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Fostering Effective Mathematical Communication: Exploring the Impact of GeoGebra-Assisted Role-Playing Model in Solving PISA-Equivalent Problems

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Abstrak. Kemampuan komunikasi matematis siswa memiliki peran penting dalam pemahaman dan penyampaian konsep matematika. Penelitian ini bertujuan untuk membandingkan penerapan tiga model pembelajaran, yaitu Model *Role Playing* berbantu GeoGebra, Model *Role Playing*, dan Model Pembelajaran Langsung, terhadap kemampuan komunikasi matematis siswa dalam menyelesaikan soal setara PISA. Metode penelitian yang digunakan adalah kuantitatif dengan desain *Quasi Experimental* menggunakan *Nonequivalent Control Group Design*. Populasi penelitian ini adalah siswa kelas VIII MTs Nurul Huda. pengambilan sampel dilakukan dengan menggunakan metode *purposive sampling*. Sampel terdiri dari tiga kelas, yaitu VIII B (kelas eksperimen 1) dengan 24 siswa, VIII C (kelas eksperimen 2) dengan 23 siswa, dan VIII A (kelas kontrol) dengan 20 siswa. Instrumen penelitian terdiri dari instrumen tes *pretest* dan *posttest* untuk mengukur kemampuan komunikasi matematis siswa dalam menyelesaikan soal setara PISA. Selain itu, juga digunakan lembar observasi guru dan siswa sebagai instrumen non-tes. Analisis data kuantitatif dilakukan menggunakan statistik para metris pada uji keseimbangan yaitu uji ANAVA satu jalur dengan prasyarat uji normalitas dan uji homogenitas. Hasil analisis menunjukkan bahwa model *Role playing* berbantuan GeoGebra lebih baik terhadap peningkatan kemampuan komunikasi matematis siswa dalam menyelesaikan soal setara PISA daripada dua model pembelajaran lainnya.

Kata Kunci: Bermain Peran; GeoGebra; Komunikasi Matematis Siswa.

Abstract. The mathematical communication abilities of students play a significant role in understanding and conveying mathematical concepts. This study aims to compare the implementation of three instructional models, namely the Role-Playing Model with GeoGebra assistance, the Role-Playing Model, and the Direct Instruction Model, on students' mathematical communication abilities in solving PISA-equivalent problems. The research method employed is quantitative with a Quasi-Experimental design using the Nonequivalent Control Group Design. The population of this study consists of eighth-grade students at MTs

Nurul Huda. Sample selection was conducted using purposive sampling. The sample consists of three classes: VIII B (experimental class 1) with 24 students, VIII C (experimental class 2) with 23 students, and VIII A (control class) with 20 students. The research instruments comprise pretest and posttest tests to measure students' mathematical communication abilities in solving PISA-equivalent problems. Additionally, observation sheets for teachers and students were used as non-test instruments. Quantitative data analysis was performed using parametric statistics for the balance test, namely a one-way ANOVA with the prerequisite of normality and homogeneity tests. The results of the analysis indicate that the Role-Playing Model with GeoGebra assistance is superior in improving students' mathematical communication abilities in solving PISA-equivalent problems compared to the other two instructional models.

Keywords: GeoGebra, Role Playing, Students' Mathematical Communication.

Pendahuluan

Efforts to enhance the quality of human resources in the 21st century encompass the development of mathematical communication skills in the context of education. Mathematical communication is the process of expressing mathematical understanding and ideas using numbers, diagrams, and words (Yuniarti, 2016). Proficiency in mathematical communication is crucial in mathematics education as it enables students to articulate their mathematical thinking both orally and in writing, comprehend concepts, and foster the development of ideas they are learning. The importance of developing mathematical communication skills is evident from several studies aimed at enhancing such skills, including research conducted by (Rahmalia et al., 2020); (Nurahman, 2020); (Lestari et al., 2019); (Saputri, 2018); (Sugandi & Bernard, 2018); (Deswita et al., 2018); (Asnawati, 2017); (Hodiyanto, 2017); (Putra, 2016).

In reality, the mathematical communication skills of students in Indonesia are still low, particularly in writing mathematical explanations for specific problems, indicating a low level of mathematical communication proficiency in this country (Hasina et al., 2020). This aligns with the findings of the PISA research conducted in 2015, which ranked Indonesia 64th out of 65 countries. The PISA survey in 2015 revealed that the average mathematical proficiency of students in Indonesia was 386 out of a standard score of 490 (OECD, 2018). In 2018, Indonesia dropped to 74th out of 79 countries with a score of 379 in mathematical proficiency (OECD, 2019), indicating a decline in mathematical abilities compared to 2015.

This indicates the need for comprehensive improvement and development of education in Indonesia, particularly in the field of mathematics. This specific research has not been conducted before and is highly relevant to the current situation, with the hope of providing a solution to enhance students' mathematical communication skills in Indonesia, particularly in the context of integrating real objects, explaining mathematical solutions, and connecting mathematical concepts to everyday life within the topic of Systems of Linear Equations with Two Variables (SPLDV) equivalent to

PISA. Previous research only compared the Role-Playing instructional model with the conventional instructional model in improving students' mathematical communication abilities (Hasni, 2021). There is a need to develop a more diverse implementation of the Role-Playing instructional model with the use of GeoGebra as a tool to validate and strengthen the findings of the previous research. Therefore, it is important to examine the differences among the three instructional models under investigation to determine the best and optimal instructional model for enhancing students' mathematical communication abilities.

Therefore, there is a need for innovation in teaching and learning activities to develop students' mathematical communication skills. One of the instructional models that can be used is the Role-Playing model. According to (Sutikno, 2019), the Role-Playing model consists of a series of activities that emphasize cooperation, communication, and interpretation of events. Thus, this instructional model is deemed worthy to be developed as an alternative to address the issues of low quality in the teaching and learning process. According to Hasni, (2021) study, the Role-Playing instructional model outperforms the conventional instructional model.

To develop the teaching and learning process, the utilization of instructional media is necessary (Mulyasa, 2014). According to (Kania, 2018), one way to enhance students' mathematical communication skills is through the use of computer media, as it can serve as a teaching aid in instructional material development and foster an effective and efficient learning environment. Among the computer programs suitable for teachers to use as instructional media is GeoGebra (Asngari, 2015); (Nur, 2017). GeoGebra is relevant to one of the indicators in students' mathematical communication as it serves as a tool for students to interpret problems, comprehend mathematical graph concepts, and effectively solve graph-related problems (Kania, 2018). According to Septian et al., (2023), students prefer using aids such as GeoGebra in mathematics learning. Jurotun's (2015) study suggests that the use of GeoGebra software is expected to be an active, creative, and enjoyable alternative in mathematics education to enhance students' mathematical abilities.

Based on the description above, it can be concluded that the mathematical communication skills of students are crucial because a low level of mathematical communication skills can impact the quality of the teaching and learning process. Therefore, it is possible to utilize GeoGebra in middle school education with the Role-Playing instructional model assisted by GeoGebra to enhance students' mathematical communication skills in solving PISA-equivalent problems. This study aims to determine the superior instructional model among GeoGebra-assisted Role Playing, Role Playing, and direct instructional models in enhancing mathematical communication skills in solving PISA-equivalent problems.

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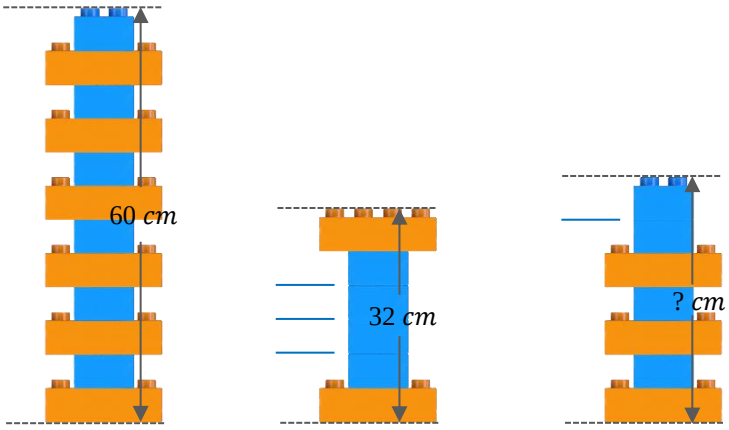
Method

This is a quantitative research study conducted using a Quasi-Experimental method with a Nonequivalent Control Group Design, involving three non-randomly selected classes. The population of this study consisted of 135 eighth-grade students from MTs Nurul Huda. The sample was chosen through purposive sampling, which is a technique of selecting samples based on specific considerations (Sugiyono, 2017). The sample size used in this study was 67 students, with 24 students in class VIII B as Experimental Group I, receiving instruction using the Role-playing model with GeoGebra assistance, 23 students in class VIII C as Experimental Group II, receiving instruction using the Role-playing model, and 20 students in class VIII A as the Control Group, receiving instruction using the Direct Instruction model.

In this study, two types of instruments were utilized: test instruments and non-test instruments. The test instruments were employed to measure students' mathematical communication abilities. The tests consisted of a pretest and posttest, comprising three open-ended items related to Systems of Linear Equations with Two Variables (SPLDV), equivalent to PISA-level questions. Before the administration of the tests, the test instruments underwent several validities, reliability, discriminant power, and difficulty level assessments to ensure the production of high-quality data. Additionally, non-test instruments in the form of teacher and student observation sheets were used to evaluate the activities of both teachers and students regarding the implemented treatments. The instrument pilot test was conducted in a class of 30 students from ninth grade at MTs Nurul-Huda. The pilot test was carried out outside of the experimental and control classes and consisted of three open-ended items. The examples used in this research can be seen in Figure 1.

In a playground, Caca, Maya, and Sopi are participating in a competition to build towers using Lego blocks.



The towers they build consist of squares and rectangles with the following specifications: Tower Caca consists of 6 rectangles and 6 squares. Tower Maya consists of 2 rectangles and 4 squares. Tower Sopi consists of 4 squares and 3 rectangles. The height of Tower Caca is 60 cm, while the height of Tower Maya is 32 cm. The question is, what is the height of the tower built by Sopi? Solve it using the graphical method and determine the set of solutions.

Image 1. Example of Mathematical Communication Skills Equivalent to PISA

The above problem includes indicators for explaining models and systems of linear equations with two variables. The problem encompasses indicators of mathematical communication, which include: Firstly, connecting real objects, diagrams, pictures, graphs, or equations to mathematical ideas. Secondly, explaining mathematical ideas, situations, or relationships orally or in writing. Thirdly, use appropriate mathematical terms, notations, or symbols based on their structure to present ideas. Fourthly, concluding orally or in writing. Additionally, the problem satisfies the content component of mathematical literacy within the PISA framework, specifically the "Change and Relationship" aspect, involving the employed process component and personal context component.

After obtaining the Pretest and Posttest results, data processing and analysis were conducted to compare the initial abilities and improvement of mathematical communication among the three samples, as well as to examine the teacher and student activities in the classroom using the Role Playing with GeoGebra-assisted learning approach in the experimental group. The data processing results will indicate whether "the mathematical communication abilities of students in solving PISA-equivalent problems using Role Playing with GeoGebra assistance are superior to the mathematical communication abilities of students using Role Playing and direct instruction." Before conducting the one-way ANOVA test to compare the mean differences, normality, and homogeneity of variance tests were performed as preliminary steps.

Results and Discussion

After testing the test instrument for students' mathematical communication skills, it was found that each item had good validity and could be used, and the test reliability was at a moderate level. According to Arikunto, (2010), a moderate level of reliability is considered reliable enough to be used as a data collection tool because the instrument is already good, resulting in trustworthy and reliable data. The discriminant power test showed a sufficient level of interpretation. According to Magdalena et al., (2021), there is no need for a high level of discriminant power. If an item has an adequate interpretation, it can still be used because it has sufficient discriminant power to differentiate between high and low-ability students. The difficulty level test showed a moderate level of difficulty. According to Arikunto, (2013), a test instrument is considered good if the items have a moderate level of difficulty. The findings of the study by Julita et al., (2022) also support this, that the selection of moderately difficult items is done to accommodate students with different levels of ability. Therefore, this instrument can be used as a pretest and posttest. Next, the data is processed and presented as follows:

1. Students' initial mathematical communication skills

Data from the pretest is used to determine students' initial proficiency in solving mathematical communication problems equivalent to PISA. Before experimenting, it is necessary to ensure that the three classes are balanced, meaning that they have the same initial proficiency level. To assess the balance of the three samples, prerequisite tests such as normality tests and homogeneity tests need to be conducted. The

normality test is used to determine whether the samples come from a normally distributed population or not. The results are presented in Table 1.

Table 1. Normality Test Results for Posttest Data

Sample	N	L_{max}	L_{table}	Decision	Description
Experiment Class I	24	0,1487	0,1766		
Experiment Class II	23	0,1216	0,1798	H_0 accepted	Normal
Control Class	20	0,1137	0,1965		

The normality test results conducted on the three classes after the treatment indicate that all three claes are divided populations that follow a normal distribution. Is confirmed by the $L_{max} < L_{table}$ indicating the acceptance of H_0. Due to the normal distribution of all three classes, a test of variance homogeneity was conducted, as presented in Table 2.

Table 2. Homogeneity Test Results for Posttest Data

Sample	Variance	$b_{calculated}$	b_{table}	Decision	Description
Experiment Class I	209,28				
Experiment Class II	255,08	1,0311	0,9088	H_0 accepted	Homogenous
Control Class	58,30				

The results of the homogeneity test for the three classes after the treatment indicate that elapses come from populations with homogeneous variances. This is confirmed by the $b_{calculated} > b_{table}$ indicating the acceptance of H_0. Since all three samples were drawn from populations that exhibited normal distribution and homogeneity of variances, a one-way ANOVA test with unequal cell sizes was conducted to assess the balance, as shown in Table 3.

Table 3. One-Way ANOVA Test Results for Non-Equal Cell Sample Pretest Data

Sample	$\bar{x}$	$F_{calculated}$	F_{table}	Decision
Experiment Class I	20,56			
Experiment Class II	20,85	2,28	3,13	H_0 accepted
Control Class	13,06			
Maximum Score	100			

The results indicate that the value of $F_{calculated} < F_{table}$, thus H_0 is accepted. As H_0 0 is accepted, it can be concluded that the three sample groups have similar means. This means that the mathematical communication abilities of the students in solving PISA-equivalent problems were balanced or equal before the intervention was applied.

2. Improvement of students' mathematical communication skills

The normality test was conducted to determine whether the sample used is derived from a normally distributed population or not. The normality test used was the Lilliefors test since the data used is not grouped data. The results of the normality test for the post-test data with a significance level of α = 5% are as follows in Table 4.

Table 4. Normality Test Results for Posttest Data

Sample	N	L_{max}	L_{table}	Decision	Description
Experiment Class I	24	0,0923	0,1766		
Experiment Class II	23	0,0832	0,1798	H_0 accepted	Normal
Control Class	20	0,1790	0,1965		

The normality test results conducted on the three classes after the treatment indicate that all three classes are derived from populations that follow a normal distribution. This is confirmed by the $L_{max} < L_{table}$ indicating the acceptance of H_0.

Homogeneity Test is used to determine whether the samples taken have homogeneous variances or not. The homogeneity test used is Bartlett's test with a significance level of α = 5%. The following are the results of the homogeneity test calculation for post-test data, as presented in Table 5.

Table 5. Homogeneity Test Results for Posttest Data

Sample	Variance	$b_{calculated}$	b_{table}	Decision	Description
Experiment Class I	263,42				
Experiment Class II	265,30	1,0223	0,9088	H_0 accepted	Homogenous
Control Class	249,25				

The results of the homogeneity test for the three classes after the treatment indicate that these classes come from populations with homogeneous variances. This is confirmed by the $b_{calculated} > b_{table}$ indicating the acceptance of H_0.

The one-way ANOVA test for unequal cell sizes is used to determine the difference in the mean mathematical communication abilities of students in solving PISA-equivalent problems after receiving treatment. The following is a summary of the results of the one-way ANOVA test for unequal cell sizes using post-test data, as presented in Table 6.

Table 6. Results of One-Way ANOVA Test for Unequal Cell Sizes Using Post-test Data.

Sample	$\bar{x}$	$F_{calculated}$	F_{table}	Decision
Experiment Class I	80,29			
Experiment Class II	68,28	12,48	3.13	H_0 Rejected
Control Class	55,89			
Maximum Score	100			

The results of the test indicate that the three instructional models have different effects on students' mathematical communication abilities in solving PISA-equivalent problems. There are differences in students' communication abilities among those who use the Role-Playing model with GeoGebra assistance, the Role-Playing model, and the direct instruction model. This is confirmed by the $F_{calculated} > F_{table}$ indicating the rejection of H_0.

Post-ANOVA tests were conducted to determine the superior instructional model among Role-Playing with GeoGebra, Role Playing, and Direct Instruction. The results of the post hoc tests using the Scheffe test are presented in Table 7.

Table 7. Post-Anova Test Results for Post-test Data

Comparison and Hypothesis			
Comparison	H_0		H_1
μ_A with μ_B	$\mu_A = \mu_B$		$\mu_A \neq \mu_B$
μ_A with μ_C	$\mu_A = \mu_C$		$\mu_A \neq \mu_C$
μ_B with μ_C	$\mu_B = \mu_C$		$\mu_B \neq \mu_C$
Computation			
Comparison	μ_A with μ_B	μ_A with μ_C	μ_B with μ_C
$\left(\overline{X}_i - \overline{X}_j\right)^2$	143,30	593,57	153,57
$\frac{1}{n_1} + \frac{1}{n_2}$	0,0852	0,0917	0,0935
RKG	259,86	259,86	259,86
$F_{calculated}$	6,47	24,91	6,32
F_{table}	6.26	6.26	6.26
Decision	H_0 rejected	H_0 rejected	H_0 rejected
Conclusion	The Role-Playing with the GeoGebra-assisted learning model is superior to the Role-Playing learning model	The Role-Playing with the GeoGebra-assisted learning model is superior to the direct learning model	The Role-Playing learning model is superior to the direct learning model

Comparison of the μ_A with μ_B

Based on the calculations using the Scheffe test, the obtained value of $F_{calculated} = 6{,}47 > 6{,}26 = F_{table}$, which means H_0 is rejected. This indicates that the Role-Playing instructional model with GeoGebra assistance has a different quality compared to the Role-Playing instructional model. Since the mean of the Role-Playing instructional model with GeoGebra assistance is higher than the mean of the Role-Playing instructional model, it can be concluded that the Role-Playing instructional model with GeoGebra assistance is better at improving students' mathematical communication skills in solving PISA-equivalent problems.

Comparison of the μ_A with μ_C

Based on the calculations using the Scheffe test, the obtained value of $F_{calculated} = 24{,}91 > 6{,}26 = F_{table}$, which means H_0 is rejected. This indicates that the Role-Playing instructional model with GeoGebra assistance has a different quality compared to the Direct instruction model. Since the mean of the Role-Playing instructional model with GeoGebra assistance is higher than the mean of the Direct instruction model, it can be concluded that the Role-Playing instructional model with GeoGebra assistance is better at improving students' mathematical communication skills in solving PISA-equivalent problems.

Comparison of the μ_B with μ_C
Based on the calculations using the Scheffe test, the obtained value of $F_{calculated} = 6{,}32 > 6{,}26 = F_{table}$, which means H_0 is rejected. This indicates that the Role-Playing instructional model has a different quality compared to the Direct instruction model. Since the mean of the Role-Playing instructional model is higher than the mean of the Direct instruction model, it can be concluded that the Role-Playing instructional model is better at improving students' mathematical communication skills in solving PISA-equivalent problems.

The hypothesis test using a non-equivalent one-way ANOVA revealed differences in students' mathematical communication abilities in solving PISA-equivalent problems using the Role Playing with GeoGebra, Role Playing, and Direct instructional models. This is because the Role Playing with GeoGebra model guides students in transitioning from concrete to abstract concepts, based on their prior understanding, and involves exploration and experimentation activities with the assistance of GeoGebra. In contrast, the Role-Playing model does not utilize any auxiliary tools for exploration and experimentation. Additionally, the Direct Instruction model lacks such activities altogether. Therefore, the three instructional models yield different effects on students' mathematical communication abilities when solving PISA-equivalent problems.

Due to the significant mean differences among the three sample groups, a post hoc analysis using the Scheffe test was conducted to determine the superior instructional model in terms of students' mathematical communication abilities in solving PISA-equivalent problems. The instructional models compared were Role Playing with GeoGebra versus Role Playing, Role Playing with GeoGebra versus Direct Instruction, and Role Playing versus Direct Instruction. The following discussion presents the results of the post hoc analysis using the Scheffe test.

The Role-Playing learning model assisted by GeoGebra is superior to both the Role Playing and Direct Instruction models because the teacher provides easily understandable explanations that are connected to everyday life. At the beginning of the class, students are introduced to GeoGebra to visualize, experiment, and explore the concepts of the subject matter, making them more active in remembering and formulating concepts. This is consistent with the research conducted by (Khotimah et al., 2019), which shows that the use of visual learning media has a positive impact on students' attention and learning outcomes. This is evident in the exploration and experimentation activities using GeoGebra, which can facilitate students in solving mathematical communication problems equivalent to PISA.

The implementation of the Role-Playing learning model without the assistance of GeoGebra in exploration and experimentation activities has a different influence on students' mathematical communication skills in solving PISA-equivalent problems. Research by (Siregar et al., 2023) also supports this finding, stating that GeoGebra provides significant benefits for teachers and students. GeoGebra, as a learning media on the topic of Linear Equation Systems with Two Variables, has a positive effect on interest and ease of completion (Arnanda et al., 2021). This indicates that the use of GeoGebra in the learning model can enhance students' mathematical communication

(Jurotun, 2015). Therefore, based on the Scheffe test results, the Role-Playing learning model assisted by GeoGebra is superior to the Role-Playing learning model.

The implementation of the direct instructional model involves students listening to the teacher's explanations and working on exercises independently. The control class does not involve exploration and experimentation, limiting student participation in the learning process. The teacher's activity is rated as excellent, while the student's activity is rated as good. Despite the teacher's effective instructional process, student participation is still suboptimal. The direct instructional model tends to reinforce the active role of the teacher and the limited active role of the students, affecting students' mathematical communication skills. Consistent with the research (Handayani & Abadi, 2020), the direct instructional method supports students in acquiring procedural and declarative knowledge but is less effective in improving students' mathematical knowledge competence and does not promote the enhancement of mathematical communication. Therefore, based on the Scheffe test results, the Role-Playing learning model assisted by GeoGebra is superior to the direct instructional model. The Role-Playing learning model is also better than the direct instructional model. Research by (Wahyuni et al., 2019) also supports this finding, demonstrating that mathematics learning with the Role-Playing learning model has a positive impact on students' mathematical communication skills in terms of learning activities, mathematical communication abilities, and high motivation to learn.

Conclusion

Based on this study, it is evident that there are differences in the use of Role Playing with the GeoGebra-assisted Learning Model, Role Playing Model, and Direct Instruction Model in terms of students' mathematical communication abilities in solving PISA-equivalent problems. Comparing the use of Role Playing with the GeoGebra-assisted Learning Model and the Role-Playing Model, it is found that the former has a better impact than Direct Instruction Model. Additionally, Role Playing with GeoGebra-assisted Learning Model has a better impact than the Role-Playing Model. Therefore, it can be generally concluded that the improvement in students' mathematical communication abilities is better when using the Role Playing with GeoGebra-assisted Learning Model than the Role Playing and Direct Instruction Model. The findings of this research can contribute as a solution to enhance students' mathematical communication abilities in Indonesia by incorporating real-life objects, explaining mathematical answers, and connecting mathematical concepts with everyday life.

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