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Problem Based Learning with GeoGebra: Impact on Mathematical Communication Skills and Mathematical Problem Solving

Eva Amallya[1)*], Bambang Sri Anggoro[2], Abi Fadila[3]
[1,2,3]Mathematic Education, UIN Raden Intan Lampung, Bandar Lampung, Indonesia
[*]*evaamaliaa75@gmail.com*

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Abstract
Students' mathematical communication and mathematical problem solving are still weak because the average test results are still below the KKM. Seeing this, the author conducted a study using the Problem Based Learning learning model. The goal is for students to be able to solve a mathematical problem properly and correctly. This study uses a quantitative approach with a quasi-experimental research type with a post-test only control group research design. The sample in this study were students in grades XI IPA I and XI IPA 2 with a simple random sampling technique. The data collection technique in this study was a test. The prerequisite techniques used were multivariate normality and homogeneity tests and hypothesis testing in this study used the Multivariate Analysis Of Variance (Manova) test. The results of the study showed that there was an influence of the GeoGebra-assisted Problem Based Learning approach on the mathematical communication and mathematical problem solving abilities of high school students and on the mathematical communication and mathematical problem solving abilities of students, there was a better influence of the GeoGebra-assisted Problem Based Learning learning model compared to conventional learning models.
Keywords: *Communication, Problem Based Learning, GeoGebra*

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INTRODUCTION

Education is the role of teachers and individual or group behavior in an effort to mature humans with learning and learning methods (Education, n.d.). Education can be stated directly to encourage changes in students' learning abilities. (Rahmat, 2013) The importance of education is by making changes in the quality of abilities such as cognitive, affective, and psychomotor; an increase that can improve the variety of his life as an individual, worker/professional, citizen and country and God's creature (Rahmat, 2013). The use of computer software in learning activities is very unlimited, there are several computer software that can provide experience and construct geometric shapes, train spatial point abilities, and

train problem-solving skills. (Dahlan et al., 2011). The learning model is a form of learning that is depicted from the beginning to the end of the learning process which is presented in a unique way by educators. (Hamzah B. Uno, 2007) Paradigms in mathematics education create mathematical communication and problem-solving skills.

Mathematical communication skills are students' abilities in conveying mathematical ideas both verbally and in writing (Siregar, 2018). The process of learning mathematics in schools is one way students can improve their mathematical communication skills (Rahadyan et al., 2018). The results of the pre-study showed that grade X students had weak mathematical communication skills because the test questions lacked explanation. The factors causing students to fail to complete the questions were lack of concentration and the fact that students usually only memorize mathematical formulas without understanding them. The role of teachers in the learning process can affect student success (Kusuma et al., 2018). The results of the 2007 TIMSS showed that Indonesian students still had weaknesses in mathematical communication. This can be seen from their answers to questions that asked them to read data in pie charts and present them in bar charts. While 27% of students worldwide were able to answer correctly, only 14% of students in Indonesia (Nuraeni & Luritawaty, 2018).

Problem solving is one part of the mathematics curriculum that is quite important in a mathematics learning process. Through problem solving activities, there are several aspects of mathematical solving abilities that need to be applied, such as applying rules to non-routine problems, finding patterns, generalizing, mathematical communication and others that can be developed properly. The problem-solving abilities of each student in Indonesia are different. This can be seen from the results of research conducted by Lusi Wira Aftriyati. Lusi's research shows that students' problem-solving abilities in mathematics learning are not as expected. Students' problem-solving abilities are dominated by the medium category, which is 75%, while the high problem-solving ability category is only 12.5%, as well as for the low category. (Mariam et al., 2019)

One of the solutions that researchers consider to be able to reduce a problem that occurs in order to achieve the success of mathematics learning activities is to carry out educational innovation, one of which is by using innovative learning models in order to change the habits of educators and efforts to overcome problems being faced by students. One of the efforts that must be made is to apply a problem-based learning model.

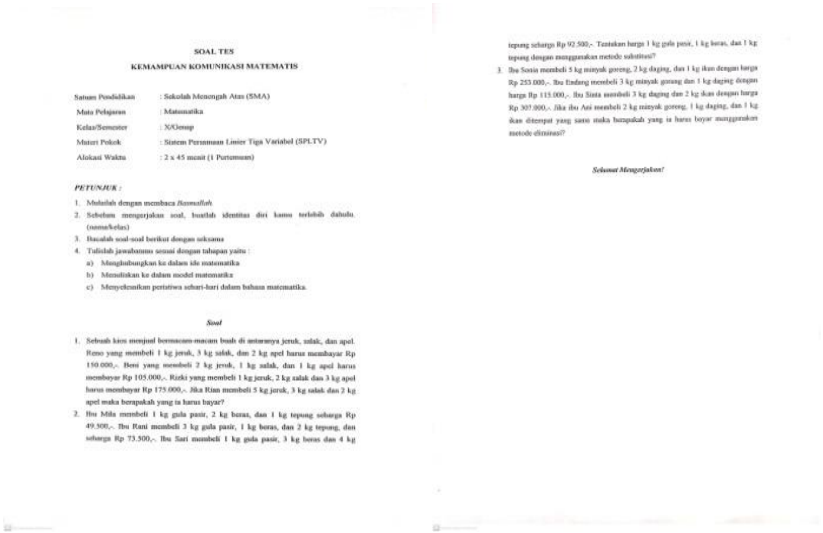
The two mathematical abilities described above have a great influence on solving mathematical problems. And have an influence on solving problems in everyday life related to Problem Based Learning or related to matters of numbers, various kinds of problems, which require skills and abilities to solve a problem. Mathematical communication skills can help produce mathematical models needed in solving problems both in various sciences and in everyday life. This means that if a student is unable to communicate ideas/ideas in the form of mathematical expressions to clarify a problem, it will make it difficult for the student to solve the problem. (Fransisca, 2021)

The use of a suitable learning model works as a single molecule of the success of the lecturer in civilization. The learning model can be interpreted as a recap used to carry out a list that ends up being arranged in a thick business architecture and helps to achieve civilization targets (Netriwati, 2019). The civilization model also creates a group of members who are thought to be communicated optimally to the quality of civilization (Taniredja et al., 2011). Problem Based Learning (PBL) creates a civilization method that is layered with complexity or problems. The problem creates a description of a story or a scandal that requires an understanding of the birth mechanism. Short groups of 8-10 foster parents will be assigned to question the birth mechanism of the complexity (P. Purwanto, 2020). Problem Based Learning (PBL) or learning based on things emphasizes exemplifying as a tool that involves resolving a problem in a real environment (Lestari et al., 2017). The sequence or steps in implementing the Problem Based Learning (PBL) method are as follows: 1) Students are given a problem by the educator (or the problem is revealed from the student's experience). 2) Students conduct a discussion in small groups. 3) Students conduct an independent study related to a problem that must be solved. They can do this by searching for sources in the library, database, internet, personal sources and conducting observations. 4) Students return to the original Problem Based Learning (PBL) group to exchange information, peer learning, and work together to solve the problem. 5) Students present the solutions they find. 6) Students are assisted by educators so that they can conduct evaluations related to all learning activities.

Some relevant research findings are related to GeoGebra-assisted Problem Based Learning. Research conducted by Rani Sugiarni, Egi Alghifari, and Ayuni R. Ifanda entitled "Improving Students' Mathematical Spatial Ability with GeoGebra-assisted Problem Based Learning Model". The results of the study showed that by implementing the GeoGebra-assisted Problem Based Learning model, the spatial abilities of the students could be

improved. This is indicated by the results of the spatial ability test for each cycle. In the action of cycle I, the classical absorption of students reached 53%, the action of cycle II increased the classical absorption of students by 76% and the action of cycle III almost 82% classical absorption increased from the results of the study concluded that the Problem Based Learning learning model assisted by GeoGebra can improve the spatial abilities of students. (Sugiarni et al., 2018) The next study was a study conducted by Lisna Siti Permana Sari and Moersetyo Rahadi entitled "Problem-Based Learning to Improve the Mathematical Communication Skills of Junior High School Students". The results of the study stated that: The improvement in the mathematical communication skills of students who received problem-based learning was better than students who received conventional learning. (Sari, L. S. P., & Rahadi, 2014)

Based on the results of interviews with grade X mathematics educators, there are several problems in the learning process, including the lack of mathematical communication skills and mathematical problem-solving skills of students. The following are questions and student answers that researchers use to measure the mathematical communication and mathematical problem-solving skills of students at SMA Negeri 2 Liwa, as follows.



SOAL TES

KEMAMPUAN KOMUNIKASI MATEMATIS

Satuan Pendidikan	: Sekolah Menengah Atas (SMA)
Mata Pelajaran	: Matematika
Kelas/Semester	: X/Genap
Materi Pokok	: Sistem Persamaan Linier Tiga Variabel (SPLTV)
Alokasi Waktu	: 2 x 45 menit (1 Pertemuan)

PETUNJUK :

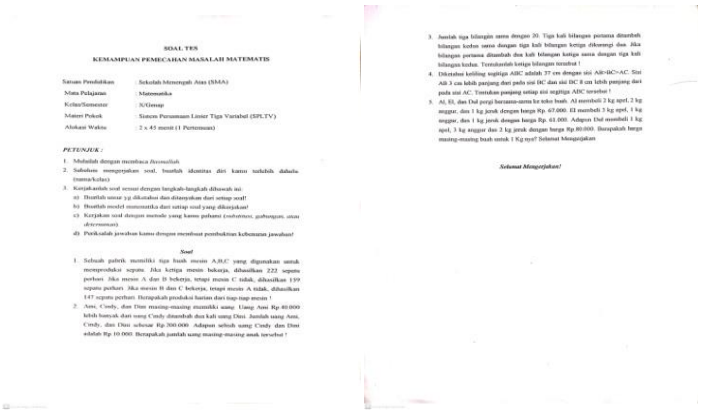
1. Mulailah dengan membaca *Basmallah*
2. Sebelum mengerjakan soal, buatlah identitas diri kamu terlebih dahulu (nama/kelas)
3. Bacalah soal-soal berikut dengan seksama
4. Tuliskah jawabanmu sesuai dengan tahapan yaitu :
   a) Menghubungkan ke dalam ide matematika
   b) Menuliskan ke dalam model matematika
   c) Menyelesaikan peristiwa sehari-hari dalam bahasa matematika.

Soal

1. Sebuah kios menjual bermacam-macam buah di antaranya jeruk, salak, dan apel. Remo yang membeli 1 kg jeruk, 3 kg salak, dan 2 kg apel harus membayar Rp 150.000,-. Beni yang membeli 2 kg jeruk, 1 kg salak, dan 1 kg apel harus membayar Rp 105.000,-. Rizki yang membeli 1 kg jeruk, 2 kg salak dan 3 kg apel harus membayar Rp 175.000,-. Jika Rian membeli 5 kg jeruk, 3 kg salak dan 2 kg apel maka berapakah yang ia harus bayar?
2. Ibu Mila membeli 1 kg gula pasir, 2 kg beras, dan 1 kg tepung seharga Rp 49.500,-. Ibu Rani membeli 3 kg gula pasir, 1 kg beras, dan 2 kg tepung, dan seharga Rp 73.500,-. Ibu Sari membeli 1 kg gula pasir, 3 kg beras dan 4 kg tepung seharga Rp 92.500,-. Tentukan harga 1 kg gula pasir, 1 kg beras, dan 1 kg tepung dengan menggunakan metode substitusi?
3. Ibu Sosin membeli 5 kg minyak goreng, 2 kg daging, dan 1 kg ikan dengan harga Rp 253.000,-. Ibu Enderg membeli 3 kg minyak goreng dan 1 kg daging dengan harga Rp 115.000,-. Ibu Sinta membeli 3 kg daging dan 2 kg ikan dengan harga Rp 307.000,-. Jika ibu Ani membeli 2 kg minyak goreng, 1 kg daging, dan 1 kg ikan ditempat yang sama maka berapakah yang ia harus bayar menggunakan metode eliminasi?

Selamat Mengerjakan!

Figure 1. Mathematical Communication Ability Test Questions



SOAL TES
KEMAMPUAN PEMECAHAN MASALAH MATEMATIS

Satuan Pendidikan	: Sekolah Menengah Atas (SMA)
Mata Pelajaran	: Matematika
Kelas/Semester	: X/Ganjil
Materi Pokok	: Sistem Persamaan Linier Tiga Variabel (SPLTV)
Alokasi Waktu	: 2 x 45 menit (1 Pertemuan)

PETUNJUK :
1. Mulailah dengan membaca *basmallah*
2. Sebelum mengerjakan soal, buatlah identitas diri kamu terlebih dahulu (nama/kelas)
3. Kerjakanlah soal sesuai dengan langkah-langkah dibawah ini:
   a) Buatlah unsur yg diketahui dan ditanyakan dari setiap soal!
   b) Buatlah model matematika dari setiap soal yang dikerjakan!
   c) Kerjakan soal dengan metode yang kamu pelajari (substitusi, gabungan, atau determinan).
   d) Periksalah jawaban kamu dengan membuat pembuktian kebenaran jawaban!

Soal

1. Sebuah pabrik memiliki tiga buah mesin A,B,C yang digunakan untuk memproduksi sepatu. Jika ketiga mesin bekerja, dihasilkan 222 sepatu perhari. Jika mesin A dan B bekerja, tetapi mesin C tidak, dihasilkan 159 sepatu perhari. Jika mesin B dan C bekerja, tetapi mesin A tidak, dihasilkan 147 sepatu perhari. Berapakah produksi harian dari tiap-tiap mesin !
2. Ansi, Cindy, dan Dini masing-masing memiliki uang. Uang Ansi Rp 40.000 lebih banyak dari uang Cindy ditambah dua kali uang Dini. Jumlah uang Ansi, Cindy, dan Dini sebesar Rp 200.000. Adapun selisih uang Cindy dan Dini adalah Rp 10.000. Berapakah jumlah uang masing-masing anak tersebut !
3. Jumlah tiga bilangan asli adalah 20. Tiga kali bilangan pertama ditambah bilangan kedua sama dengan tiga kali bilangan ketiga dikurangi dua. Jika bilangan pertama ditambah dua kali bilangan ketiga sama dengan tiga kali bilangan kedua. Tentukanlah ketiga bilangan tersebut !
4. Diketahui keliling segitiga ABC adalah 37 cm dengan sisi AB=BC=AC. Sisi AB 3 cm lebih panjang dari pada sisi BC dan sisi BC 8 cm lebih panjang dari pada sisi AC. Tentukan panjang setiap sisi segitiga ABC tersebut !
5. Ai, Ei, dan Dal pergi bersama-sama ke toko buah. Ai membeli 2 kg aprl, 2 kg anggur, dan 1 kg jeruk dengan harga Rp. 67.000. Ei membeli 3 kg aprl, 1 kg anggur, dan 1 kg jeruk dengan harga Rp. 61.000. Adapun Dal membeli 1 kg aprl, 3 kg anggur dan 2 kg jeruk dengan harga Rp.80.000. Berapakah harga masing-masing buah untuk 1 Kg nya? Selamat Mengerjakan

Selamat Mengerjakan!

Figure 2. Mathematical Problem Solving Ability Test Questions

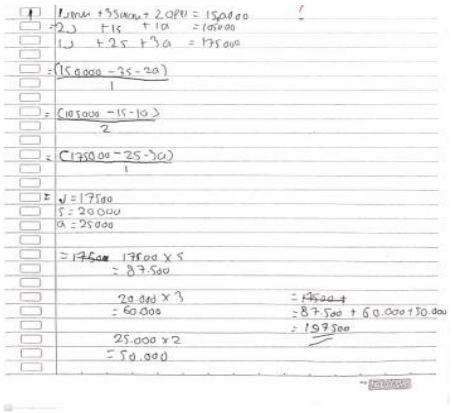


Figure 3. Student's Answer Sheet for Mathematical Communication Question No. 1

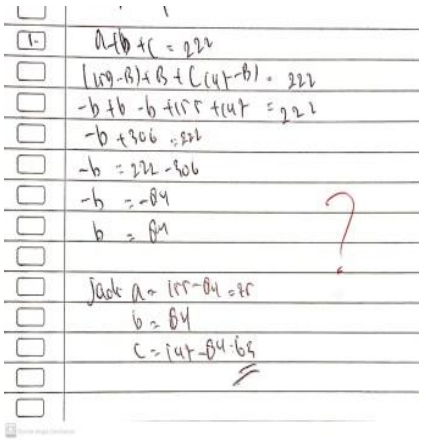


Figure 4. Student's Answer Sheet for Mathematical Problem Solving Questions No. 1

Based on Figures 3 and 4, it shows that students still have difficulty in interpreting problems into mathematical forms and are not yet familiar with the steps of mathematical communication and problem solving. This can be seen from the stages of mathematical communication and mathematical problem solving of students, namely students are not yet accurate in identifying, planning and implementing the solution plan correctly, and are not yet accustomed to re-checking the results of the problems contained in the questions. Therefore, the researcher concludes that the mathematical communication and mathematical problem solving skills of students at SMA Negeri 2 Liwa are still relatively low. This situation must be overcome by accustoming and training students in answering mathematical communication and problem solving questions in class or so that students become independent in solving problems from the questions given.

Based on the various problems that have been explained above and seen from previous research, the author conducted a study entitled "The Effect of GeoGebra-Based Problem Based Learning Approach on High School Students' Mathematical Communication and Mathematical Problem Solving Skills"

METHOD

This quantitative study aims to see the effect of the Problem Based Learning learning model on the mathematical communication skills and mathematical problem solving of high school students. This study is a Quasi Experimental Design study, using post-test-only control because it is to show the level of mastery of the material after receiving learning. The research design with post-test-only control design (Yudhanegara, 2015).

The population in this study was class XI of SMA Negeri 2 Liwa and the sample was taken using simple random sampling technique (Purwanti et al., 2016). The study took place at SMA Negeri 2 Liwa with class XI IPA I as the experimental class and class XI IPA 2 as the control class. The data collection technique used was a test (Netriwati, 2022). The research instrument consisted of a mathematical communication ability test and a mathematical problem-solving ability test from matrix material. The trial of mathematical communication ability and mathematical problem solving was conducted in class XII IPA 3 with 28 students. Furthermore, the data analysis test used in this study was MANOVA, where before testing MANOVA, the prerequisites were first tested using the multivariate normality test and Box' S homogeneity.

RESULTS AND DISCUSSION

The description in this study contains two abilities in the control and experimental classes. The following are the results of the data description of mathematical communication and mathematical problem solving abilities in the control and experimental classes:

Table 1. Description of Student Mathematical Communication Observation Data

Group	(X_{maks})	(X_{min})	Tendancy Measurement Central			Dispersio Measurement	
			$\overline{X}$	M_e	M_o	R	S
Experimental	95	65	79,46	80,00	75	30	7,496
Control	75	55	66,04	67,50	70	20	7,220

Based on the results of the observation data above, the mathematical communication skills of students in the experimental class are better compared to the control class as seen from the highest score, the lowest score, and the measure of central tendency.

Table 2. Description of Student Mathematical Problem Solving Observation Data

Group	(X_{maks})	(X_{min})	Tendancy Measurement Central			Dispersio Measurement	
			$\overline{X}$	M_e	M_o	R	S
Experimental	96	66	79,50	78,00	76	30	8,048
Control	78	52	68,42	68,00	66	26	7,223

The conclusion from the observation data above is that the mathematical problem-solving ability of students in the experimental class is better than that of the control class as seen from the highest score, the lowest score, and the measure of central tendency.

Next, the prerequisite analysis test was carried out using multivariate normality and homogeneity tests. The normality test in this study used multivariate testing with a significance level of 5% or 0.05. This test was carried out on the experimental class and control class based on the results of the post-test. The results of the normality test carried out are shown in the Figure 5.

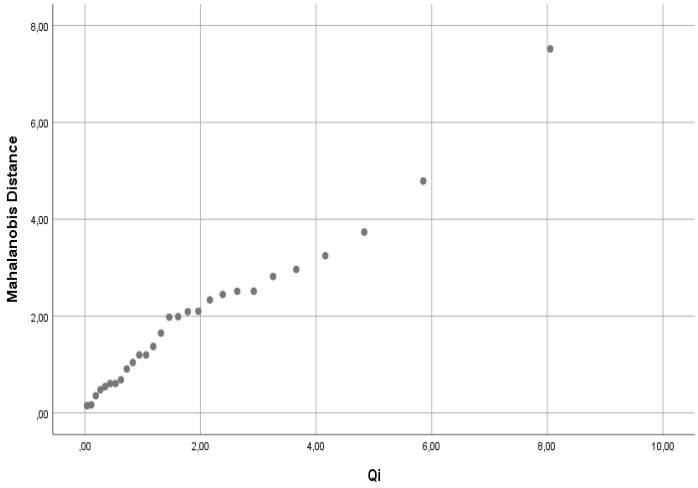


Figure 5. *Scatter Plot* Experimental Class

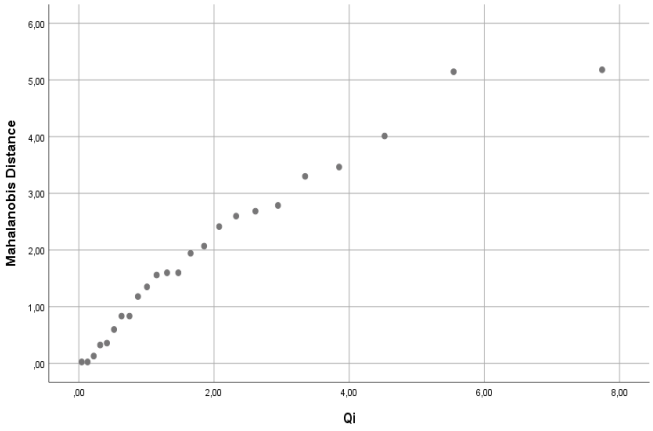


Figure 6. *Scatter Plot* Control Class

The graph shows a tendency for the data distribution to form a straight line. This shows that the distribution of the dependent variable data is multivariate normal. This can also be seen in the following correlation values:

Table 3. Multivariate Normality Test Results

Class	Correlation Coefficient	Test Results
Experimental	0,985	H_0 accepted
Control	0,968	H_0 accepted

Based on the values in Table 3, the correlation value between the experimental class and the control class shows a fairly high correlation, namely the experimental class 0.985, and the control class 0.968. This strengthens the statement that the distribution of data for both dependent variables is multivariate normal.

After calculating the normality test, then calculate the homogeneity test of the control class and the experimental class using the Box's M statistical test. The homogeneity test is used to determine whether the data has the same variance or not using the Box's-M test with a significance level of $\alpha = 0.05$.

Table 4. Levene's Test of Equality of Error Variances

		Levene Statistic	df1	df2	Sig.
Mathematical Communication (Y1)	Based on Mean	,004	1	50	,950
	Based on Median	,015	1	50	,902
	Based on Median and with adjusted df	,015	1	49,367	,902
	Based on trimmed mean	,003	1	50	,956
Mathematical Problem Solving (Y2)	Based on Mean	,453	1	50	,504
	Based on Median	,341	1	50	,562
	Based on Median and with adjusted df	,341	1	49,313	,562
	Based on trimmed mean	,409	1	50	,525

The significance value obtained on the mathematical communication question is 0.950 and the significance value of mathematical problem solving is 0.504. The value is above the predetermined significance level of 0.05. It can be concluded that mathematical communication and mathematical problem solving in the experimental class and control class have homogeneous (same) variance. In the homogeneity test, Box's M sig. is 0.938. Where this value is greater than the predetermined significance level of 0.05. It can be concluded that the Box's M homogeneity test results show that the data is homogeneous.

Based on the data obtained, the results of the prerequisite test, namely the normality test, show that the data in each class comes from a normally distributed population and has homogeneous variance. Furthermore, a hypothesis test is carried out using the MANOVA (Multivariate Analysis of Variance) analysis test at a significance level of 0.05.

Table 5. MANOVA Test Results on Mathematical Communication and Mathematical Problem Solving Simultaneously

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	,991	2761,045[b]	2,000	49,000	,000
	Wilks' Lambda	,009	2761,045[b]	2,000	49,000	,000
	Hotelling's Trace	112,696	2761,045[b]	2,000	49,000	,000

	Roy's Largest Root	112,696	2761,045[b]	2,000	49,000	,000
Model	Pillai's Trace	,463	21,104[b]	2,000	49,000	,000
	Wilks' Lambda	,537	21,104[b]	2,000	49,000	,000
	Hotelling's Trace	,861	21,104[b]	2,000	49,000	,000
	Roy's Largest Root	,861	21,104[b]	2,000	49,000	,000

The results of the normality and homogeneity tests indicate that the sample in this study is normal and homogeneous, thus fulfilling the previous test. Furthermore, a MANOVA (Multivariate Analysis of Variance) test can be conducted for hypothesis 1. The results of the MANOVA test calculation for the hypothesis show that the value of Pillai's Trace, Wilk's Lambda, Hotelling's Trace, Roy's Largest Root = 0.000 and the test criterion value = 0.05, which means sig. Smaller than that, so it is rejected, so it can be concluded that there is an influence between Problem Based Learning on students' mathematical communication skills and mathematical problem solving.

Table 6. MANOVA Test Results on Mathematical Communication and Mathematical Problem Solving Individually

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Mathematical Communication	2328,308[a]	1	2328,308	42,864	,000
	Pemecahan Masalah Matematis	1587,474[b]	1	1587,474	26,917	,000
Intercept	Mathematical Communication	273607,154	1	273607,154	5037,094	,000
	Pemecahan Masalah Matematis	282748,397	1	282748,397	4794,242	,000
Model	Mathematical Communication	2328,308	1	2328,308	42,864	,000
	Pemecahan Masalah Matematis	1587,474	1	1587,474	26,917	,000
Error	Mathematical Communication	2715,923	50	54,318		
	Pemecahan Masalah Matematis	2948,833	50	58,977		
Total	Mathematical Communication	284200,000	52			
	Pemecahan Masalah Matematis	292256,000	52			
Corrected Total	Mathematical Communication	5044,231	51			
	Pemecahan Masalah Matematis	4536,308	51			

The MANOVA test results based on the table above can be concluded:

a. The sig value of mathematical communication = 0.000 and the value of α testing criteria = 0.05 means the sig value is less than α then H0 is rejected, so it can be

concluded that there is an influence between the Problem Based Learning learning model assisted by GeoGebra on mathematical communication.

b. The sig value of mathematical problem solving = 0.000 and the value of α testing criteria = 0.05 means the sig value is less than α then H0 is rejected, so it can be concluded that there is an influence between the Problem Based Learning learning model assisted by GeoGebra on mathematical problem solving.

Based on this, it can be concluded that mathematical problem solving ability is more dominant than mathematical communication ability with an average deviation of 282748.397. Learning using Problem Based Learning can also improve students' mathematical communication and mathematical problem solving abilities compared to learning in the control class. Learning activities with Problem Based Learning begin by encouraging students to be able to solve a problem. Then students are given a problem by the educator then students identify the cases presented and design new solutions or maybe reuse existing solutions to solve the problem. After completion, review the designed solution. Selected groups present their work in front of the class. After presenting the author clarifies the questions and answers given by students. Then with this research, it can simultaneously measure mathematical communication and mathematical solving abilities using the Problem Based Learning learning method assisted by GeoGebra while previous relevant research only measures one ability.

CONCLUSION

There is a difference between Problem Based Learning and conventional learning on students' mathematical communication and problem solving skills. Students who use Problem Based Learning have better mathematical communication and problem solving skills compared to those using conventional learning models, this can be seen in the post-test results and observations that have been made by researchers. Based on the analysis and conclusions, the researcher suggests the following: Educators in an effort to improve students' mathematical communication and problem-solving skills are expected to apply the Problem Based Learning learning model to other materials so that students' mathematical communication and problem-solving skills increase. Students are able to study diligently and persistently in order to understand the material well so that they can solve the problems given by the educator. In group discussions, students are expected to be more confident and play an active role in expressing opinions or asking questions related to material that is not yet

understood. For subsequent researchers who want to use the Problem Based Learning learning model, it is expected to see other mathematical abilities possessed by student participants.

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