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EXPLORING THE EFFECTIVENESS OF PROBLEM-BASED LEARNING ON MATHEMATICAL PROBLEM-SOLVING: A GENDER PERSPECTIVE

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ABSTRACT

Salah satu kemampuan yang penting untuk dikembangkan dalam pembelajaran matematika yaitu kemampuan pemecahan masalah. Tujuan penelitian ini yaitu untuk menganalisis efektivitas model pembelajaran *problem-based learning* (PBL) terhadap kemampuan siswa dalam memecahkan masalah matematis, dengan mempertimbangkan perbedaan *gender* (perempuan dan laki-laki). Penelitian dengan metode eksperimen menggunakan *Control Group Posttest Design*. Kemampuan pemecahan masalah digunakan sebagai variabel terikat, model pembelajaran menjadi variabel bebas, sedangkan *gender* sebagai variabel moderator. Teknik pengumpulan data berupa tes yang terdiri dari 5 soal esai, dirancang sesuai indikator kemampuan pemecahan masalah Polya. Analisis data dilakukan dengan uji normalitas, uji homogenitas dan uji ANOVA Dua Arah. Hasil penelitian menunjukkan bahwa model pembelajaran *Problem-Based Learning* (PBL) efektif dalam meningkatkan kemampuan pemecahan masalah matematis siswa tanpa dipengaruhi oleh gender.

One of the essential skills to be developed in mathematics learning is problem-solving ability. The purpose of this study is to analyze the effect of the problem-based learning (PBL) model on students' mathematical problem-solving skills, considering gender aspects (female and male). This experimental study employs a Control Group Posttest Design. Problem-solving ability is used as the dependent variable, the learning model as the independent variable, and gender as the moderating variable. Data collection techniques involve tests consisting of 5 essay questions designed according to Polya's problem-solving indicators. Data analysis is conducted using normality tests, homogeneity tests, and two-way ANOVA tests. The results indicate that the Problem-Based Learning (PBL) model is effective in improving students' mathematical problem-solving skills regardless of gender.

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1. INTRODUCTION

Mathematics must be studied by students starting from elementary school to high school. According to Putri et al (2019) math has a close relationship with daily activities. Siregar & Panjaitan (2018) said that mathematics plays an important role in fostering students' creativity and problem-solving skills because mathematics can teach students to think logically and reason, which they can use when finding solutions to everyday problems.

One of the math materials that is close to everyday life is the System of Linear Equations of Two Variables (SPLDV), where students are often asked to solve story problems. According to Asri et al (2019) students often experience difficulties in solving story problems related to the system of linear equations. This difficulty is due to the low mathematical problem solving ability of students (Marlita & Adirakasiwi, 2024). Therefore, Shadiq (dalam Yuliana et al., 2021) emphasized that problem solving skills are very important for students in solving various problems.

Mathematical problem solving ability refers to students' efforts in utilizing their skills and knowledge to find a solution to a problem (Davita & Pujiastuti, 2020). Meanwhile, Sumarmo (dalam Jainuri, 2014) defines problem solving as an activity that involves solving story problems, handling non-routine problems, applying mathematical concepts to everyday life or other situations, and proving, creating, or testing conjectures. Meanwhil (Santika et al., 2020) said problem solving can be interpreted as a process of finding solutions, because it involves solving a problem using a collection of known concepts, rules, and information.

Problem solving is very important in mathematics learning because students need to learn how to understand problems, choose approaches, make solution plans, and solve problems. The problem solving process allows students to experiment, explore, observe, and solve problems (Siswanto & Meiliasari, 2024). According to Polya there are four stages in the problem solving process, namely: understanding the problem, devising a plan, carrying out the plan, and looking back (Agustina et al., 2023). So that according to Harefa & Surya (2020) improving problem solving skills can require teachers to provide opportunities and support for students to independently construct knowledge, gain deep understanding, and develop problem solving skills with the teacher as a facilitator.

The results of interviews with mathematics teachers at MTsS Modern Arafah show that some students still have low mathematical problem solving skills. The same thing was also found by Syahril (2021) who stated that students' mathematical problem solving skills were very low. The low problem solving ability of MTsS Modern Arafah students can be seen from the test results of several students who obtained low scores on problem-solving questions. Students tend to skip the problem-solving steps and directly perform calculations without first going through the "planning the solution" stage. In addition, they also do not carry out the "checking the correctness of the results" stage, which ultimately leads to incorrect answers. Errors made by students can occur because students are not accustomed to solving problems with problem solving steps so that students ignore the steps in solving problems which result in miscalculations.Umanailo et al (2018) stated that the low problem solving ability of students can occur due to obstacles faced by students when following problem solving procedures. In addition, Riyanto & Amidi (2024) state that low problem-solving skills may occur because teachers do not provide opportunities for students to enhance their abilities.

The lack of students' mathematical problem solving ability is one of the failure factors in learning (R. J. Saputra et al., 2023). The low ability of students to solve a problem also results in students not being confident in their own abilities so that they have difficulty in expressing their opinions clearly and precisely (Monica et al., 2019). In line with this, Sriwahyuni & Iyam Maryati (2022) said that the lack of mathematical problem solving skills can cause students to have difficulty solving problem solving problems.

Mathematics teachers should be able to create a learning environment that helps students learn to solve problems (Ratnawati et al., 2024). The problem-based learning (PBL) learning model comes as one of the most effective solutions to improve students' mathematical problem solving skills (Supraptinah, 2019). This is because in the PBL model, students do not get information from the teacher, but the teacher is also responsible for encouraging students to actively participate in the learning process (A. Y. Yusri, 2018). In addition, problem-based learning (PBL) starts from a problem that helps students integrate and collect new information (Faturrohman; Fauzia, 2018). Thus, problem-based learning (PBL) can help students solve math problems.

However, the effectiveness of PBL is often influenced by various factors, one of which is gender. Various studies have shown differences in learning characteristics between male and female students, such as differences in learning styles (Fatmawati et al., 2020); ways of thinking (Martania et al., 2023); and ways of understanding problems and developing a solution plan (Tarigan et al., 2022). These differences can affect the effectiveness of a learning model, including PBL.

Previous researchers have conducted various studies related to problem-based learning (PBL) in improving problem solving skills. For example, various problem-based learning tools have been developed to improve students' mathematical problem solving skills (D. R. L. Yusri et al., 2021); (Husna et al., 2022); (Pane et al., 2023) & (Asrar et al., 2023). In addition, research conducted by Permatasari & Marlina (2023); Susino et al. (2023); Yulianti & Zetriuslita (2024); & Ardianti et al. (2024) discussed the effect of the problem-based learning model on mathematical problem solving skills involving students in general. This research focuses on seeing how the problem-based learning (PBL) model affects students' mathematical problem solving skills based on gender (female and male).

Based on the issues mentioned above, research needs to be conducted to investigate the effect of the problem-based learning model on students' mathematical problem-solving abilities based on gender (female and male). This research will consider the analysis of the impact of the learning models (problem-based learning and conventional) on students' mathematical problem-solving abilities, the effect of gender on students' mathematical problem-solving abilities, as well as the interaction between the learning model and gender on students' mathematical problem-solving abilities. It is hoped that this research will improve the quality of mathematics learning, find solutions to problems in students' mathematical problem solving ability, and add to the literature and references in the field of education.

2. METHOD

The type of research is experimental research using Control Group Posttest. Problem solving ability is used as the dependent variable, the learning model becomes the independent variable, while gender is the moderator variable. All students of class VIII MTsS Modern Arafat became the population in this study. The sample consists of four classes which include 2 experimental classes and 2 control classes. Because the condition of each class VIII MTsS Arafah Modern (equalized) is relatively the same, the sampling is done randomly using cluster random sampling. The Control Group Posttest Design research design can be presented in Table 1

Table 1. *Control Group Posttest Design*

Group	Treatment	Posttest	Classification
R (Exsperimen 1)	X	O	Male
R (Control 1)	-	O	Male
R (Exsperimen 2)	X	O	Famale
R (Control 2)	-	O	Famale

Table 1 shows that R represents random sample selection, X indicates problem-based learning (PBL) treatment, and O is the post-test given to the experimental and control groups. Class VIII A and VIII C did not receive treatment or considered as control class. While classes VIII B and VIII D were treated with the problem-based learning (PBL) learning model as the experimental class which was categorized into male (classes VIII A and VIII B) and female (classes VIII C and VIII D) based on gender variables.

The data for this study were collected through a test consisting of five essay questions to measure students' mathematical problem solving ability according to Polya's problem solving ability indicators. The questions underwent validity, reliability, discrimination power, and difficulty level tests before being used. The validity test showed that all five questions were valid. The reliability test resulted in a reliability coefficient of 0.90, indicating that the questions had a very high level of reliability. The results of the discrimination power test showed that the questions had good discrimination. Meanwhile, the difficulty level test indicated that the questions were easy. Documentation was conducted to obtain data on male and female students. The data needed for the research is the score of students' mathematical ability in solving problems. Data analysis techniques were carried out with normality test, homogeneity test and two-way ANOVA test.

3. RESULTS AND DISCUSSION

3.1. Result

In this study, researchers used the problem-based learning (PBL) model in four meetings in the experimental class. As well as holding one meeting in the control class and experimental class to carry out the posttest. Data on problem solving skills were then analyzed and the results are presented in Table 2.

Tabel 2. Descriptive Statistics of Students' Mathematical Problem Solving Ability

Learning Model	Gender	Mean	Std. Deviation	N
PBL	Famale	73.73	9.647	15
	Male	76.80	11.400	10
	Total	74.96	10.265	25
Konvensional	Famale	53.20	13.067	15
	Male	50.67	12.601	12
	Total	52.07	12.679	27
Total	Famale	63.47	15.375	30
	Male	62.55	17.784	22
	Total	63.08	16.274	52

The results of the posttest scores shown in Table 2 indicate that both male and female students in the experimental class received higher scores compared to the control class. This proves that the generalization of the problem-based learning (PBL) model is more effective in improving problem-solving skills compared to the conventional learning model. However, further analysis shows that in the experimental class, the male students' scores were higher than those of the female students, namely 78.80 > 73.73. Conversely, the scores of the female students in the control class were higher than those of the male students, namely 53.20 > 50.67. Overall, the statistical results indicate that the male students in the experimental class achieved the highest score of 76.80, while the male students in the control class received the lowest score of 50.67.

Table 3. Achievement of Mathematical Problem Solving Ability Indicators

Indikator	**Persentage of Famale Class**		**Percentage of Male Class**	
	Experimen	**Kontrol**	**Experimen**	**Kontrol**
Understanding the Problem	92%	60%	88%	45%
Planing for Completion	89,33%	78,22%	92%	78,33%
Perform Calculations	70,66%	46,66%	72%	48,33%
Checking the Correctness of the Results	38%	16%	48%	18,33%

From all indicators, both male and female students in the experimental class had a higher percentage than the control class, as shown in Table 3. These results indicate that the problem based learning (PBL) model can improve mathematical problem solving skills better than the conventional model.

In Table 3, it can be seen that the percentage of achievement of the "understanding the problem" indicator of the female experimental class is higher than the male experimental class, with a percentage of 92%> 88%. The same thing also happened in the control class, where female students obtained a higher percentage than male students, namely 60%> 45%. In this indicator, female students in the experimental class obtained the highest percentage, reaching 92%, while the lowest percentage was obtained by male students in the control class, amounting to 45%. Based on these data, it can be concluded that both in the experimental and control classes, female students have better abilities than male students in understanding problems.

Table 3, shows that in the "Planning for Completion" indicator, the male experimental class has a greater percentage than the female experimental class, namely 92%> 89.33%. In the control class, male students also obtained a higher percentage than females, namely 78.33% > 78.22%. The highest percentage for the indicator "Planning for Completion" was obtained by the male experimental class, which is 92%, while the lowest score was obtained by the female control class, which is 78.22%. Therefore, it is evident that male students perform better than female students in planning solutions to problems.

The percentage of indicators in "Performing Calculations" in table 3, it can be seen that the male experimental class obtained a greater percentage of indicator achievement than the female experimental class, namely 72%> 70.66%. Likewise in the control class, where the percentage of men is higher than women, namely 48.33%> 46.66%. The highest percentage for the " Performing Calculations " indicator was found in the male experimental class, 72%, while the lowest value was found in the female control class, 46.66%. This data shows that male students are more thorough than female students in doing calculations.

In Table 3, the percentage of achievement of the "Checking the Correctness of Results" indicator shows that the percentage of male experimental classes is higher than female experimental classes, namely 48%> 38%. The same thing happened in the control class, where the percentage of male students was higher than female students, namely 18.33%> 16%. The highest percentage of the "Checking the Correctness of Results" indicator is 48% which is found in the male experimental class while the lowest percentage is found in the female control class which is 16%. The percentage of checking the correctness of the results of the female and male classes is still relatively low. This is due to the fact that both female and male students consider the process of checking the correctness of the results not so important. As a result, students just continued to solve the problem to the next number without doing the activity of checking the correctness of the results.

Normality Test

Before proceeding to the next statistical test, a data normality test was conducted to determine whether the sample came from a normal distribution. The results of the test conducted with shapiro-wilk are in Table 4.

Tabel 4. Data Normality Test Results (Shapiro-Wilk)

	Statistic	**df**	**Sig.**
Standardized Residul for Score	.976	52	.358

From Table 4. It was found that the sig value. 0.358 > 0.05 (alpha) which indicates that the data is normally distributed

Homogenity Test

The homogeneity test determines whether the data has the same variance (homogeneous) or not. This data is the basis for ensuring that the assumption of homogeneity is met before proceeding to the next stage. Table 5 shows the results of the homogeneity test analysis.

Tabel 5. Results of Data Homogeneity Test

Levene's Test of Equality of Error Variances[a,b]

		Levene Statistic	df1	df2	Sig.
Problem-Solving Ability Score	Based on Mean	.789	3	48	.506
	Based on Median	.589	3	48	.625
	Based on Median and with adjusted df	.589	3	44.787	.625
	Based on trimmed mean	.762	3	48	.521

Tests the null hypothesis that the error variance of the dependent variable is equal across groups

a. Dependent variabel: Problem-Solving Ability Score
b. Design: Intercept + Learning Model + Gender + Learning Model * Gender

In Table 5, it can be seen that all Sig. values are > 0.05. This indicates that the assumption of homogeneity of variance is met.

The results of the study with two-way anova analysis of variance (two-way anova) can be described in Table 6 below:

Table 6. Results of Two Way Anova Analysis of Variance

Variabel Terikat: Kemampuan Pemecahan Masalah Matematis Siswa					
Source	**Type III Sum of Squares**	***df***	**Mean Square**	**F**	**Sig.**
Corrected Model	6898.092[a]	3	2299.364	16.698	<,001
Intercept	204376.926	1	204376.926	1484.219	<,001
Learning Model	6877.193	1	6877.193	49.943	<,001
Gender	.898	1	.898	.007	.936
Learning Model * Gender	99.032	1	99.032	.719	.401
Error	6609.600	48	137.700		
Total	220400.000	52			
Corrected Total	13507.692	52			

a. R Squared = .511 (Adjusted R Squared = .480)

From Table 6, it can be seen that: In the "corrected model", the independent variables (gender, learning model and gender interaction with learning model or "gender * learning model) together on the dependent variable (problem solving ability) with sig value = <0.001 is smaller than the value of alpha = 0.05 which means overall there is a significant difference. From the value of "intercept", the sig value is <0.001 which is smaller than 0.05 (alpha) which means that the intercept value is significant, so it is known that without the influence of gender and learning model, problem solving ability can change its value. Likewise, the value of "learning model" shows that sig. < 0.001 which is smaller than 0.05, meaning that there is a significant difference in problem solving ability between students who study with a problem-based learning (PBL) learning model and a conventional learning model. while in "gender" it was found that the sig. 0.936 > 0.05 which means there is no significant difference in problem solving ability between female students and male students. The value of "learning model * gender" shows sig. 0.401 > 0.05 which means there is no interaction effect between learning models (PBL and Conventional) and gender (female and male) on students' mathematical problem-solving ability.

Effect of Learning Model (Problem Based Learning and Conventional) on Students' Mathematical Problem Solving Ability

From the results of ANOVA analysis, the sig. value is obtained <0.001 which is smaller than 0.05. This means that the learning model has a significant effect on students' mathematical problem-solving ability or in other words, there is a significant difference in problem solving ability between students who study with a problem-based learning model (PBL) and a conventional learning model. The average score of mathematical problem-solving ability obtained by the experimental class (with problem-based learning (PBL) learning model) is 74.96 and the control class (with conventional learning model) is 52.07. From the average score results, it is evident that the experimental class has a higher average mathematical problem-solving ability compared to the control class. Thus, learning with the problem-based learning (PBL) model yields better learning outcomes than conventional learning.

The Effect of Gender on Students' Mathematical Problem Solving Ability

The results of the analysis show that gender does not have a significant influence on students' mathematical problem-solving skills with a sig value. 0,936 > 0,05. This finding indicates that there is no difference in problem solving ability between male and female students.

The Interaction Effect Between Learning Model and Gender on Students' Mathematical Problem Solving Ability

The results of the analysis also showed that there was no significant interaction between the learning model (PBL and Conventional) and gender (female and male) on students' mathematical problem-solving ability with a sig value. 0,401 > 0,05. In other words, the effectiveness of the PBL model is not influenced by student gender.

3.2. Discussion

The research results that have been described show that the average score of experimental class students is higher than the control class. The same thing was found by Yanti (2017) that students showed significant improvement in problem solving when they were taught with the PBL model compared to the conventional learning model. This is in line with the findings of Yulianti & Zetriuslita (2024) who also showed that, thanks to the application of the PBL model, students in the experimental group had better mathematical problem solving scores compared to students in the control group. This shows that PBL learning is more effective in improving problem solving skills compared to conventional learning models. This finding is also reinforced by the findings of Susino et al (2023) which prove that the PBL learning model is better than the traditional learning model. One of the reasons is because the problems raised in the PBL model are real problems that are open and unstructured in everyday life, and the learning process requires systematic implementation (H. Saputra, 2021). Thus, PBL can train students to find solutions to the problems they face (Waldopo, 2012). Meanwhile, conventional learning focuses on the teacher, so students only receive explanations from the teacher. As a result, students do not have the opportunity to improve their mathematical proble-solving skills.

When viewed from the achievement of problem solving indicators, it is known that female students in "understanding the problem" are superior to men. This is in accordance with the results of Annisa et al (2021) which state that female students on the indicator of understanding the problem are better than male students. According to Dorisno (2019) one of the factors is that female students are more complete in making what is known and formulating problems so that they are able to understand the problem. In connection with this, Nursakiah & Ramdani (2022) said female students can repeat problem information by mentioning elements that they already know. In contrast, male students were less able to understand the problem well, so they did not complete writing what was known and formulating the problem. However, male students were superior in the indicators of "planning the solution", "performing calculations" and "checking the correctness of the results", compared to female students. Because male students are very meticulous, as evidenced by their carefulness, thorough planning of answers, precise calculations to arrive at the correct answer, and repeatedly checking their steps. This is in accordance with the results of Nuriadin et al (2022) who said that male students have better problem solving skills than female students, especially in terms of identifying relationships between topics and performing mathematical arithmetic operations more accurately.

Effect of Learning Model (Problem Based Learning and Conventional) on Students' Mathematical Problem Solving Ability

The results showed that the learning model has a significant effect on students' mathematical problem solving ability or in other words, there is a significant difference in problem solving ability between students who learn with problem-based learning (PBL) learning model and conventional learning model. It is known that learning with a problem-based learning (PBL) model can improve students' mathematical problem solving skills compared to conventional learning. This is in line with the research of D. E. N. Putri et al (2024) which states that PBL has a greater impact than conventional learning. The research results of Gultom (2022), Sihombing et al (2023) and Lathifah & Yolanda also show that the PBL model helps students solve mathematical problems better. Thus, it can be concluded that the PBL model is effective in improving students' ability to solve mathematical problems, as expressed by (Ramadoni & Admulya, 2023).

This can be explained because in problem based learning (PBL), students are given the opportunity to actively participate with the stages of PBL in the learning process. Starting from orienting students to the problem, diagnosing problems, conducting individual or group investigations, developing and presenting problem solving results, to evaluating (Supraptinah, 2019). With the PBL stages, students not only listen, record, and memorize subject matter, they also participate in active thinking, communicate, search and process data, and finally conclude (Sinurat & Surya, 2020). So that students' ability to solve mathematical problems will increase as a result of the problem-solving skills provided by the PBL stages. This process is different from conventional learning models that tend to be passive, where students only receive information from the teacher without much interaction with the learning material in depth. In accordance with this, Riyanto & Amidi (2024) said that the lack of opportunities for students to actively participate in learning can affect their ability to solve problems.

The Effect of Gender on Students' Mathematical Problem Solving Ability

The results of the analysis show that gender does not have a significant influence on students' mathematical problem solving ability. In other words, there is no significant difference in problem solving ability between male and female students. The same thing was also found by Jakhar (2019) research, which showed that gender has no significant effect on problem solving ability. Ingkiriwang et al (2021) also stated the same thing, that gender has no effect on student learning outcomes. According to Safri et al (2018) differences in problem solving refer more to the ability of an individual who refers to his way of thinking, thinking patterns or strategies in a particular problem. he results of this study prove that mathematical problem solving ability is more influenced by learning methods and the level of student engagement than gender factors. Therefore, Gender does not need to be the main consideration in designing mathematics learning, especially when using the PBL model.

The Interaction Effect Between Learning Model and Gender on Students' Mathematical Problem Solving Ability

The analysis also showed that there was no significant interaction between the learning model (PBL and Conventional) and gender (female and male) on students' mathematical problem solving ability. In other words, the effectiveness of the PBL model is not influenced by students' gender. This proves that PBL can be applied universally without worrying about gender differences. This means that PBL is a fair and equal approach and can provide benefits for all students, both male and female. This is also proven by Dorisno (2019) who found that PBL affects the problem solving ability of male and female students in the same way. Similar findings were also obtained by Herawati et al (2021) who found that male and female students both showed better learning outcomes when using the PBL model.

4. CONCLUSION

Based on the results of the research and discussion above, it can be seen (1) there is a significant effect between learning models (problem-based learning and conventional) onstudents' mathematical problem solving skills; (2) gender does not significantly affect students' mathematical problem solving skills, (3) there is no significant interaction between learning models and gender on students' mathematical problem solving skills. So it can be concluded that the problem-based learning (PBL) model is effective in improving students' mathematical problem solving skills without being influenced by gender. This finding provides empirical evidence that pbl is an inclusive and relevant learning strategy to be applied in mathematics learning.

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