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Study of effect of argument driven inquiry model and mathematical literacy on student mathematical communication

Riyama Ambarwati*, Nanang Supriadi, Dewi Noviana, Rizki Wahyu Yunian Putra, Mujib, Siska Andriani
Universitas Islam Negeri Raden Intan Lampung, Indonesia
✉ riyama@radenintan.ac.id*

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Abstract

Background: Mathematical communication skills are an important aspect of mathematics learning that allows students to explore and consolidate their mathematical thinking clearly and precisely.
Aim: This study aims to analyze the effect of Argument Driven Inquiry learning model and Mathematical Literacy on students' mathematical communication skills.
Method: This research is a quantitative study that examines the mathematical communication skills of students by applying the argument driven inquiry learning model and mathematical literacy. The subjects of this study consisted of 30 students learning using the Argument Driven Inquiry model and 30 students using the conventional model. Data were collected through tests and analyzed using One-way Ancova.
Results: The findings showed a significant effect of using Argument Driven Inquiry and Mathematical Literacy learning model on students' mathematical communication skills compared to using Conventional learning model. The experimental class obtained higher scores than the control class. Learners were able to organize mathematical arguments more systematically, formulate relevant questions, and convey mathematical thinking more clearly.
Conclusion: Argument Driven Inquiry model and mathematical literacy together can affect the mathematical communication skills of students. These results have important implications in the development of mathematics curriculum that pays attention to communication aspects in mathematics learning.

INTRODUCTION

One of the main objectives of mathematics learning is to improve students' mathematical communication skills (Lore et al., 2019; Umar, 2012; Siagian, 2016). This ability allows students to explore and consolidate their mathematical thinking and develop knowledge and skills in solving problems using mathematical language (Supriyanti et al., 2021). According to Setiawan (2020), mathematical manipulation, proof preparation, and explanation of mathematical ideas and statements are very important. This ability includes communication of ideas through tables, diagrams, and other representations that clarify concepts and appreciate the usefulness of mathematics in everyday life. In addition, students are expected to have curiosity, interest in learning mathematics, resilience, and confidence in solving problems (Hendriana et al., 2019). However, facts in the field show that students' communication skills are still low (Hapsoh & Sofyan, 2022). One of the causes is that students are less able to communicate mathematical ideas (Hendriana et al., 2019). Factors such as inadequate learning

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resources, limited comprehensive skills, and challenges in expressing mathematical concepts contribute to this problem (Setiyani et al., 2020; Rohid et al., 2019). Therefore, it is important to improve and enhance students' mathematical communication skills through more effective learning approaches and adequate learning resources, in order to improve the quality of mathematics learning and students' ability to articulate their mathematical ideas.

The Argument Driven Inquiry model is thought to be an effective solution to improve students' mathematical communication skills (Walker & Sampson, 2013). This model encourages students to actively engage in the learning process through arguments based on data and evidence (Walker & Lower, 2019; Rosidin et al., 2019). With Argument Driven Inquiry, students are invited to collaborate and discuss intensively, helping them to organize and communicate mathematical ideas more effectively which facilitates the preparation of evidence and explanation of ideas in a structured manner, and trains students to think critically and analytically to improve understanding of mathematical concepts (Haeruman, 2024; Dirgantoro, 2018; Antari, 2022). This approach encourages the use of mathematical representations, such as tables and diagrams, to clarify the ideas conveyed (Mufidah et al., 2021). In addition, the Argument Driven Inquiry model helps students develop self-confidence and strong argumentation skills, and appreciate the usefulness of mathematics in everyday life (Putri et al., 2020; Azizah, 2021). Therefore, the implementation of Argument Driven Inquiry in the mathematics classroom is expected to be a strategic step to overcome the obstacles in mathematical communication that have been previously identified.

In addition, mathematical literacy is thought to affect students' mathematical communication skills (Manurung et al., 2022; Kurniawan & Khotimah, 2022). Mathematical literacy involves understanding, using, and evaluating mathematical concepts and procedures in various contexts (Hodiyanto, 2017; Nuryami et al., 2022). With good mathematical literacy, students can interpret and express mathematical ideas clearly and accurately, and solve problems more effectively and efficiently (Amelia, 2024). It also strengthens students' understanding of the relevance of mathematics in everyday life, increasing their interest and motivation to learn (Magfiroh, 2024; Masfufah &Afriansyah, 2022). In addition, mathematical literacy supports critical and analytical thinking skills (Alimuddin, 2024). Therefore, mathematical literacy skills need to be considered by educators in the learning process. The combination of Argument Driven Inquiry and good mathematical literacy is expected to produce more effective and meaningful mathematics learning for students. In this study, we will look at the effect of applying the Argument Driven Inquiry model and the category of mathematical literacy skills on mathematical communication skills.

Several previous studies related to the application of the Argument Driven Inquiry model in learning have shown positive impacts (Hidayatussakinah et al., 2021; Rosyidah et al., 2023; Utami et al., 2022). The research includes improving critical thinking skills (Diartika, 2024a, 2024b; Putri et al., 2020), creative thinking (Dani, 2021), learning outcomes (Mutiah & Ulfa, 2022), science literacy (Citra et al., 2023; Manurung et al., 2020; Novitasari et al., 2022). However, research that specifically explores the application of the Argument Driven Inquiry model to mathematical communication skills from the perspective of mathematical literacy has not been found. Therefore, this study aims to analyze: 1) The effect of Argument Driven Inquiry model on mathematical communication skills; 2) The effect of mathematical literacy on

mathematical communication skills; and 3) The effect of Argument Driven Inquiry model on mathematical communication ability seen from mathematical literacy ability.

METHODS

Design

This study used a Quasi Experimental design with a quantitative approach. This study connects two independent variables and one dependent variable. The argument driven inquiry model acts as the first independent variable and mathematical literacy acts as the second independent variable as well as the covariate variable, and mathematical communication ability acts as the dependent variable. The sampling technique in this study uses probability techniques, specifically cluster random sampling (area sampling), to determine random samples. This is because it is not allowed to create a new class at the research location, the research sample was selected by drawing two classes, with one class designated as the experimental class and one class as the control class, then obtained class VIII 2 as the control class and VIII 3 as the experimental class. The research design used in this study is using a 1 × 2 factorial which can be seen in Table 1.

Table 1. Factorial Design of 1×2 Study

G			
Experiment		**Control**	
x_1	y_1	x_2	y_2
$x_{1.1}$	$y_{1.1}$	$x_{2.1}$	$y_{2.1}$
$x_{1.2}$	$y_{1.2}$	$x_{2.2}$	$y_{2.2}$
$x_{1.3}$	$y_{1.3}$	$x_{2.3}$	$y_{2.3}$
...	...	...	...
...	...	...	...
$x_{1.n}$	$y_{1.n}$	$x_{2.n}$	$y_{2.n}$

Description:

G : Group

E : Treatment of Argument Driven Inquiry Learning model and Mathematical Literacy

C : Problem Based Learning model treatment

x : Mathematical literacy

y : Mathematical Communication Ability

n : Number of respondents

The purpose of using a 1 x 2 factorial design is to identify and analyze the effect of the experimental and control classes on mathematical literacy and mathematical communication skills. The experimental class will be applied the argument drivent inquiry learning model while the control class will be applied the problem-based learning learning model. This design is used to test the interaction between experimental and control classes, as well as to evaluate the effect of each class individually on the results or influence on students' mathematical communication skills. The research flow can be seen in the figure below:

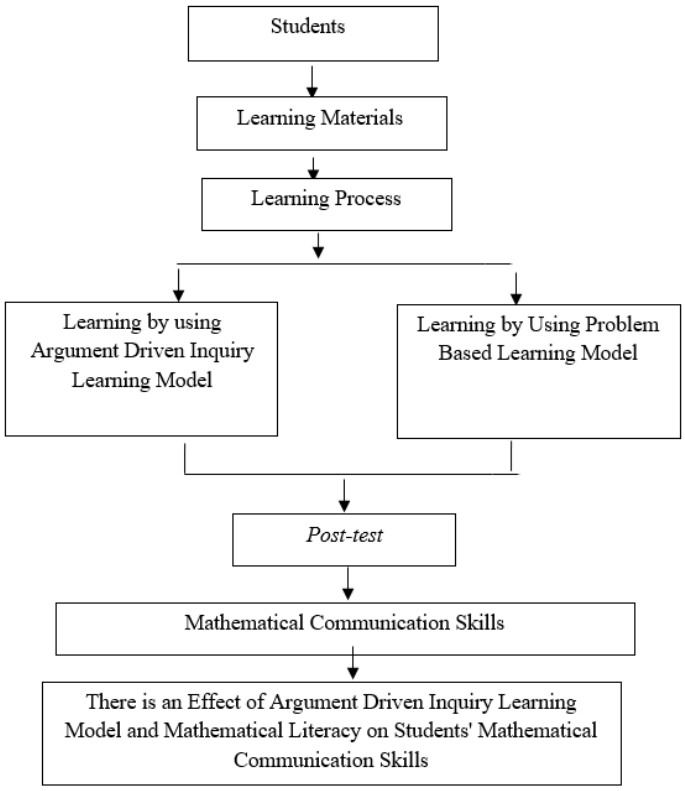

Figure 1. Research flow diagram

Participants

The demographics of the participants in this study are listed in Table 2.

Table 2. Demographic Characteristics of the Sample

Demographics		Frequency	Percentage (%)
Gender	Male	24	40%
	Female	36	60%
Place of residenc	City	0	0%
	Village	60	100%
Tribe	Javanese	30	50%
	Sundanese	11	18%
	Lampung	19	32%

Note. N = 60, average age 14 years old (SD = 0,056 $S.E$ = 0,445).

Based on Table 2, the demographics of the participants in this study were 60 learners with an average age range of 14 years. The 60 learners were VIII grade students at the junior high school level in one of the schools in Lampung Province in the odd semester. All participants were divided into two classes with details of 30 students who studied with the Argument Driven Inquiry model in class VIII-2 and 30 students who studied with the Problem Based Learning model in class VIII-3. Determination of class VIII as a research target on the grounds: a) the results of initial analysis through observations and interviews that class VIII students still consider that mathematics is a difficult subject to understand; b) some students' mathematical communication skills are still not good; c) students still have difficulty connecting mathematics with everyday life. Therefore, the Argument Driven Inquiry learning model and mathematical literacy will be applied to class VIII students to see how much influence it has on students' mathematical communication skills.

Instruments

The instruments used in this study consisted of tests to measure mathematical communication skills and mathematical literacy with Number Pattern material totaling 4 description questions. The Mathematical Communication Ability test and Mathematical Literacy test have been tested on 33 students outside the sample group, and the results show validity with a correlation value of more than 0.3 with a significant Cronbach alpha, which also shows a value exceeding 0.7 which means reliable, so that both tests can be used to measure mathematical communication ability and mathematical literacy.

Data Analysis

The analysis technique was carried out by independent t test and Analysis of Covariance (One-Way Ancova). The independent t test was used to determine the balance of the class at the beginning before being given treatment while the one-way ancova test can be done after fulfilling four prerequisite tests. The prerequisite tests consist of normality test, homogeneity test of data variation, regression linearity test, and regression coefficient homogeneity test (Rutherford, 2011). The purpose of the One-Way Ancova test is to increase the accuracy of a treatment, as it regulates the influence of external factors that cannot be controlled (Rutherford, 2011). The hypothesis that can be made to answer this problem is:

- $H_0: \alpha_1 = \alpha_2$: There is no effect of Argument Driven Inquiry Learning model on students' mathematical communication skills by controlling Mathematical Literacy;
- $H_0: \alpha_1 \neq \alpha_2$: There is an effect of Argument Driven Inquiry Learning model on students' mathematical communication skills by controlling Mathematical Literacy;
- $H_0: x = 0$: There is no effect of the covariate variable of mathematical literacy on students' mathematical communication ability;
- $H_0: x \neq 0$: There is an effect of the covariate variable of mathematical literacy on students' mathematical communication ability;
- $H_0: \alpha_i x = 0$: There is no simultaneous influence of Argument Driven Inquiry learning model and Mathematical Literacy on students' Mathematical Communication ability;
- $H_0: \alpha_i x \neq 0$: There is no simultaneous influence of Argument Driven Inquiry learning model and Mathematical Literacy on students' Mathematical Communication ability;

Based on these hypotheses, the criteria used to determine these conjectures are: if Sig in the table $< 0{,}05$, then H_0 is rejected, and if Sig $\geq 0{,}05$, then H_0 is accepted. Hypothesis testing and prerequisite tests in this study used SPSS 25 for windows software.

RESULTS AND DISCUSSION

Result

In this study, the data obtained came from the results of the pretest and posttest. Pretest was conducted before applying the argument driven inquiry model to see the initial ability between the experimental class and the control class. The posttest was conducted after applying the Argument Driven Inquiry model to see if there was a significant difference between the experimental group and the control group. Before the research was conducted, the researcher

tested the test instrument on 33 students outside the sample and declared valid. Before testing the hypothesis, it is necessary to do the prerequisite test first, which is as follows:

Analysis of Covariance (One-Way Ancova) Prerequisite Test

The first prerequisite test carried out was the normality test. This test is carried out to determine whether the research results in the form of questionnaires and test questions in the experimental class and control class are normally distributed or not. The data in the prerequisite test used posttest data. The calculation of the normality test in this study used Kolmogorov Smirnov with the help of SPSS 25 software. The following normality test results can be seen in Table 3.

Table 3. Normality Test

Tests of Normality							
X1		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Y	Experiment	.137	30	.160	.940	30	.093
	Control	.149	30	.088	.938	30	.081
X2	Experiment	.145	30	.108	.924	30	.035
	Control	.152	30	.074	.884	30	.004
a. Lilliefors Significance Correction							

Based on the data in Table 3 shows that the results of the normality test of mathematical literacy and mathematical communication skills of students at the level of $\alpha = 0{,}05$. So it can be concluded that the data obtained in the control and experimental classes are normally distributed because $p - value > \alpha$. The second prerequisite test is the homogeneity test The following results of the homogeneity test of data variation can be seen in Table 4.

Table 4. Homogeneity Test

Levene's Test of Equality of Error Variances[a]			
Dependent Variable: Y			
F	df1	df2	Sig.
2.251	1	58	.139
Tests the null hypothesis that the error variance of the dependent variable is equal across groups.			
a. Design: Intercept + X2 + X1			

Table 4 shows that the results of the homogeneity test of mathematical literacy and mathematical communication skills come from the same variance or homogeneous, because $p - value$ $(0{,}139) > \alpha$ $(0{,}05)$. The third prerequisite test is the regression linearity test. The regression linearity test can be fulfilled if there is a linear relationship between the covariate variables and the dependent variable. The following regression linearity test results can be seen in Table 5.

Table 5. Regression Linearity Test

Tests of Between-Subjects Effects					
Dependent Variable: Y					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	6557.188[a]	2	3278.594	20.201	.000
Intercept	7443.618	1	7443.618	45.864	.000
X2	656.771	1	656.771	4.047	.049
X1	3650.398	1	3650.398	22.492	.000
Error	9250.995	57	162.298		
Total	244345.000	60			
Corrected Total	15808.183	59			
a. R Squared = .415 (Adjusted R Squared = .394)					

Table 5 shows the covariate Sig (X_2) is less than α or $0{,}049 \leq 0{,}05$. So it can be concluded that there is a linear relationship between the covariate variable (mathematical literacy) and the dependent variable (mathematical communication ability). The following results of the regression coefficient homogeneity test can be seen in Table 6.

Table 6. Homogeneity Test of Regression Coefficients

Tests of Between-Subjects Effects					
Dependent Variable: Y					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	6576.131[a]	3	2192.044	13.297	.000
Intercept	7240.242	1	7240.242	43.918	.000
X1	376.291	1	376.291	2.283	.136
X2	673.236	1	673.236	4.084	.048
X1 * X2	18.943	1	18.943	.115	.736
Error	9232.052	56	164.858		
Total	244345.000	60			
Corrected Total	15808.183	59			
a. R Squared = .416 (Adjusted R Squared = .385)					

Based on Table 6 above, it shows that the results of the regression coefficient homogeneity test have a Sig = $0{,}736 > 0{,}05$. So it can be concluded that there is no linear relationship between the covariate variable and the independent variable, so the assumption test is fulfilled.

Hypothesis Test Analysis of Covariance (One-Way Ancova)

Hypothesis testing using analysis of covariance (one-way Ancova) test. one way ancova is a statistical technique that combines regression and anova (analysis of variance) which is believed to reduce errors that arise in variance analysis (Rutherford, 2011). Researchers used SPSS 25 software in conducting the One-Way Ancova test. The following One-Way Ancova test results can be seen in Table 7.

Table 7. One-Way Ancova Test

Tests of Between-Subjects Effects

Dependent Variable: Y

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	6557.188[a]	2	3278.594	20.201	.000	.415
Intercept	7443.618	1	7443.618	45.864	.000	.446
X2	656.771	1	656.771	4.047	.049	.066
X1	3650.398	1	3650.398	22.492	.000	.283
Error	9250.995	57	162.298			
Total	244345.000	60				
Corrected Total	15808.183	59				

a. R Squared = .415 (Adjusted R Squared = .394)

Based on Table 7, it can be seen that in row (X_1) shows the value of $F_{calculate}$ or $F_0(X_1) = 22{,}492$ with $p - value = 0{,}000$, it can be concluded that there is an effect of Argument driven Inquiry learning model on students' mathematical communication skills by controlling mathematical literacy. Then, the row (X_2) shows the value of $F_{calculate}$ or $F_0(X_2) = 4{,}047$ with $p - value = 0{,}049$, it can be concluded that there is an effect of covariate variables on students' mathematical communication skills. Furthermore, based on the corrected model results in table 7, it can be seen that the value of $F_{calculate}$ or $F_0 = 20.201$ and $p - value = 0{,}000$. Therefore, it can be concluded that there is a simultaneous influence of Argument Driven Inquiry learning model and mathematical literacy on students' mathematical communication skills. Furthermore, further tests will be carried out to determine which learning model is better between the argument driven inquiry learning model or problem-based learning using the parameter estimates test. The following further test results using the parameter estimates test can be seen in Table 8.

Table 8. Advanced Test Results

Parameter Estimates

Dependent Variable: Y

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval		Partial Eta Squared
					Lower Bound	Upper Bound	
Intercept	39.391	6.592	5.975	.000	26.190	52.592	.385
X2	.204	.101	2.012	.049	.001	.407	.066
[X1=1]	16.984	3.581	4.743	.000	9.813	24.156	.283
[X1=2]	0[a]	.	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

Based on Table 8 in the row $[X_1 = 1]$ it can be seen that the value of $t_0 = 4{,}743$. with $p - value = 0{,}000$, it can be concluded that the mathematical communication skills of students taught using the Argument Driven Inquiry learning model are better than students taught using the Problem Based Learning model after controlling for mathematical literacy.

Discussion

Based on the results of this study, it shows that by using the Argument Driven Inquiry learning model in the experimental class, students' mathematical communication skills have increased more significantly than the Problem Based Learning learning model in the control class as well as students' mathematical literacy also affects the results of students' mathematical communication skills. Mathematical communication skills are improved by using the Argument Driven Inquiry learning model, showing that learning using the Argument Driven Inquiry model can improve students' mathematical communication skills well (Hayati & Fuadiyah, 2023).

The result of the first hypothesis is that there is a direct relationship between the Argument driven Inquiry learning model and mathematical communication skills. This can occur because the Argument driven Inquiry learning model can significantly affect mathematical communication skills. The results of statistical analysis in general have pretty good results on mathematical communication skills using the Argument driven Inquiry learning model. However, referring to the results that have been obtained, there are still students who have not mastered mathematical communication skills by using the Argument driven Inquiry learning model. The findings of this study support the statement of Zahratul Hayati and Sa'diatul Fuadiyah that learning using the Argument Driven Inquiry model can improve students' communication skills well. The application of the Argument driven Inquiry model provides a good response, such as confident students in expressing arguments actively and having good communication in the learning process compared to learning using the Problem Based Learning model. Learners in the control class using Problem Based Learning look still passive so that students are still difficult in solving the problems given by the teacher, although in the experimental class using the Argument Driven Inquiry learning model there are still passive in solving problems and expressing their opinions, but overall the class with the Argument Driven Inquiry learning model can understand the material well.

The result of the second hypothesis is that there is a direct relationship between mathematical literacy and mathematical communication skills. This can occur because mathematical literacy has a significant effect on mathematical communication skills. The results of statistical analysis in general result in the value of mathematical literacy and mathematical communication skills of students are also quite good. Learners who have low literacy have difficulty in solving the problems given, this proves that mathematical literacy has an influence on students' mathematical communication skills, because if students have high mathematical literacy skills, then sensitivity to mathematical concepts that are relevant to the problems they are facing is also good. As explained in research conducted by Syarifatu Zahrotin, et al (2020), the purpose of the study was to improve students' critical thinking and mathematical communication skills using a mathematical literacy-based learning model. Based on the results of the study, it shows that students who have high mathematical literacy look active in learning, students are able to ask questions and answer questions well, and discussions conducted by students, it appears that they work together in solving problems.

The third hypothesis is that there is a direct relationship between learning models and mathematical literacy on mathematical communication skills. This can occur because the argument driven inquiry learning model and mathematical literacy together have a significant effect on mathematical communication skills. The results of statistical analysis seen from the value of r square and f test multiple regression analysis it can be interpreted that the higher the

learning model and mathematical literacy, the more mathematical communication skills will increase. Based on the results of the analysis there is a greater influence of mathematical literacy on mathematical communication skills, this can be seen from the value of f count. Because in mathematical communication, mathematical literacy is needed by students.

This proves that there is a simultaneous relationship between the argument driven inquiry learning model and mathematical literacy on students' mathematical communication skills. The conclusion obtained after analyzing the data and the results obtained from the research on the experimental class and control class can be concluded that there is an effect of Argument driven inquiry learning model and mathematical literacy on students' mathematical communication skills.

Implication

Argument driven inquiry and mathematical literacy learning models affect students' communication skills, which means that the use of Argument driven inquiry and mathematical literacy learning models can be a recommendation compared to conventional learning which only relies on group discussions and lectures.

Limitations and Suggestions for Further Researchers

This study has several weaknesses and limitations, including only involving three variables and using a limited sample, namely 60 VIII grade students from one public junior high school in Lampung Province. The focus of the subject matter was also limited to Number Patterns. Therefore, future relevant research can increase the validity by involving a larger number of students from various schools, taking a wider range of mathematics subject matter, and considering additional factors that may affect the results of the study.

CONCLUSIONS

Based on data analysis and discussion, it can be concluded that there is an effect of argument driven inquiry learning model on students' mathematical communication skills by controlling mathematical literacy. There is an effect of the covariate variable of mathematical literacy on students' mathematical communication ability. There is a simultaneous influence of argument driven inquiry learning model and mathematical literacy on students' mathematical communication ability. Based on the conclusions of the research results, here are some things that researchers need to suggest, namely Educators can use the argument driven inquiry learning model to improve students' mathematical communication skills, as evidenced by this study which applies the argument driven inquiry learning model which has good test results to improve students' mathematical communication skills compared to using problem-based learning models. Educators are expected to pay attention to mathematical literacy to help educators in measuring and predicting students' mathematical communication skills. Researchers also hope that this research can provide benefits for educators in general and especially researchers themselves.

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AUTHOR CONTRIBUTIONS STATEMENT

This research was conducted in one of the State Junior High Schools in Lampung Province, which was carried out by DN, who was in charge of providing teaching using the Argument Driven Inquiry Model and Mathematical Literacy. The research process was assisted by NS and RA as supervisors and management of research equipment and administration at school, then all supporting instruments were validated by RWYP and M, and the calculation and analysis of the data obtained was carried out by DN and hypothesis testing was carried out by RA.

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