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The Effect of Project-Based Learning on Students' Mathematical Communication Skills

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Abstract: The low level of students' mathematical communication skills in mathematics learning is caused by a learning process that is still teacher-centered. Therefore, a more student-centered learning model is needed, one of which is the project-based learning model as an alternative solution. This study was conducted to determine the effect of the project-based learning model on students' mathematical communication skills. This study employed a quasi-experimental approach using a nonequivalent pretest-posttest control group design. All 10th grade classes were the research population. The sample was taken using purposive sampling, where X-2 was used as the experimental class and X-3 was used as the control class. Data was obtained by administering a test instrument to students. To test the hypothesis, the researcher used the Shapiro-Wilk normality test and the Mann-Whitney test, assisted by SPSS software version 26. Based on the results of hypothesis testing using the Mann-Whitney test, the Asymp. Sig. (2-tailed) value was 0,000 (≤ 0,05), resulting in the rejection of H0, concluding that there is an effect of the PjBL model on students' mathematical communication skills.

Keywords: mathematical communication skills; project based learning model; students'.

INTRODUCTION

Effective and relevant education for the future is education that does not merely provide information but also has the ability to develop students' skills in applying that knowledge to address various real-life problems, both those occurring now and in the future. Some real-life situations can be solved mathematically, although not all have mathematical solutions. Mathematics is a subject that is present at every level of education, so students must understand it (Elisyah, Rohantizani & Maulida, 2024). This is in line with (Ariani et al., 2025), who state that mathematics learning plays an important role and requires a strong understanding so that students can use it to solve everyday problems. Aware of the significant role of mathematics, students should master it thoroughly to maximize learning outcomes. However, in reality, many students dislike mathematics education. Mathematics is often perceived as extremely difficult, boring, and intimidating (Aminah et al., 2023).

Mastering 21st-century skills is essential for teachers, as they are at the forefront of education and students need to adapt to changing times. One of the demands of the 21st century is mastery of the four core competencies known as the 4Cs: critical thinking, communication, creative thinking, and collaboration (Aeni et al., 2024). The Indonesian government's latest policy through the Merdeka Curriculum emphasizes the development of 21st-century skills, including mathematical communication skills. This curriculum promotes active learning, such as project-based learning, which trains students to express mathematical ideas both verbally and in writing. Mathematical communication skills encompass the ability to convey mathematical ideas through speaking and writing, using symbols, graphs, tables, or other media (Sudianto & Yaqin, 2024). Mathematical communication skills play a crucial role in mathematics education, as they enable teachers to assess how well students understand, construct, and apply mathematical concepts and processes. Therefore, these skills must be enhanced in mathematics education. This study measures the level of students' mathematical communication skills using indicators from (Suhenda & Munandar, 2023) namely: 1)

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Creating mathematical situations by providing written form; 2) Explaining mathematical ideas in writing, with tables and graphs; 3) Connecting images (graphs) to mathematical ideas; 4) Expressing everyday events in symbols, language or mathematical models.

The results of the 2022 PISA international study conducted by the OECD on 15-year-old students show that Indonesian students still have low mathematics scores, ranking 70th out of 81 countries assessed (OECD, 2023). The 2022 PISA study shows that Indonesian students scored significantly lower than the OECD average, with a mathematics score of 366, while the OECD average mathematics score was 472. Mathematics scores in the 2022 PISA study reflect students' mathematical communication skills applied in solving problems at level 6. Based on these facts, it can be concluded that Indonesian students' mathematical communication skills are still unsatisfactory.

The observation conducted at the high school involved administering essay-type test questions designed to measure students' mathematical communication skills. The test results indicate that students' mathematical communication skills are still very low. Field observations reveal that project-based learning models have not yet been fully implemented or utilized in mathematics education at the high school, as the school continues to employ conventional teaching methods (lecture-based instruction) for mathematics lessons. Regarding the problem of students' mathematical communication skills, which are still very low, the solution that can be applied is the use of a more interactive and project-based learning model, such as the Project-Based Learning model, which allows students to learn through direct project implementation, encouraging active and student-centered learning. The project-based learning model also supports the development of 21st-century skills. The project-based learning model was chosen because it is more comprehensive in developing students' mathematical communication skills through real projects, group discussions, and presentations so that students not only know but also can communicate what they know mathematically (Kizkapan & Bektas, 2017). This aligns with (Rochmiati & Ardiyatno, 2023), who state that project-based learning emphasizes project activities, where students are involved in real projects that require them to be more active in solving problems through collaboration and applying their knowledge and skills in appropriate contexts. According to (Zulkifli, Awaludin & Hasnawati, 2024), teachers view the use of learning models that effectively support students' mathematical communication skills as crucial in the learning process.

In the project-based learning model, students work in small groups to complete assigned projects. During this process, students are required to point out mathematical concepts using symbols and logical explanations (Lubis, Pangaribuan & Tambunan, 2024). The steps for implementing learning using the Project-Based Learning model are as follows: 1) Formulating fundamental questions; 2) Designing the project; 3) Creating a schedule; 4) Conducting monitoring; 5) Testing the results; and 6) Evaluating the learning process (Aeni et al., 2024).

The advantages of the project-based learning model, according to (Maharani & Winanto, 2023) are 1) helping to increase student motivation during the learning process; 2) encouraging students' enthusiasm in designing projects; 3) strengthening cooperation and unity among students; and 4) developing students' skills in managing resources. The disadvantages of the Project-Based Learning model, according to (Rineksiane, 2022) are: 1) implementing the Project-Based Learning model requires a significant amount of time from planning to execution; 2) implementing the Project-Based Learning model also requires substantial costs; 3) the Project-Based Learning model is a modern method designed to help students think more critically; 4) a variety of learning aids are required to conduct practical learning activities; and 5) students are required to be actively engaged, and those who are not active tend to remain silent during group learning activities.

Research conducted by (Jais et al., 2024), on the project-based learning model's effect on students' mathematical communication skills states that the project-based learning model has an effect on the mathematical communication skills of eighth-grade students at SMP Negeri 2 Baubau. Research conducted by (Zakiyah, Supandi & Dwijayanti, 2023) shows that students' mathematical communication skills using the project-based learning model are better than those using the conventional learning model. Furthermore, research conducted by (Lubis, Pangaribuan & Tambunan, 2024), based on research results and data analysis, concluded that the project-based learning model has an effect on students' mathematical communication skills. Given these conditions, the researchers decided to conduct further research with the aim of examining the effect of the project-based learning model on students' mathematical communication skills.

METHODS

This study uses experimental research with a quantitative approach. The research design used is a quasi-experimental design with a nonequivalent control group design. Details of the nonequivalent control group design used in this study are provided in Table 1.

Table 1. Nonequivalent Control Group Design

Class	*Pretest*	Treatment	*Posttest*
Experiment	O_1	X	O_2
Control	O_1	-	O_2

(Sugiyono, 2022)

With, O_1 : pretest and posttest of experimental and control classes, O_2 : posttest and posttest of experimental and control classes, and X : treatment in the form of learning with the project-based learning model.

The population of this study was tenth-grade students comprising seven classes, namely X-1 to X-7. The sample was determined using purposive sampling. According to (Sugiyono, 2022), purposive sampling is the selection of samples based on specific criteria. Class X-2 was selected as the experimental class using the project-based learning model. However, class X-3 was the control class using the conventional learning model.

This study focuses on determining the effect of the project-based learning model on students' mathematical communication skills. The research instrument consists of essay questions on mathematical communication skills. Before the test instrument was administered, it was first validated by expert lecturers. Thereafter, it was piloted on students in class XI-2 as an initial stage. The purpose of this pilot test was to assess the level of validity, reliability, discriminating power, and difficulty level. The results of the instrument testing were analyzed using SPSS.

Data collection in this study was conducted through pretest-posttest administration. The pretest was administered before the experimental class received treatment through the application of the project-based learning model, while the control class followed the learning process using the conventional model. The purpose of administering the pretest was to confirm that the initial abilities of the two classes were equivalent or the same. Next, the posttest was administered after the experimental class received treatment through the application of the project-based learning model, while the control class followed the learning process using the conventional model. Both classes were given the same test instruments.

Data analysis was conducted in two stages. First, descriptive analysis to describe teacher and student activities during the teaching and learning process. Second, statistical analysis to test the research hypothesis. The purpose of the normality test is to find out if the data follows a normal distribution. Because the sample was less than 50 ($n < 50$), the Shapiro-Wilk test was used. The normality test was carried out with the help of SPSS software. With testing criteria: when the Sig ≥ α, it means the data is considered normally distributed, and when the Sig < α, it means the data is not normally distributed with α=0.05=5%. Non-parametric tests are used if the data fails to meet the assumption of normality, namely the Mann-Whitney U-test. This test was also carried out with SPSS software. Test criteria: when the significance ≤ 0.05, there is a significant difference, and when the significance > 0.05, there is no significant difference.

RESULTS AND DISCUSSION

The research findings include descriptive analysis and statistical analysis. All statistical analyses in this study were conducted directly in accordance with the provisions and procedures of the research method used. Descriptive analysis was performed based on quantitative data from the post-test of students' mathematical communication skills, including 32 students assigned to the experimental class and 24 to the control class. The learning process was carried out in two sessions with material on quadratic functions, where the experimental class applied the project-based learning model, and the control class applied the conventional model. The implementation of teaching and learning with the Project-Based Learning model in the experimental class was carried out consistently from the first to the second session. The results of the observation of the implementation of learning can be seen in Table 2.

Table 2. Results of Observations of Teacher and Student Activities of Experimental Classes

Meeting	Teacher		Students	
	Score	Percentage	Score	Percentage
Ke-1	87	94.56%	104	96.30%
Ke-2	88	95.65%	107	99.07%

Based on the data in Table 2, the results of the teacher activity observation sheet show that the management of the learning process in the first meeting was very good, at 94.56% with a maximum score of 92. This achievement shows that teachers are able to design and implement learning effectively in accordance with the project-based learning model. This percentage provides a positive indication of the success of the project-based learning model in improving the quality of learning activity organization in quadratic function material. Furthermore, there was an increase in achievement in the second meeting, reflecting improvements and adjustments to learning strategies that were increasingly optimal.

Furthermore, the results of student activity observations showed that in the first meeting, activity achievement reached 96.30% and was in the very good category. In the second meeting, activity achievement increased significantly to 99.07%, which was in the very good category and was the highest score during the learning process, with a maximum score of 108. The increase in student activity percentage during these two meetings shows consistent development, indicating that students are beginning to get used to and are more actively involved in the learning process using the Project-Based Learning model. Based on the above findings, students require an adaptation process to adjust to a learning model that has never been implemented in the classroom before. Furthermore, the posttest descriptive data on students' mathematical communication skills from both the experimental class (using Project-Based Learning) and the control class (using conventional learning) were analyzed with SPSS version 26.

Table 3. Statistical Descriptive Results

Descriptive Statistics	Experimental Class	Control Class
N	32	24
Mean	14,69	9,92
Median	16,00	12,50
Modus	17	14
Std. Deviation	3,702	5,778
Variance	13,706	33,384
Minimum	0	0
Maximum	18	17

Based on the results of Table 3, the average posttest value of mathematical communication skills in the experimental class was 14.69. Meanwhile, the control class only reached 9.92. The scores for each part of students' mathematical communication skills can be seen in Table 4.

Table 4. Percentage of Mathematical Communication Skills Based on Indicators

No Indicator	Indicator of Mathematical Communication Skills	Score	
		Experiment Class	Control Class
1	Creating mathematical situations by providing information in written form	74,65%	50,92%
2	Explaining mathematical ideas in writing, with tables and graphs	91,66%	61,11%
3	Connecting pictures (graphs) to mathematical ideas	83,33%	62,50%
4	Expressing everyday events in mathematical symbols, language or models	90,62%	54,16%

Based on Table 4, the experimental class using the project based learning model excelled in three indicators of mathematical communication skills, namely indicators 2, 3, and 4. Meanwhile, the control class using the conventional model excelled in two indicators, namely indicators 2 and 3. These findings indicate a relative difference in excellence between the learning models compared.

Statistical analysis was used to test the research hypothesis. Before testing the hypothesis, a normality test was conducted. The normality test aims to determine whether the data obtained is normally distributed. To determine whether the data is normally distributed, the Shapiro-Wilk statistical test was used. The normality test outcomes can be seen in Table 5.

Table 5. Posttest Normality Test Results

Class	*Shapiro-Wilk*		
	Statistic	***df***	***Sig.***
Experiment Posttest	0,757	32	0,000
Control Posttest	0,847	24	0,002

From the results above, both experimental and control classes show a significance value below 0.05, meaning that the data is not normal. Therefore, the hypothesis test was continued with a non-parametric test, namely the Mann-Whitney U Test. The findings from the Mann-Whitney U test are presented in Table 6.

Table 6. Posttest Data Hypothesis Test Results

Test Statistics[a]	
	Posttest Results
Mann-Whitney U	160,500
Wilcoxon W	460,500
Z	-3,725
Asymp. Sig. (2-tailed)	0,000

The Mann-Whitney U Test results show that the Asymp. Sig. (2-tailed) is 0.000 ($\leq$ 0,05), so H_0 is rejected. This means there is a clear difference between the experimental and control classes, which shows that the project-based learning model influences students' mathematical communication skills. The analysis results indicate that the project-based learning model influences students' mathematical communication skills. This study was conducted in four meetings for each class, with one meeting used for implementation, two meetings for the learning process in class, and the last meeting for the posttest.

The project-based learning model requires active student involvement in completing tasks relevant to real life (Jais et al., 2024). The PjBL model encourages students to work independently or in groups and take responsibility for their work. This aligns with (Padji, Nuhamara & Wadu, 2024), which states that the project-based learning model also provides students with opportunities for independent learning. Through this model, students can develop ideas and concepts while strengthening their mathematical communication skills, with teachers acting as facilitators. The learning stages in the experimental class that used the project-based learning model were as follows: 1) determine the basic questions; 2) plan the project; 3) set up the project schedule; 4) monitor the project implementation; 5) test the project results; 6) evaluate (Fidela, Fadilah & Padang, 2024).

The teaching and learning activity began with a greeting and prayer, followed by checking student attendance and conveying the learning objectives related to the material to be studied. The learning process began with providing stimuli in the form of problems related to quadratic functions through examples of quadratic function graphs that can be found in the real world and the students' surroundings. The teacher encourages students to identify examples of quadratic function graphs in their surroundings, such as children jumping rope, the shape of a rainbow, and so on. Next, the teacher guides students to form five groups. The teacher instructs students to bring the mentioned objects to the next session for use in a project activity. These objects will be utilized to create posters.

During the project planning stage, students discuss with their groups how to develop a plan for completing the project and the questions contained in the LKPD. The plan includes the division of tasks, preparation of tools and materials, and other necessary resources. The next stage involves guidance on creating a project implementation schedule. The project implementation schedule is divided into two sessions. In the first session, students identify contextual images in the form of open curves pointing upward or downward, then use the GeoGebra application to derive quadratic function graphs from these images. In the second session, students create posters using cardboard based on the quadratic function graphs obtained.

After the scheduling process was completed, the students began working on the project in groups according to the plan that had been drawn up during the planning stage. At the first meeting, the students searched for images as requested in the LKPD. After obtaining the images, the students were instructed to use GeoGebra to obtain the quadratic function graph from the images they had obtained. Once the quadratic function graph had been obtained from the Geogebra application, the image was printed to make a poster. Students also complete the problems in the LKPD. In the second meeting, students create a poster from the quadratic function graph obtained from the Geogebra application. During the project implementation, the teacher monitors the process to ensure activities proceed smoothly and provides assistance to groups facing difficulties or obstacles in their work.

After going through the project monitoring stage, the next stage is to test the project results. Teachers assess each group's work thoroughly. Students then determine the order in which groups will come forward to present their project results. Each group is given approximately 10 minutes to present their project results. The presentation is guided by a student moderator who is in charge of organizing it. After the entire learning process has been completed, from determining the fundamental questions to testing the project results, the next step is the collaborative evaluation between teachers and students at the end of the learning process. This activity aims to review the learning process and outcomes that have been achieved.

The average score for students' mathematical communication skills using the project-based learning model was 14,69, while the average score using the conventional model was 9,92. The findings show that the project-based learning model helps improve students' mathematical communication skills. The difference in average scores between the two classes can be attributed to differences in treatment in the application of the learning model. A series of statistical tests were conducted. The normality of the data on students' mathematical communication skills was tested using the Shapiro-Wilk test, which showed that the two classes were not normally distributed. It was followed by the non-parametric Mann-Whitney U-test. The results of the Mann-Whitney U-test showed that H_1 was accepted, indicating that the project-based learning model had an effect on students' mathematical communication skills. The findings of this study are consistent with (Zakiyah, Supandi & Dwijayanti, 2023), who found that students' mathematical communication skills were more efficient when applying the project-based learning model than when applying the conventional learning model. Furthermore, research (Jais et al., 2024) found that the project-based learning model had an effect on students' mathematical communication skills.

CONCLUSION

The findings of the study indicate that applying the project-based learning model significantly influences students' mathematical communication skills. This is evidenced by the results of the Mann-Whitney U Test, where the value of Asymp. Sig. (2-tailed) reached 0.000 ($\leq$ 0,05), so H0 is rejected and H1 is accepted. In other words, it can be concluded that the project-based learning model has an effect on students' mathematical communication skills. Based on the results of the discussion outlined above, the researcher suggests that in the implementation of the project-based learning model, interaction among students increases significantly through active group discussions. Therefore, the teacher's role in maintaining order and being firm is essential to ensure that the learning process continues to run effectively. For future researchers, it is hoped that this study can serve as a foundation or initial reference and further develop the application of the project-based learning model to achieve more optimal results in the context of learning.

REFERENCES

Aeni, A. N., Hanifah, N., Djuanda, D., Maulana, M., Erlina, T., Dewi, D. P., Hadi, F. L., & Ramadhani, S. (2024). Meningkatkan Keterampilan Abad 21 Guru SD Melalui Pelatihan Convert Powerpoint Menjadi Media Pembelajaran Aplikasi Android. *To Maega : Jurnal Pengabdian Masyarakat, 7*(2), 384. https://doi.org/10.35914/tomaega.v7i2.2656

Aminah, S., Taqiyyah, F., Ma, R., & Puryati, L. K. (2023). *Pengaruh Model Pembelajaran Kooperatif Tipe NHT terhadap Kemampuan Pemecahan Masalah Matematis di Sekolah Dasar*. *7*(4), 2040–2047. https://doi.org/https://doi.org/10.31004/basicedu.v7i4.5831

Ariani, D., Wulandari, W., Ningtiyas, F. A., Fajriana, & Hidayatsyah. (2025). Analisis Kesalahan Siswa Berdasarkan Kriteria Watson Terhadap Kemampuan Berpikir Kreatif Matematis Dalam Menyelesaikan Soal Hots. *Jurnal Pendidikan Matematika Malikussaleh*, *5*(1), 9–23. https://doi.org/10.29103/jpmm.v5i1.19186

Elisyah, N., Rohantizani, & Maulida. (2024). Analysis Of Mathematics Learning Activities Material Limit Function Algebra Using Quick On The Draw Strategy. *Proceedings of Malikussaleh International Conference On Education Social Humanities And Innovation (Miceshi)*, *1*(1). https://ojs.unimal.ac.id/mijeshi/

Fidela, W., Fadilah, M., & Padang, U. N. (2024). Literature Review : Penerapan Model Project Based Learning (PjBL) untuk Meningkatkan Hasil Belajar dan Kemampuan Berpikir Kreatif Siswa SMA. *Jurnal Pendidikan Dan Pembelajaran Indonesia (JPPI)*, *4*, 1498–1511. https://doi.org/https://doi.org/10.53299/jppi.v4i4.745

Jais, E., Usa, S. La, & Intifadah, W. (2024). Pengaruh Model Project Based Learning (PjBL) terhadap Kemampuan Komunikasi Matematis Siswa SMP Negeri 2 Baubau. *Jurnal Akademik Pendidikan Matematika*, *10*(1), 32–36. https://doi.org/https://doi.org/10.55340/japm.v10i1.1522

Kizkapan, O., & Bektas, O. (2017). The effect of project based learning on seventh grade students' academic achievement. *International Journal of Instruction*, *10*(1), 37–54. https://doi.org/10.12973/iji.2017.1013a

Lubis, M. J. K., Pangaribuan, F., & Tambunan, H. (2024). Pengaruh Model Pembelajaran Project Based Learning Terhadap Kemampuan Komunikasi Matematis Dan Self Confidence Siswa. *Journal on Education*, *06*(02), 14842–14850. http://jonedu.org/index.php/joe

Maharani, D. P., & Winanto, A. (2023). Peningkatan Kemampuan Komunikasi Matematis Siswa Kelas IV Melalui Model Project Based Learning. *Jurnal Ilmiah Pendidikan Dasar*, *31*(1), 82–87.

OECD. (2023). Results Factsheets Indonesia. *OECD (Organisation for Economic Co-Operation and Development) Publication*, 1–9. https://www.oecd.org/en/publications/pisa-2022-results-volume-i-and-ii-country-notes_ed6fbcc5-en/indonesia_c2e1ae0e-en.html

Padji, M. F. D., Nuhamara, Y. T. I., & Wadu, D. I. (2024). Pengaruh Model Project Based Learning Terhadap Hasil Belajar Matematika Siswa Smp. *Prima Magistra: Jurnal Ilmiah Kependidikan*, *5*(1), 38–45. https://doi.org/10.37478/jpm.v5i1.3593

Rineksiane, N. P. (2022). Penerapan Metode Pembelajaran Project Based Learning Untuk Membantu Siswa Dalam Berpikir Kritis. *Jurnal Pendidikan Manajemen Perkantoran*, *7*(1), 82–91. https://doi.org/10.17509/jpm.v7i1.43124

Rochmiati, S., & Ardiyatno, H. (2023). Improving Cursive Writing Skills Through a Project Based Learning Model for Grade 2 Elementary School Students in Yogyakarta, Indonesia. *Proceedings of International ...*, *July*, 973–985. https://seminar.ustjogja.ac.id/index.php/ICoTPE/article/view/1047/588

Sudianto, & Yaqin, S. S. (2024). Jurnal Didactical Mathematics Efektivitas Model Project Based Learning Berbantuan Canva Terhadap Kemampuan Komunikasi Matematis Siswa. *Jurnal Didactical Mathematics*, *6*, 323–332. https://ejournal.unma.ac.id/index.php/dm

Sugiyono. (2022). *Metode Penelitian Kuantitatif* (Setiyawami (ed.)). Alfabeta, CV.

Suhenda, L. L. A., & Munandar, D. R. (2023). Kemampuan Komunikasi Matematis Siswa Dalam Pembelajaran Matematika. *Jurnal Educatio*, *9*(2), 1100–1107. https://doi.org/10.31949/educatio.v9i2.5049

Zakiyah, L., Supandi, S., & Dwijayanti, I. (2023). Pengaruh Model Pembelajaran Problem Based Learning (PBL) Dan Project Based Learning (PjBL) Terhadap Kemampuan Komunikasi Matematis Siswa. *Jurnal Ilmiah Matematika Dan Pendidikan Matematika*, *15*(1), 55. https://doi.org/10.20884/1.jmp.2023.15.1.6551

Zulkifli, M., Awaludin, & Hasnawati. (2024). Pengaruh Model Pembelajaran Kooperatif Tipe Student Facilitator and Explaining (SFAE) Terhadap Kemampuan Komunikasi Matematis Siswa SMP. *Jurnal Penelitian Pendidikan Matematika*, *12*(3), 321-336. https://doi.org/DOI: http://dx.doi.org/10.36709/jppm.v12i2.48921