the value is greater than 0.05, the systematically classified data sets are normally distributed (Purnomo, 2016). Since the obtained values exceed this threshold, it is concluded that the mathematical communication ability growth data for both classes fulfil the normality assumption.

Table 4. Test of Normality

Group	Statistic	df	Sig.
GIL	0.084	34	0.200
PBL	0.097	33	0.22

Once the normality verification was met, the next crucial step was to perform a homogeneity test, which is operated to assess whether the variance of the data indicates equality or homogeneity (Nuryadi et al., 2017). This test is essential to ensure that the data distribution in both groups shares similar characteristics, so that the subsequent comparative test results are not biased by unequal variances. Table 5 presents the results of Levene's Test.

Table 5 shows the significance value for the Based on Mean category is 0.842. Because this value significantly exceeds the 0.05 alpha level (sig. 0.842 > 0.05), the N-gain data from both experimental groups are confirmed to be homogeneous (Purnomo, 2016). The fulfilment of both normality and homogeneity provides a valid and robust foundation for proceeding with the independent sample t-test.

The fulfilment of these two fundamental assumptions (normality and homogeneity) provides a valid methodological foundation to move forward to the hypothesis testing stage. Data that are already normally distributed and have uniform variance will be continued with a parametric statistical test using independent sample t-tests to compare the effectiveness of the GIL and PBL models on students' mathematical communication ability.

Table 5. Test of Homogeneity

Statistical Basis	**Levene Statistic**	**df1**	**df2**	**Asymp. Sig.**
Calculated from Mean	0.040	1	65	0.842
Calculated from Median	0.038	1	65	0.846
Adjusted Median Framework	0.038	1	64.513	0.846
Trimmed Mean Distribution	0.041	1	65	0.840

Hypothesis Testing and Discussion

Following the confirmation of data suitability through prerequisite assessments, a formal hypothesis evaluation was administered to discern the statistical significance of the variation in effectiveness between both instructional methods. Since the distribution successfully met the standard parameters of normality and variance uniformity, the Independent Samples T-test was employed to evaluate the Normalized Gain (N-gain) scores. These analytical outcomes, outlined in Table 6, supply the essential empirical evidence needed to quantify how each teaching framework impacts the development of mathematical communication skills.

Table 6. Independent Sample Test

	F	Sig.	t	df	Sig. (2-tailed)
Equal variances assumed	0.40	0.842	-4.007	65	0.000
Equal variances not assumed			-4.007	64.961	0.000

Following the statistical analysis, the recorded two-tailed significance value (p-value) came out to 0.000, which is substantially lower than the standard alpha level of 0.05. In statistical terminology, this result provides the basis to reject the null hypothesis (h_0) and accept the alternative hypothesis (h_a). These results prove that there are differences in the effectiveness of GIL and PBL on mathematical communication ability.

Furthermore, the t-value of -4.007 illustrates the strength of this difference. When combined with the descriptive data from previous analyses (where the PBL group achieved a significantly higher mean N-gain of 0.486 compared to the GIL group's 0.289), these results indicate a clear pedagogical advantage for the PBL model at SMA Negeri 50 Jakarta.

These findings prove that the different instructional mechanisms of the two models have a diverse influence on students' mathematical communication abilities. Broadly, this phenomenon asserts that students' active role in building their own understanding is a major variable in the development of mathematical ideas. In line with this, Riyanti & Mardiani (2021) emphasized that an interactive learning environment provides a platform for students to absorb concepts while further sharpening their mathematical communication ability optimally.

Specifically, the analysis of the GIL model demonstrates its capacity to facilitate students in acquiring knowledge through a structured investigation process. Students are trained to construct arguments based on the findings of their own inquiries, which theoretically supports the improvement of mathematical communication ability in accordance with the findings of Samsidar et al. (2018) and Ningtias & Soraya (2022). However, the N-gain achievement in the low category indicates a limited rate of improvement. This is presumably related to the nature of guidance within the inquiry process; if not balanced correctly, it may lead students to rely on instructional prompts rather than engaging in independent argumentative exploration.

Additionally, the limitation of the GIL model in achieving a higher category of mathematical communication ability on the SPLTV topic is also closely related to the heavy cognitive load students face during structured investigations. In a guided inquiry setting, students are required to construct mathematical concepts from scratch based on teacher guidance. For a complex topic like Three-Variable Linear Equation Systems, which involves multiple variables and abstract elimination-substitution steps, this process consumes a significant amount of time. As a result, the classroom timeline became restricted, leaving fewer opportunities for students to actively practice explaining mathematical ideas in writing or validating their final problem-solving conclusions independently.

Conversely, the PBL model exhibits a more prominent advantage by positioning contextual problems as the central pivot of learning. This characteristic compels students to engage in deep discussion, critical problem analysis, and collaborative solution formulation, as noted by Losi et al. (2021) and Solikhin (2022). The significant improvement in the PBL class is supported by the fact that students are continuously encouraged to interact through the expression of ideas and the presentation of problem-solving results, a point also highlighted by Salsabilla et al. (2023).

Furthermore, these findings substantiate the empirical evidence documented byWahyuni & Swastika (2024), who emphasized the high efficacy of the PBL model in sharpening students' mathematical communication ability, particularly within the context of the System of Linear Equations in Three Variables (SPLTV). This is attributed to the model's ability to provide space for students to evaluate their own reasoning before presenting it publicly. Through the process of deconstructing authentic problems into mathematical models, students in the PBL class achieved a more comprehensive quality of written explanation and mathematical expression compared to those in the GIL class.

This divergence in written quality and student performance is deeply rooted in the level of strategic flexibility allowed in each classroom environment. In the GIL group, the highly structured guidance and rigid step-by-step instructions tend to foster procedural dependency. Consequently, when students encounter cognitive obstacles or unfamiliar problem variations, they experience hesitation rather than exploring alternative methods outside the predetermined directions. Conversely, the PBL environment grants students full cognitive autonomy to determine their own problem-solving trajectories, such as freely choosing which initial variable to eliminate based on their group's consensus. This flexibility cumulatively encourages students to test various mathematical schemes, rendering them more adaptive and confident in organizing their mathematical arguments independently.

The synthesis of these statistical results and pedagogical theories underscores that while both models positively contribute to the learning process, the PBL framework provides a more robust environment for students to excel in mathematical communication. This evidence provides a clear trajectory for understanding how different problem-centered approaches influence student performance within the classroom setting.

CONCLUSION

In summary, this study demonstrates a significant difference in the effectiveness of the Problem-Based Learning (PBL) and Guided Inquiry Learning (GIL) models in improving the mathematical communication ability of Grade 10 students at SMA Negeri 50 Jakarta when learning the Three-Variable Linear Equation System (SPLTV). An independent samples t-test indicated that the difference between the two groups was statistically significant ($p < 0.001$), leading to the rejection of the null hypothesis. Consistent with these results, the N-gain analysis revealed that the PBL group recorded an average N-gain score of 0.486, which was categorized as medium improvement. Meanwhile, the GIL group obtained an average N-gain score of 0.289, which was categorized as medium improvement. Overall, these findings suggest that the PBL model was more effective than the GIL model in improving students' mathematical communication ability on the SPLTV topic.

According to the empirical evidence from this research, the PBL model is widely recognized as an effective instructional approach for mathematics educators to improve students' mathematical communication ability, particularly when teaching the SPLTV topic. However, these findings should be interpreted cautiously. This study was limited to one mathematics topic and involved students from only one school, so the results may not fully apply to other contexts. Future study is therefore needed to examine the effectiveness of the PBL and GIL models in different mathematical topics, grade levels, and educational settings. Such *studies* would help strengthen the evidence on the effectiveness of these instructional models and provide a clearer picture of their broader applicability.

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