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Improving Mathematical Communication Skills Through the Geogebra-helped PBL and Direct Instruction Reviewed from the Level of Learning Independence

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Abstract

This research aims to analyze the improvement of junior high school students' mathematical communication skills through Problem Based Learning (PBL) assisted by Geogebra and Direct Instruction assisted by Geogebra. The research also considers the level of student learning independence. The research method used was a quasi-experiment with a pretest-posttest control group design involving two treatment groups. Groups that underwent the PBL approach with the help of Geogebra and Direct Instruction with the help of Geogebra. Students in this study were divided based on their level of learning independence. Data was collected through an initial test (pretest), implementation of learning, and a final test (posttest). Data analysis involved a comparison between the increase in students' mathematical communication skills before and after treatment in the two treatment groups, as well as the influence of the level of learning independence on increasing mathematical communication skills. The research results show that both learning approaches contribute to improving students' mathematical communication skills. However, the group that took part in PBL assisted by Geogebra showed more significant improvement compared to the Direct Instruction group assisted by Geogebra. In addition, it was identified that the level of student learning independence influences the results of improving mathematical communication skills, where students with a high level of learning independence tend to benefit more from PBL assisted by Geogebra. In order to improve students' mathematical communication skills in learning spatial material, it is recommended that educators consider using Geogebra-assisted PBL and pay attention to students' level of learning independence in designing effective learning strategies.

Keywords: Mathematical Communication Skills, Problem Based Learning (PBL), Direct Instruction, Geogebra, Level of Learning Independence, Building Space, Middle School Students

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INTRODUCTION

Education is a basic need that must be possessed by every individual and fulfilled by a country. The importance of education encourages great attention from the government, because this will become the basic foundation for the nation's future successors. Aini (2015) stated that education is an important requirement for the development and progress of a nation. The better a country's education, the more it will produce human resources capable of managing the country well, so that the country's goals will be achieved. One of the activities that supports the achievement of an educational goal is learning activities. One of the lessons contained in education is mathematics learning and communication. Maftukhin et al. (2014) stated that to master and create technology in the future, strong mastery of mathematical material is needed from an early age. Mathematics learning has important benefits in real life because it is used to develop science and technology. The more a country's science and technology develops, the more it will help achieve the country's goals. Juanda et al. (2014) stated that mathematics subjects need to be given to all students starting from elementary school to equip students with the ability to think logically, analytically, systematically, critically and creatively, as well as the ability to work together.

According to NCTM as quoted by Hodiyanto (2017), the general goals in learning mathematics are learning to communicate *(mathematical communication)* , learning to reason *(mathematical reasoning)* , learning to solve problems *(mathematical problem solving)* , learning to link ideas *(mathematical connection)* , and learn to present ideas *(mathematical representation).*

Lomibao et al. (2016) stated that mathematical communication skills are the ability to express ideas, describe and discuss mathematical concepts coherently and clearly. Prayitno (2013) believes that mathematical communication is needed to communicate ideas or solve mathematical problems, either orally, in writing or visually, both in mathematics learning and outside of mathematics learning. Mathematics learning places more emphasis on written mathematical communication because during the learning process a lot of symbols or images are used to make it easier to solve a problem. Several studies have stated that students' mathematical connection abilities are still relatively low, proving that students still experience difficulties in the process of mathematical communication skills. Mathematical communication skills are important in learning mathematics, because students who have good mathematical communication can easily interpret and solve problems. This is in accordance with research conducted by Choridah (2013) which stated that mathematical communication skills are very important to develop so that students are actively involved in learning and eliminate the impression that mathematics is a difficult and scary subject. Mathematical communication skills are an important ability in mathematics learning activities. Based on this, it is considered important to achieve the goals and the need to implement regulations and rules which are of course related to the implementation of learning carried out by educators.

The main problem in this research is the low level of mathematical communication skills because according to Yulandari & Asmin (2023) stated that 5193% of students had difficulty in making mathematical representations and according to research by Rahmawati, Cholily, & Zukhrufurrohmah (2023) revealed that 16 out of 21 students were involved in research is included in the low mathematical communication ability group, and none is included in the high group . Furthermore, another factor in research conducted by Darkasyi (2014), mathematical communication, is that teachers still tend to be active with a lecture approach in conveying material to students so that students in mathematical communication are still very lacking .

Law of the Republic of Indonesia Number 20 of 2003 which regulates the National Education System states that, The learning model functions as an instrument that helps or makes it easier for students to gain a number of learning experiences. Each learning model has its own characteristics and conditions when the learning model is effective to use. A learning model that is suitable for improving mathematical communication skills is a learning model with characteristics that support the achievement of each indicator of mathematical communication skills using PBL learning.

The PBL model was chosen by researchers for several reasons, the main one being because the model is directed at real world issues (Wijaya & Yusup, 2023). Because the problems presented are problems that are familiar or directly experienced by students, and because the context is applied through Three-Dimensional material, this feature allows students to communicate actively. Second, PBL can help students become more proficient in communicating mathematical ideas when working on Triangle material, in accordance with the findings of several studies (Wijaya & Yusup, 2023). Third, according to Evariyani, Kartono, and Suminar (2023), the PBL learning paradigm can provide students with the opportunity to apply Triangle material to communicate their understanding. Fourth, PBL provides opportunities for students to actively learn while expanding their knowledge (Kanah & Mardiani, 2022) .

Considering the importance of technological developments and advances in influencing efforts to optimize the improvement of students' mathematical communication skills, it is not only done through models which influence the optimality of students' KKM but also requires media in the PBL model and one of the media I chose is the Geogebra application . According to Agung, (2018) The GeoGebra application can help students' abilities , this is supported by Supriadi (2015) who concluded that GeoGebra-based geometry learning in the learning process has been proven to significantly increase students' mathematical communication skills. Apart from that, there are other elements that can have an effect, for example learning motivation. students, independence and motivation of the students themselves. From several references regarding learning models, researchers chose the *Problem Based Learning* (PBL) model and Direct Learning *(DI)* for use in writing this research

Based on the description above, the researcher is interested in conducting research which aims to obtain analysis and description results relating to the acquisition and improvement of mathematical communication skills of students who receive PBL with the help of Geogebra and students who receive *Direct Instruction* with the help of Geogebra in terms of the level of student learning independence. Based on the description above, the problem in this research is "How to obtain and increasing the mathematical communication skills of Class VIII students on Flat Side Building Material who received PBL and *Direct learning Instructions* Geogebra assistance is reviewed from the level of learning independence ?" This problem can be identified into several research questions as follows: (1) What is the description of the acquisition of mathematical communication skills for students who learn using the Geogebra-assisted PBL learning model?; (2) What are the criteria for improving students' mathematical communication skills who receive the PBL learning model assisted by Geogebra?; (3) Does the implementation of PBL assisted by Geogebra have a significant effect on students' acquisition of communication skills?; (4) Is there a difference in the influence of PBL and *Direct implementation? Geogebra-assisted instruction* to improve students' mathematical communication skills?; (5) Does the level of student learning independence influence the improvement of students' mathematical communication skills?; (6) Is there an interaction effect between PBL and *Direct learning? Instruction* and the level of student learning independence on improving student communication skills?

This research aims to obtain analysis and description results relating to the acquisition and improvement of mathematical communication skills of students who receive Geogebra-assisted PBL and students who receive *Direct Geogebra-assisted instruction* is reviewed from the level of learning independence of Class VIII students on flat-sided room building materials.

LITERATURE REVIEW

Mathematical Communication Skills

According to NCTM as quoted by Hodiyanto (2017), the general goals in learning mathematics are learning to communicate *(mathematical communication)* , learning to reason *(mathematical reasoning)* , learning to solve problems *(mathematical problem solving)* , learning to link ideas *(mathematical connection)* , and learn to present ideas *(mathematical representation).* Mathematical communication skills are very important considering "Mathematical Communication Skills are a critical aspect in mathematics learning, describing the extent to which students are able to convey their mathematical thinking clearly and precisely" (Fauzi, 2019) especially as Yulandari & Asmin (2023) stated that 5193% of students had difficulty in making mathematical representation and according to research by Rahmawati, Cholily, & Zukhrufurrohmah (2023) revealed that 16 of the 21 students involved in the research were in the low mathematical communication ability group, and none were in the high group . Furthermore, another factor in research conducted by Darkasyi (2014) is that mathematical communication is because teachers still tend to be active with a lecture approach in conveying material to students so that students in mathematical communication are still very lacking.

Problem Based Learning (PBL)

The Problem Based Learning (PBL) model has proven to be effective in improving students' mathematical communication skills, because it invites them to actively participate in the process of solving mathematical problems (Rochmad, 2018) . This is in line with the opinion of Wijaya & Yusup (2023) who stated that the model is directed at real world issues. Apart from that, PBL can help students become more proficient in communicating mathematical ideas when working on Triangle material, in accordance with the findings of several studies (Wijaya & Yusup , 2023). Furthermore, according to Evariyani, Kartono, and Suminar (2023), the PBL learning paradigm can provide opportunities for students to apply Triangle material to communicate their understanding. Fourth, PBL provides opportunities for students to actively learn while expanding their knowledge (Kanah & Mardiani, 2022).

Direct Instruction Learning

Direct Instruction learning is a learning model that emphasizes mastering concepts and changing behavior by prioritizing a deductive approach (Rahmawati & et al, 2020). According to Joyed and Weil in Santrock (2007) *Direct Instruction* learning is a structured teacher-centered approach. Learning *Direct Instruction* provides opportunities for students to learn by selectively observing, remembering, and imitating what is modeled by the educator.

Geogebra Media

a strong visual dimension, facilitating students to explore mathematical concepts interactively and improving their ability to communicate mathematical ideas" (Yanti & Hartono, 2019). Based on Agung 's opinion , (2018) The GeoGebra application can help students' abilities, this is supported by Supriadi (2015) who concluded that GeoGebra-based geometry learning in the learning process has been proven to significantly increase students' mathematical communication skills .

Level of Learning Independence

Noer (2010) asserts that independent learning offers a thorough foundation for understanding the procedures involved in empowering students to take an active role in their own education. The characteristics of independent learning according to Chabib Thoha (in Aqla, 2011) are the ability to think critically, creatively and innovatively; inability to be easily influenced by other people's opinions; refusal to escape or avoid difficulties; and the ability to solve problems by digging deeply into them when they arise. Be responsible for your own actions, work diligently and with discipline, solve problems independently without seeking help from others, and do not feel inferior if you are different from other people.

METHOD

In this research, descriptive and inferential statistics were used. Descriptive statistics are used to answer descriptive questions. Inferential statistics is used to answer and analyze hypothetical questions so this research is quasi-experimental research. Table 1, Table 2, and Table 3 shows 3 designs used in this study, namely *One group pretest-posttest design, Pretest-posttest control group design and Two factor experiments* with the following design.

Table 1. *One group pretest-posttest design*

Class	Pretest	Treatment	Posttest
Experiment	O	*X*	O

According to Sugiono (2014: 74), *One Group Pretest- Posttest Design* is a research design that contains a pretest, before treatment is given. In this way, the results of the treatment can be known more accurately, because it can be compared with the situation before the treatment was given and after the treatment has been given. In this study, researchers conducted a pretest.

Table 2. Pretest-posttest control group design

Class	Pretest	Treatment	Posttest
Experiment	O	X	O
Control	O	Y	O

According to Sugiyono (2017, p. 79) Nonequivalent *Pretest and Posttest Control Group Design* is the most popular approach in quasi-experiments, the experimental group and control group are not chosen randomly . Both classes were given a pretest and posttest and only the experimental group received treatment. The experimental group was given treatment using the Problem Based Learning learning model.

Table 3. *Two factor experiments*

Class / LEVEL LEARNING INDEPENDENCE	Experiment (X_1)	Control (X_2)
Low(Y_1)	X_1, Y_1	X_2, Y_1
Currently(Y_2)	X_1, Y_2	X_2, Y_2
Tall(Y_3)	X_1, Y_3	X_2, Y_3

Because the quasi-experimental design used in this research is a *non-equivalent group control design* which allows each group to receive treatment rather than just one group not receiving treatment (Gall, Gall & Borg, 2007 : 416). So the design used in this research is a 2 x 3 factorial design. The first factor is the application of PBL learning assisted by Geogebra (X1) and the application of direct instruction learning assisted by Geogebra (X2). The second factor is the category of learning independence level which is divided into three levels, namely high level (Y1), medium level (Y2), and low level (Y3). The conclusion is that these three designs must be used in this research.

Population and Sample

The population in this study was all class VIII but the sample was only 12 class VIII students of SMP Negeri 1 Lembang for the 2022/2023 academic year. For sample selection, researchers used a *simple random sampling method* by drawing lots.

Research Instruments and Data Collection Procedures

The test instrument in this research is a test of students' mathematical communication skills which consists of *a pretest* and *posttest* . The material that will be used in this research is "Flat Side Building Material".

The pretest is carried out before treatment is given, while the posttest is carried out at the end of learning, precisely after certain *treatments* or treatments have been carried out. Both tests were given to both sample classes. The questions given in *the pretest* and *posttest* are identical and are questions to test students' mathematical communication skills according to the indicators. The test questions used must be questions that are valid after testing the questions. The instrument items showed in Table 4.

Table 4. The instrument items

Sub-Main Material	Indicators of Mathematical Communication Skills	Question Indicator	No. Question	Question Form
3.1 Surface Area of Cubes and Cubes	a. Describe the problem situation and state the solution to the problem using pictures.	Students can provide a conclusion regarding the problem of the surface area of cubes and blocks	1	Essay

Sub-Main Material	Indicators of Mathematical Communication Skills	Question Indicator	No. Question	Question Form
	b. State the results in written form.	Students can determine the truth and explanation related to a problem of the surface area of a cube and cuboid .	2	Essay
3.2 Surface Area of a Prism .	c. Uses comprehensive mathematical representations to express mathematical concepts and solutions.	Students are able to provide personal answers regarding the problem of the surface area of a prism which is related to the Pythagorean concept and buying and selling .	3	Essay
	d. Create mathematical situations by providing ideas and information in written form.	Students are able to determine the truth of a conclusion regarding the ratio between the surface areas of prisms	4	Essay
Surface Area of a Pyramid	e. Uses mathematical language and symbols appropriately.	Students are able to solve pyramid surface area problems that are linked to the concept of comparison	5	Essay

Analysis of Research Instruments

Validity test

The correlation validity coefficient will use the *product moment correlation formula* with the formula being:

$$r_{AB} = \frac{N(\sum AB)-(\sum A)(\sum B)}{\sqrt{\{N(\sum A^2)-(\sum A)^2\}\{N(\sum B^2)-(\sum B)^2\}}} \quad \text{.......(1)}$$

Where: A: Value of an item for each student; B: Assess all items for each student; $\sum A$: The sum of all A values; $\sum B$: The sum of all B values; A^2: The square of the value A; B^2: The square of the B value; AB: Multiplication between the values A and B; N: the number of subjects; r_{AB}: *Pearson product moment* correlation value.

For interpretation regarding the magnitude of the correlation of the validity coefficient of the items, the calculated $r > r$ table d imana test is used n is the number of students processed with an error level of 5%. *The product moment* is presented in Table 5.

Table 5. Validity Criteria for Test Instruments

Validity Coefficient	Interpretation of Validity
$0.80 < r_{AB} \leq 1.00$	Very high
$0.60 < r_{AB} \leq 0.80$	Tall
$0.40 < r_{AB} \leq 0.60$	Currently
$0.20 < r_{AB} \leq 0.40$	Low
$0.00 < r_{AB} \leq 0.20$	Very low
$r_{AB} \leq 0.00$	Invalid

(Ananda et al., 2018)

Reliability Test

"Reliability is the determination of a test if it is tested on the same subjects . To calculate the reliability of a test, you can use a formula called *Cronbach's Alpha"* (Arikunto, 2006) that is:

$$r_{11} = \left[\frac{k}{k-1}\right]\left[1 - \frac{\sum \alpha_h{}^2}{\alpha_i{}^2}\right] \quad (2)$$

Where r_{11}: Reliability coefficient of questions; k: Many Question Items; $\sum \alpha_h{}^2$: Number of item variances; $\alpha_i{}^2$: Total Variance.

The result $r\ hitung$ is compared with $rtabel$ with the criteria (1) a question is reliable if the question item has $r\ hitung > rtabel$; and (2) The question is not reliable if the question item has $r\ hitung \leq rtabel$.

Table 6. Interpretation of Reliability Correlation Values

Reliability Value	Interpretation of Reliability Levels
$r_{11} \leq 0.20$	Very low
$0.20 < r_{11} \leq 0.40$	Low
$0.40 < r_{11} \leq 0.60$	Currently
$0.60 < r_{11} \leq 0.80$	High
$0.80 < r_{11} \leq 1.00$	Very high

(Ananda, Rusydi & Fadhli, 2018)

RESULTS AND DISCUSSION

To answer the results and discussion, use data on *Pretest*, *Posttest* and Gain scores, as well as data on mathematical communication ability scores of students who study with PBL and *Direct Instruction* assisted by Geogebra in terms of the level of learning independence.

An illustration of the acquisition of mathematical communication skills of students who receive learning using the PBL learning model assisted by Geogebra

This research question (1) is answered through descriptive statistical analysis using SPSS, the output of that the average score for obtaining mathematical communication skills for students who received the PBL learning model was 79.17 , the standard deviation was 2.858 and the posttest score distribution was negative $(-1{,}407)$ as illustrated in the Figure 1.

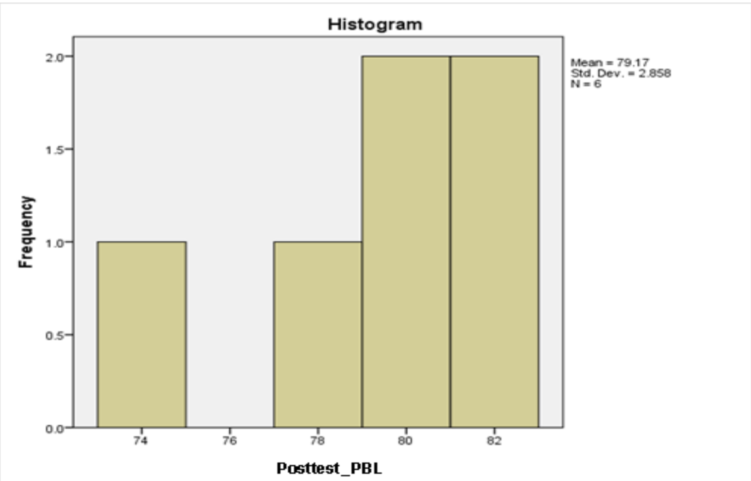

Figure 1. Mathematical communication skills of students in the PBL learning model assisted by Geogebra

Based on the results, the average score for obtaining mathematical communication skills for students who apply the PBL learning model is 79.17 . This figure reflects a good level of achievement, and can be interpreted that the PBL learning model makes a positive contribution to students' mathematical communication skills and the standard deviation of the average score is around 2.858. Standard deviation describes how far the data is spread from the average value. The smaller the standard deviation, the more homogeneous the score distribution. Therefore, a relatively small standard deviation can mean that the results of students' acquisition of mathematical communication skills tend to be consistent. Furthermore, the distribution of posttest scores which shows a negative value (-1.407) can be an interesting aspect for further analysis. Negative values in the posttest score distribution may reflect a negative change or partial decline in mathematical communication skills after implementing the PBL learning model. It should be noted that these results can be interpreted in more depth by analyzing students' answer patterns on certain aspects of mathematical communication skills . This is in accordance with research by Rahmalia et al (2020) that increasing students' mathematical communication skills and students' mathematical disposition by implementing PBL is better than students who apply conventional learning models.

Criteria for increasing students' mathematical communication skills who receive the Geogebra-assisted PBL learning model

This research question (2) is answered through descriptive statistical analysis using SPSS that shows in the Table 7.

Table 7. Descriptive analysis results of students' mathematical communication skills

	N	Minimum	Maximum	Mean	Std. Deviation
Gain_PBL	6	.66	.77	.7317	.03869
Valid N (listwise)	6				

Because the average increase (N-gain) is 0.7317, the criteria for increasing the mathematical connection ability of students who receive PBL is in the high category. Based on these results, there is a significant increase in students' mathematical connection abilities after following the PBL learning model and this research classifies the increase in mathematical connection abilities in the high category. This criterion illustrates that the PBL learning model effectively increases students' ability to connect mathematical concepts, thereby achieving positive achievements . An increase in the high category shows that PBL has a strong impact in helping students understand and relate mathematical concepts. These results are in line with the findings of several previous studies which highlight the effectiveness of PBL in increasing students' understanding of mathematical concepts . This is in line with research by Hanipah and Sumartini (2021) which attempts to analyze the comparison of mathematical communication skills between students who receive PBL. The KKM of students who receive PBL is better than students who receive *Direct Instruction.*

Geogebra-assisted PBL implementation has a significant effect on students' acquisition of mathematical communication skills.

The implementation of PBL has a significant effect on students' acquisition of mathematical communication skills. Formally, the statistical hypothesis (H_0) and research hypothesis) is as follows:

$$H_0: \mu_1 = \mu_2$$
$$H_1: \mu_1 \neq \mu_2$$

For testing this hypothesis is used$\alpha = 0{,}05\ (5\%)$. With μ_1 And $\mu_2$respectively are the average pretest and posttest of the population of students who received PBL learning.

Table 8. Pair t-test result

Pair	Item	Mean	SD	t	df	Sig.
Pair 1	Pretest-posttest	-56,667	3,559	-39,001	5	,000

Based on the output in Table 8, 2 things can be concluded that (1) With a sig value. 0.86 on paired samples correlations and sig value . is greater than $0{,}05$then there is no significant correlation between the pretest score and the posttest score for students' mathematical communication abilities; and (2) Because the sig value. the output of the paired samples t-test is $0{,}000$and this value is smaller than $0{,}05$what is H_1accepted, which means that the implementation of the PBL model has a significant effect on students' acquisition of mathematical communication skills. Based on point number (1), the conclusion from the sig. greater than a significance level of 0.05 is that the correlation between pretest and posttest scores cannot be considered statistically significant. This means that an increase or decrease in pretest scores does not correlate strongly with changes in posttest scores in students' mathematical communication abilities and although there is no significant correlation, it is important to consider the possibility that there are other factors that could influence posttest results. Factors such as instructional interventions, variability in how students respond to posttests, or factors outside the classroom may play a role in score differences. Based on point (2), these results reflect the positive impact of using the PBL model in increasing students' acquisition of mathematical communication skills . PBL, as an approach that emphasizes active learning and application of knowledge in real contexts, successfully achieved learning objectives as measured through significant differences in pretest and posttest scores and although the results showed statistical significance, it is important to conduct contextual analysis to understand the factors that may contribute towards the acquisition of students' mathematical communication skills. Variability in PBL implementation, student characteristics, or other factors may provide further insight.

There are differences in the influence of the implementation of PBL and Geogebra-assisted *Direct Instruction* on increasing students' acquisition of mathematical communication skills.

There are differences in the influence of the implementation of PBL and Geogebra-assisted Direct Instruction on increasing students' acquisition of mathematical communication skills. Formally, the statistical hypothesis (H_0) and research hypothesis) is as follows:

$$H_0 \colon \mu_1 = \mu_2$$
$$H_1 \colon \mu_1 \neq \mu_2$$

For testing this hypothesis is used$\alpha = 0{,}05\ (5\%)$. μ_1 And $\mu_2$respectively is the average gain of the student population who received PBL and Direct Instruction learning. Assuming the sample is normally distributed and homogeneous, the analysis continues with the Independent Sample T-Test with the following results (Table 9).

Table 9. independent t-test result of PBL vs. direct instruction

Learning model	**N**	**Mean**	**SD**	**F**	**t**	**p**
PBL	6	.7317	.03869	1.226	.909	.385
Direct Instruction	6	.7083	.04956			

From the output above, the value of sig is obtained. (2-tailed) is 0.386 and this value is more than $\alpha = 0{,}05$acceptable H_0. So it can be concluded that there is no difference in the influence of the implementation of PBL and *Direct Instruction* assisted by Geogebra on improving students' mathematical communication skills.

Based on the results above, it shows that there is no significant difference in the influence between the implementation of PBL and *Direct Instruction* assisted by Geogebra on improving students' mathematical communication skills . These results indicate that, in the context of this research, the PBL and *Direct Instruction learning methods* assisted by Geogebra do not have different significant effects on improving students' mathematical communication skills . Sig value. a high one indicates that the observed difference could have occurred by chance and is not large enough to be considered significant . This conclusion can be linked to previous studies which may show similar or opposite results such as the research results. Hosnan's research (2014) aims to explain learning through PBL but in his research there was no influence of the learning method applied.

The level of student learning independence influences the improvement of students' mathematical communication skills

Formally, the statistical hypothesis (H_0) and research hypothesis) is as follows:

$$H_0: \mu_1 = \mu_2 = \mu_3$$
$$H_1: \mathrm{H}_0\ false$$

For testing this hypothesis is used$\alpha = 0{,}05$ (5%). μ_1, μ_2, μ_3 respectively are the average gain of the population of students with high, medium and low learning independence. Assuming the sample is normally distributed and homogeneous, the analysis continues with the Anova test with the following results (Table 10).

Table 10. Anova test result

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	,004	2	,002	1,101	,374
Within Groups	.017	9	,002		
Total	.021	11			

From the output above, the value of sig is obtained. is 0.374 and this value is more than $\alpha = 0{,}05$the meaning of H_1being rejected. So it can be concluded that the level of student learning independence has no effect on increasing students' mathematical communication skills. So based on this conclusion it is no longer possible to continue with post hoc testing.

Based on the results of the analysis, it shows a significance value (sig.) of 0.374 in the statistical test, exceeding the significance level of α= 0.05 . This indicates the rejection of H_1 which states that there is an influence between the level of student learning independence and increasing students' mathematical communication skills. Thus, it can be concluded that there is no significant influence between the level of student learning independence and the increase in students' mathematical communication skills in the context of this research. This interpretation is in line with several previous studies that highlight the complexity of the relationship between learning independence and academic achievement (Zhang, 2019). Although independent learning is considered important in the development of mathematical communication skills, these results suggest that other factors or additional interventions may play a role in improving students' mathematical communication abilities .

The effect of interaction between PBL learning and *Direct Instruction* with the help of Geogebra and the level of learning independence to improve students' mathematical communication skills

There is an interaction effect between PBL learning and *Direct Instruction* assisted by Geogebra and the level of learning independence on improving students' mathematical communication skills. Formally, the statistical hypothesis (H_0) and research hypothesis) is as follows:

$$H_0: \mu_1 = \mu_2$$
$$H_0: \mu_{\mathrm{Tall}} = \mu_{\mathrm{Currently}} = \mu_{\mathrm{Low}}$$
$$H_1: \mathrm{H}_0\ False$$

For testing this hypothesis is used$\alpha = 0{,}05$ (5%). μ_1, μ_2 respectively , is the average gain of the student population who received PBL and *Direct Instruction learning* assisted by Geogebra. Assuming the sample is normally distributed and homogeneous, the analysis continues with the **Two Way Anova test** with the following results (Tabel 11).

Table 11. Between-Subjects Factors and Tests of Between-Subjects Effects

		Value Labels	N
Level Of Learning Independence	1	Tall	4
	2	Currently	4
	3	Low	4
learning model	1	Pbl	6
	2	In	6

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.017 [a]	5	,003	6,212	.023
Intercept	6,206	1	6,206	11115.955	,000
Level of Learning Independence	,004	2	,002	3,642	,092
learning model	,002	1	,002	3,358	.117
Learning Independence Level * learning_model	.011	2	,006	10,209	.012
Error	,003	6	,001		
Total	6,227	12			
Corrected Total	.021	11			

From the output above, it is obtained in the Learning_Model* Independence_Learning line that the value of sig. is 0.012 and this value is less than $\alpha = 0{,}05$it means H_1it is rejected. So it can be concluded that there is an interaction effect between PBL learning and *Direct Instruction* assisted by Geogebra and the level of learning independence on improving students' mathematical communication skills.

The results of the analysis show a significance value (sig.) of 0.012 in the interaction between PBL learning and *Direct Instruction* assisted by Geogebra and the level of student learning independence, lower than the significance level of α=0.05. Therefore, H_1 which states that there is an interaction effect between the learning model and the level of learning independence on increasing students' mathematical communication skills is accepted. These findings indicate that the combined effect of PBL and *Direct Instruction types of learning* assisted by Geogebra and the level of student learning independence has a significant impact on improving communication skills. student mathematics . These results are in line with previous research which emphasizes the importance of considering variable interactions in the context of mathematics learning (Santoso et al., 2021).

To see the comparison of the increase in students' mathematical communication skills per level of student learning independence, the test was continued with a post hoc test. Post hoc tests are used to evaluate differences between two or more groups after statistical analysis shows that there are overall differences. When analyzing **ANOVA** *(Analysis of Variance)* or other tests show that there are significant differences between the groups, post hoc tests can provide further information about which pairs of groups show significant differences . The post hoc test output is as follows (Table 12).

Table 12. Multiple Comparisons

(I) level of learning independence	(j) level of learning independence	Mean Difference (IJ)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Tall	Currently	.0250	.01671	,357	-.0263	.0763
	Low	.0450	.01671	,080	-.0063	.0963
Currently	Tall	-.0250	.01671	,357	-.0763	.0263

(I) level of learning independence	(j) level of learning independence	Mean Difference (IJ)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
	Low	.0200	.01671	,497	-.0313	.0713
Low	Tall	-.0450	.01671	,080	-.0963	.0063
	Currently	-.0200	.01671	,497	-.0713	.0313

Between High and Medium independence, the sig value was 0.357, which was more than $\alpha = 0{,}05$. The conclusion that there was no significant difference between students with High and Medium levels of learning independence in increasing students' acquisition of mathematical communication skills. Between High and Low independence, the sig value was 0.080, which was more than $\alpha = 0{,}05$the conclusion that there was no significant difference between students with High and Low levels of learning independence in increasing students' acquisition of mathematical communication skills. Between Medium and Low independence, the sig value was 0.497, which was more than $\alpha = 0{,}05$the conclusion that there was no significant difference between students with Medium and Low levels of learning independence in increasing students' acquisition of mathematical communication skills. The following is a plot of the interaction between PBL learning and *Direct Instruction* assisted by Geogebra and the level of learning independence towards increasing students' mathematical communication skills.

The results of the analysis through interaction plots between PBL and *Direct Instruction* assisted by Geogebra and the level of student learning independence show a significant pattern of increasing students' mathematical communication skills . The plot above shows that the positive impact of Geogebra-assisted PBL and *Direct Instruction learning* on students' mathematical communication skills is stronger when accessed by students with a high level of learning independence. In other words, the level of student learning independence strengthens the positive effects of learning, especially through the PBL and *Direct Instruction models* assisted by Geogebra. These findings contribute to further understanding of how individual factors, such as the level of learning independence, can moderate the effectiveness of certain learning strategies (Misirli, 2018). The implication is that teachers can better consider individual student differences in designing and implementing learning models to improve mathematics learning outcomes.

CONCLUSION

The conclusions of this research are (1) The mathematical communication ability of students who received the Geogebra-assisted PBL learning model was 79.17, the standard deviation was 2.858 and the posttest score distribution was negative $(-1{,}407)$; (2) The criteria for increasing the mathematical connection abilities of students who receive Geogebra-assisted PBL are in the high category; (3) The implementation of the Geogebra-assisted PBL model has a significant effect on students' acquisition of mathematical communication skills; (4) There is no difference in the effect of implementing PBL and Geogebra-assisted *Direct Instruction* on improving students' mathematical communication skills; (5) The level of student learning independence has no effect on increasing students' mathematical communication skills; and (6) There is an interaction effect between PBL learning and *Direct Instruction* Geogebra assistance and the level of learning independence can improve students' mathematical communication skills.

RECOMMENDATION

In terms of providing mathematics learning, it is recommended, especially for educators, to use the PBL learning model or Geogebra-assisted *Direct Instruction* on flat-sided geometric material with other topics, this is specifically for the implementation of learning activities.

Apart from that, it is also important to implement learning models that are appropriate to regional/regional characteristics. There is a need for new, creative and innovative ways of learning in order to improve students' mathematical communication skills . Considering that mathematical communication skills are very important for students, it is necessary to conduct further research regarding mathematical communication skills on learning materials that have been determined with a more creative and innovative learning approach, PBL learning models and Geogebra-assisted Direct Instruction. In the research that has been carried out, there are still many obstacles faced, one of which is limited time and there are still data errors, especially data on increases in this case N-gain. Therefore, for further research it is recommended to maximize time and examine the data more accurately in order to achieve good research results in line with expectations.

REFERENCES

Aini, N. N., Sukestiyarno, & Waluya, B. (2015). Analisis Komunikasi Matematis dan Tanggung Jawab Pada Pembelajaran Formulate Share Listen Create Materi Segiempat. Unnes Journal of Mathematics Education Research, 4(2):115-121.

Aqla, Syarifah. (2011). Peningkatan Kemandirian dan Hasil Belajar Siswa Menggunakan Model Problem Based Learning dalam Pembelajaran Matematika di Kelas VII SMP Negeri 2 Sungai Raya Kabupaten Kubu Raya. Skripsi. FKIP Untan. Pontianak

Aminah, Wijaya, & Yuspriyati (2018). Analisis Kemampuan Komunikasi Matematis Siswa Kelas VIII pada Materi Himpunan Journal Cendekia: Jurnal Pendidikan Matematika Volume 1, No. 1, pp. 15-22.

Choridah, D. T. (2013). Peran Pembelajaran Berbasis Masalah untuk Meningkatkan Kemampuan Komunikasi dan Berfikir Kreatif serta Disposisi Matematis Siswa SMA. Infinity Jurnal Ilmiah Program Studi Matematika STKIP Siliwangi Bandung, 2(2): 194-202.

Darkasyi, M., Johar, R., & Ahmad, A. (2014). Peningkatan Kemampuan Komunikasi Matematis dan Motivasi Siswa dengan Pembelajaran Pendekatan Quantum Learning pada Siswa SMP Negeri 5 Lhokseumawe. Jurnal Didaktik Matematika https://doi.org/10.24815/dm...v1i1.1336

Evariyani, Kartono, & Suminar, 2023. Kemampuan Komunikasi Matematis dalam Pembelajaran Problem Based Learning dengan Teacher Feedback Ditinjau dari Gaya Kognitif Siswa SMA. *Journal on Education, (5)2, 3120-3128*

Fauzi, A. (2019). "Peningkatan Kemampuan Komunikasi Matematis Siswa Melalui Model Pembelajaran Berbasis Masalah pada Materi Geometri." Jurnal Pendidikan Matematika dan Ilmu Pengetahuan Alam, 5(1), 45-58.

Hodiyanto, H. (2017). "Pengaruh Model Pembelajaran Problem Solving Terhadap Kemampuan Komunikasi Matematis Ditinjau dari Gender". Jurnal Riset Pendidikan Matematika, 4(2): 219- 228

Juanda, M., Johar, R., & Ikhsan, M. (2014). Peningkatan Kemampuan Pemecahan Masalah dan Komunikasi Matematis Siswa SMP melalui Model Pembelajaran Means-ends Analysis (MeA). Jurnal Kreano, 5(2): 105-113

Kanah, I., & Mardiani, D. (2022). Kemampuan Komunikasi dan Kemandirian Belajar Siswa Melalui Problem Based Learning dan Discovery Learning. *Plusminus: Jurnal Pendidikan Matematika, 2(2), 255-264*

Kristiyani, T. (2016). Self-Regulated Learning Konsep, Implikasi dan Tantangannya Bagi Siswa Di Indonesia. Sanata Dharma University Press

Lomibao, L. S., Luna, C. A., & Namoco, R. A. (2016). The Influence of Mathematical Communication on Students' Mathematics Performance and Anxiety. American Journal of Education Research, 4(5): 378-382

Maftukhin, M., Dwijanto, & Veronica, R. B. (2014). Keefektifan Model Pembelajan Creative Problem Solving Berbantuan CD Pembelajaran Terhadap Kemampuan Berpikir Kritis. Unnes Journal of Mathematics Education, 3(1): 29-34

Maulida, Ningsih, Bastian (2018). Pengaruh Model Discovery Learning Terhadap Kemampuan Komunikasi Matematis dan Keaktifan Belajar Siswa SMP, DELTA Jurnal Ilmiah Pendidikan Matematika Vol. 6 No.1.

Misirli, O. (2018). The Impact of a Problem-Based Learning Approach on Mathematics Achievement: Evidence from Turkey. International Journal of Instruction, 11(4), 807-824

Noer, Sri Hastuti. (2010). Peningkatan Kemampuan Berpikir Kritis, Kreatif, dan Reflektif (K2R) Matematis Siswa SMP Melalui Pembelajaran Berbasis Masalah. Disertasi. Universitas Pendidikan Indonesia, Bandung. Tidak Diterbitkan.

Prayitno, S., Suwarsono, & Siswono, T. Y. (2013). Identifikasi Indikator Kemampuan Komunikasi Matematis Siswa dalam Menyelesaikan Soal Matematika Berjenjang pada Tiap-Tiap Jenjangnya. Konferensi Nasional Pendidikan Matematika V. Malang: Universitas Negeri Malang.

Rahmawati, Cholily, & Zukhrufurrohmah (2023). Analyzing Students' Mathematical Communication Ability in Solving Numerical Literacy Problems. *Mosharafa: Jurnal Pendidikan Matematika, (12)1, 59-70*

Rochmad. (2018). "Penerapan Model Problem Based Learning untuk Meningkatkan Kemampuan Komunikasi Matematis Siswa." Jurnal Pendidikan Matematika, 12(3), 231-242.

Santoso, T. H., Prayitno, B. A., & Sumarmo, U. (2021). The Effectiveness of GeoGebra-Integrated Dynamic Geometry Software to Enhance Students' Spatial Ability. Journal of Physics: Conference Series, 1867(1), 012038. doi:10.1088/1742-6596/1867/1/012038

Septiani, M. D., Sukestiyarno, & Suyitno, A. (2013). Pembentukan Karakter dan Komunikasi Matematika Melalui Model Problem Posing Berbantuan Scaffolding Materi Segitiga. Jurnal Kreano, 4(1): 41- 49

Siregar, (2020). The Effects of a Discovery Learning Module on Geometry for Improving Students' Mathematical Reasoning Skills, Communication and Self-Confidence, International Journal of Learning, Teaching and Educational Research Vol. 19, No. 3, pp. 214-228

Sumarmo, Utari. (2012). Bahan Belajar Matakuliah Proses Berpikir Matematik. Bandung: STKIP Siliwangi.

Suratno, (2019). The effect of guided discovery learning on students' mathematical communication skill, AIP Conference Proceedings.

Suyadi. (2013). *Strategi Pembelajaran Pendidikan Karakter*. Bandung: Remaja Rosdakarya.

Umar, W. (2012). Membangun Kemampuan Komunikasi Matematis dalam Pembelajaran Matematika. Infinity Jurnal Ilmiah Program Studi Matematika STKIP Siliwangi Bandung.

Yanti, H., & Hartono, Y. (2019). "Penggunaan GeoGebra dalam Pembelajaran Geometri untuk Meningkatkan Kemampuan Komunikasi Matematis." Jurnal Pendidikan Matematika dan Sains, 4(2), 80-90.

Yulandari & Asmin. (2023). Analisis Kemampuan Komunikasi Matematissiswa melalui Model Pembelajaran Kooperatif Tipe TSTS. *Jurnal Riset Rumpun Matematika dan Ilmu Pengetahuan Alam (JURRIMIPA), (2)1, 153-166.*

Wijaya, A. P., & Yusup, M. (2023). Kemampuan Komunikasi Matematis Tertulis Peserta Didik dengan Model Problem Based Learning pada Materi SPLDV. *Plusminus: Jurnal Pendidikan Matematika, 3(1), 61-72*

Wina Sanjaya, (2006). Strategi Pembelajaran Berorientasi Standar Proses Pendidikan, Jakarta : Kencana, h.194.

Zhang, D. (2019). The Influence of Self-Regulation on Mathematical Performance: A Meta-Analysis. Frontiers in Psychology, 10, 2733. doi:10.3389/fpsyg.2019.02733.

Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. In Theory into Practice (Vol. 41, Issue 2, pp. 64–70). Ohio State University Press. https://doi.org/10.1207/s15430421tip4102_2.