The effect of the project-based learning model on students' mathematics problem-solving abilities

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Abstract

This research aims to investigate the impact of the project-based learning model on students' problem-solving abilities. The study employed a quantitative research methodology with a quasi-experimental design. Specifically, a pretest-posttest control group approach was used. The population under investigation consisted of all students in the Mathematics Education study program at the Faculty of Tarbiyah and Teacher Training (FITK), UIN North Sumatra Medan. The sampling technique employed cluster random sampling, resulting in 26 students from the PMM-2 class being selected as the experimental group, while 27 students from the PMM-1 class served as the control group. Data collection involved a problem-solving ability test in descriptive form. For hypothesis testing, the independent sample t-test was utilized, preceded by tests to assess normality and homogeneity. The analysis of post-test data revealed a significance value of $0.0000 < \alpha = 0.05$, leading to the rejection of the null hypothesis (Ho) and acceptance of the alternative hypothesis (Ha). This finding indicates a significant difference in problem-solving abilities between students who experienced the project-based learning model and those who underwent direct learning. In conclusion, the project-based learning model has a discernible influence on students' problem-solving abilities.

Keywords: Project based learning, Problem solving ability

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Introduction

According to Law Number 12 of 2012 concerning the aims of higher education, one of the aims of education at the tertiary level is to produce graduates who master a field of science and technology that will be applied and developed in social and state life. In line with the goals of higher education, according to (Muhammad & Karso, 2018), higher education students will go through a learning phase that leads to the development of knowledge, changes in rational thought patterns, and an independent character. To form rational thinking abilities, one of the thinking abilities that students should possess is a problem-solving ability.

Problem-solving ability is a student's ability to solve a problem that cannot be solved in a normal or non-routine way (Agustami et al., 2021). In solving various complex and non-routine problems, students can understand the problem and then apply appropriate procedures to solve the problem. This is in line with the opinion of (Rahmawati & Warmi, 2022) that problem-

solving ability is defined as a process of activities carried out by a person actively applying methods, procedures, and strategies to solve problems completely and fulfill the requirements that have been set. Another opinion regarding problem-solving abilities was expressed by (Nunung & Masri, 2020) in that problem-solving abilities are a process of high-level mental activity and require more complex thinking abilities. Through problem-solving activities in classroom learning, students can think more critically in analyzing a problem, and it can make students more skilled in understanding and solving a problem. Based on several opinions, it can be stated that problem-solving ability is the ability of students to solve non-routine problems until they are completed and meet the requirements and require a more complex way of thinking.

Problem-solving ability has several indicators as stated by (Polya, 1985), and those indicators of problem-solving ability include: (a) understanding the problem, namely determining what is known and asked, (b) making a plan to solve the problem, (c) solving the problem according to the plan that has been made and (d) recheck the solution obtained. Furthermore, according to (Hendriana et al., 2017) indicators of problem-solving ability are (a) understanding the problem; (b) formulating the problem in the form of a mathematical model; (c) choosing a solution strategy, (d) carrying out calculations or solving mathematical models; (e) interpret the results according to the initial problem and (f) recheck the correctness of the solution. Indicators of problem-solving abilities used in this research are understanding the problem, planning to solve the problem, resolving the problem according to plan, and checking again.

Solving ability is an important ability that must be developed by students, especially students of Mathematics Education study program, so students are expected to be able and accustomed to solving mathematical problems well, students will be able to use the problem-solving abilities they have in solving problems in the real world or their daily lives in the future (Amam, 2017). Similarly, (Dewi et al., 2020) stated that if students have good problem-solving skills, then these students will also have good analytical thinking skills which can be applied by students in dealing with various problem situations, especially open and non-routine problems. In line with the previous opinion of (Aliah et al., 2020), stated that students in everyday life are often faced with various problems that must be solved so by having problem-solving skills students will be accustomed to and able to develop appropriate strategies that can be used to solve the problems they face.

However, the statement above is inversely proportional to the facts in the field based on the research results of (Albab et al., 2017) it was found that out of 25 students who were given questions on problem-solving abilities, the results showed that 10 students answered the questions incorrectly and used inappropriate arguments, 10 students were able to answer up to the stage of understanding the problem, and 5 students answered up to the question modeling stage but the modeling they did was still not correct. Therefore, overall students have not been able to model problems correctly. Furthermore, the results of the initial test carried out by researchers on 27 students of the Mathematics Education study program, Faculty of Tarbiyah and Teacher Training, UIN North Sumatra Medan in the numerical methods course by giving problem-solving ability test questions, obtained quantitative data for 9 students (33.33%) who could answer questions well and correctly and according to the indicators of problem-solving ability, while 18 students (66.67%) other students could not answer the questions given

correctly and the answers given were not per the indicators of problem-solving ability. This shows that students' problem-solving abilities are still low.

Several factors influence students' low problem-solving abilities, one of the factors that has a big influence is the learning model applied by lecturers during class. According to Effendi, the low problem-solving abilities of students indicate that there is something that is not optimal in the learning used by lecturers so far where students are mostly passive during learning (Mariani & Susanti, 2019). This is because students only receive knowledge from lecturers and rarely explore knowledge so students' problem-solving abilities do not develop optimally. Based on the results of a preliminary study conducted by researchers regarding the learning applied by lecturers in numerical methods courses so far, the fact is that lecturers still often apply lecturer-centred learning models such as direct learning models in terms of delivering lecture material. Therefore, to improve students' mathematical problem-solving abilities, they need to be supported by appropriate learning models so that they can achieve the set learning objectives (Sumartini, 2018).

One innovative learning model that can be applied in learning that focuses on students' problem-solving abilities is project-based learning (Isro'atun & Rosmala, 2018) The project-based learning model is a learning model that uses real-world problems to produce new knowledge based on students' experiences (Daryanto & Raharjo, 2014). The problems presented are usually complex. Another opinion was expressed by (Trianto, 2018) who mentioned that the project-based learning model is a learning model that involves students in problem-solving and provides opportunities for students to learn independently in constructing their knowledge which ultimately produces products. In this learning, students will carry out authentic investigations to solve problems in the real world. Furthermore, according to (Wena, 2018), the project-based learning model is a learning model that provides educators with opportunities to manage learning by involving students in project work. Through the projects given, students will be trained in working together in working on projects and solving problems. Based on several experts above, it can be concluded that the project-based learning model is a learning model that uses projects to solve problems in the real world to construct new knowledge and produce products.

The main focus and goal in implementing project-based learning is to improve problem-solving abilities. This will make learning more meaningful because students not only understand the material being studied but can also understand the benefits of this material in their real lives (Kosasih, 2014). Apart from that, according to (Hosnan, 2014) the project-based learning model has characteristics in its application such as students trying to solve problems that do not have definite answers. Students also design the process that will be used to solve the problem. Therefore, it is hoped that the application of the project-based learning model will be able to improve students' problem-solving abilities.

Several previous studies related to the application of the project-based learning model to problem-solving abilities were carried out by (Muslim, 2017) where the research results showed that there was a positive influence of the application of the project-based learning model on students' mathematical problem-solving abilities. Apart from that, research by (Safithri et al., 2021) showed that research results showed that there was an influence of the application of PBL and PjBL learning on students' problem-solving abilities. The difference between this research and previous research lies in the application of project-based learning in

this research using the help of ICT-based learning media such as PowerPoint to present the results of problem-solving, video editing applications such as video maker to produce learning video products and the Canva application to create product designs. learning module. Based on the statement above, researchers are interested in conducting research with the title "The Effect of The Project-Based Learning Model on Students' Problem-Solving Abilities".

Methods

This research uses a quantitative research methodology using a quasi-experimental type of research. This research design uses a pretest-posttest control group design. This research was conducted at the Mathematics Education Study Program, Faculty of Tarbiyah and Teacher Training, UIN North Sumatra, Medan in the even semester of the 2022/2023 academic year. The research population was all students of the Mathematics Education study program, Faculty of Tarbiyah and Teacher Training, UIN North Sumatra, Medan. The sample in this study was selected using the cluster random sampling method so that the PMM-2 class was selected, totaling 26 people in the experimental class and the PMM-1 class, totaling 27 people in the control class. Research procedures include preliminary studies and problem identification, preparing research instruments and learning designs, determining population and samples, giving pre-test questions, implementing learning in numerical methods courses in 7 meetings, giving post-tests, collecting data, analyzing data, and drawing conclusions. Data collection in this research was carried out using problem-solving ability test instruments. The problem-solving ability test given is in the form of an essay test consisting of 4 questions. The problem-solving ability test questions given were previously validated by validators, namely 2 permanent lecturers from the Mathematics Education study program. The data analysis technique used in hypothesis testing is to carry out prerequisite tests first, namely normality and homogeneity tests. Normality testing was carried out using the Kolmogrov Sminornov test and data homogeneity testing was carried out using the Levene test.

Next, to test the hypothesis, use the independent sample t-test with $\alpha = 5\%$. The hypothesis tested is as follows.

H_0: There is no effect of the Project Based Learning learning model on students' problem-solving abilities.

H_a: There is an effect of the Project Based Learning learning model on students' problem-solving abilities.

The test criteria are to accept $H0$ if the significance value (sig) > 0.05 and reject $H0$ if the significance value (sig) < 0.05. Data analysis techniques are carried out using the help of data processing applications.

Results

Based on the results of the pre-test given by researchers to students in both the experimental and control classes, pre-test data on problem-solving abilities were obtained in the experimental and control classes which can be seen in Table 1. The data in Table 1 shows that the minimum pre-test score for students' problem-solving abilities in the experimental class is 18 and the minimum score for the control class is 18, so it can be stated that the minimum pre-test score for students' problem-solving abilities in both classes has the same value. The

maximum pre-test score for students' problem-solving abilities in the experimental class is 26 and the maximum score in the control class is 26, so it can be stated that the maximum pre-test score for students' problem-solving abilities in both classes has the same value. The average pre-test score for students' problem-solving abilities in the experimental class is 22.539 and the average score in the control class is 22.667, so it can be stated that there is a difference in the pre-test mean for students' problem-solving abilities in the experimental class and the control class, where the average score in the control class is 0, 1282 higher than the average value in the experimental class. Furthermore, the pre-test standard deviation of students' problem-solving abilities in the experimental class is 2.370 and the standard deviation value in the control class is 1.641, so it can be stated that there is a difference in the standard deviation value between the experimental class and the control class where the standard deviation value in the experimental class is greater than 0.726 if compared to the control class. This means that the pre-test data on students' problem-solving abilities in the experimental class is more spread out and has different data tendencies compared to the control class. The results of the pre-test on students' problem-solving abilities are also presented in the form of a bar chart as shown in Figure 1.

Table 1. Pre-Test Data on Students' Problem-Solving Abilities in the Experimental and Control Class

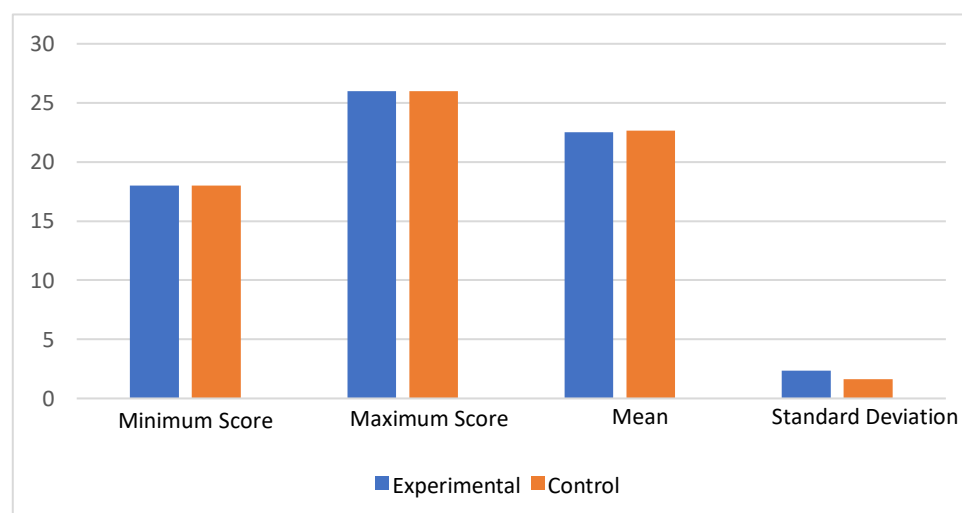| Class	Minimum Score	Maximum Score	Mean	Standard deviation
Experimental	18	26	22,539	2,370
Control	18	26	22,667	1,644

Figure 1. The Pre-test Data about Problem Solving Ability

Furthermore, the post-test scores for students' problem-solving abilities in both the experimental class and the control class can be seen in Table 2 below.

Table 2. *Post-test* Data about Students' Problem Solving Ability in the Experimental and Control Class

Class	Minimum Score	Maximum Score	Mean	Standard Deviation
Experimental class	28	38	33,920	2,965
Control class	22	32	27,410	2,763

The data in Table 2 shows that the minimum post-test score for students' problem-solving abilities in the experimental class is 28 and the minimum score for the control class is 22, so it

can be stated that there is a difference in the minimum post-test score for students' problem-solving abilities in the two classes, where the minimum post-test score for ability student problem-solving in the experimental class is higher than the control class and has a difference of 6. The maximum post-test score for students' problem-solving ability in the experimental class is 38 and the maximum score in the control class is 32 so it can be stated that there is a difference in the maximum post-test score for ability. Students' problem-solving in both classes where the maximum post-test score for students' problem-solving abilities in the experimental class was higher than the control class and had a difference of 6. The average post-test score for students' problem-solving abilities in the experimental class was 33.920 and the average score in the control class namely 27.410 so it can be stated that there is a difference in the post-test mean of students' problem-solving abilities in the experimental class and the control class where the mean score in the experimental class is higher than the mean score in the experimental class with a difference of 6.510. Furthermore, the post-test standard deviation of students' problem-solving abilities in the experimental class is 2.965 and the standard deviation value in the control class is 2.763 so it can be stated that there is a difference in the standard deviation value between the experimental class and the control class where the standard deviation value in the experimental class is greater than 0.202 if compared to the control class. This means that the post-test data on students' problem-solving abilities in the experimental class is more spread out and has different data tendencies compared to the control class. The results of the post-test on students' problem-solving abilities are also presented in the form of a bar chart as shown in Figure 2 below.
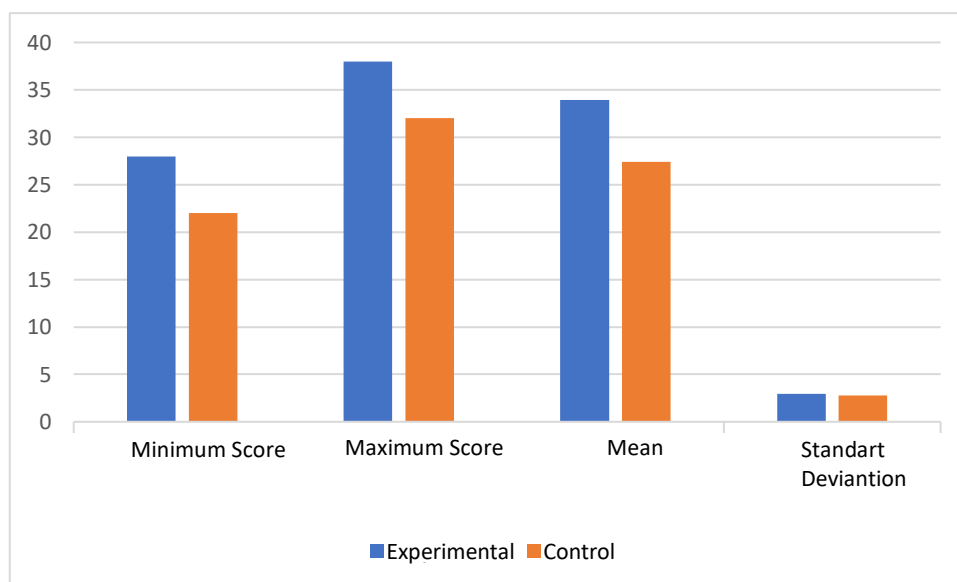

Figure 2. *Post-test* Data about Problem-Solving Ability

The post-test data on problem-solving abilities that have been obtained were analyzed using the t-test. However, before testing the hypothesis, prerequisite tests were out first, namely the normality test and homogeneity test. Post-test data normality testing was carried out using the Kolmogorov-Smirnov test which is presented in Table 3. Based on the results of the post-test data normality test on students' problem-solving abilities contained in Table 3, it was found that the significance value for the experimental class was $0.185 > \alpha = 0.05$ and the significance value for the control class was $0.184 > \alpha = 0.05$ where the significance value for both classes

has a value greater than 0.05 so it can be stated that the post-test data on students' problem-solving abilities in the experimental class and control class have a normal distribution, which means H0 is accepted. Next, the post-test data on students' problem-solving abilities will be tested for homogeneity using the Levene test which can be seen in Table 4.

Table 3. The Results of the Normality Test on Post-Test Data

Class	Significance
Experimental class	0,185
Control class	0,184

Table 4. The Results of the Homogeneity Test on Post-Test Data

Class	Significance
Experimental class	0,793
Control class	

Based on the results of the homogeneity test of the post-test data on students' problem-solving abilities in Table 4, it was found that the significance value for the experimental class and control class was $0.793 > \alpha = 0.05$ where the significance value in both classes had a value greater than 0.05 so it could be stated that the data The post-test of students' problem-solving abilities in the experimental class and control class has the same or homogeneous variance, which means that H0 is accepted.

After testing the prerequisites for post-test data on students' problem-solving abilities, the next step is hypothesis testing. Hypothesis testing was carried out using the independent sample t-test with a significance level of $\alpha = 0.05$. The results of testing the hypothesis can be seen in Table 5 below.

Table 5. The Results of the Hypothesis Test on Post-Test Data

	T	Df	Sig. (2-tailed)
t-test for Equality of Means	8,279	51	0,000
	8,268	50,402	0,000

Based on Table 5 of hypothesis testing, the significance value (Sig 2-tailed) is obtained, namely $0.000 < \alpha = 0.05$ so it can be stated that $H0$ is rejected and Ha is accepted. This means that there is a significant difference in the problem-solving abilities of students who apply project-based learning and the problem-solving abilities of students who apply direct learning. Therefore, it can be concluded that there is an influence of the project-based learning model on students' problem-solving abilities.

Discussion

Based on the research results, it was obtained that the experimental class pre-test obtained the lowest score of 18, the highest score of 26, the average of 22,538, and the final deviation of 2,370. Meanwhile, for the pre-test in the control class, the lowest score was 18, the highest score was 26, the average was 22.666 and the deviation was 1.664. The maximum and minimum scores for the experimental and control classes if seen to have the same value. This hall also showed that the pre-test general scores of students' problem-solving abilities in the experimental and control classes were not much different, namely 22.538 and 22.667. The

experimental class post-test results obtained the lowest score of 28, the highest score of 38, the average of 33.920, and the final deviation of 2.965. Meanwhile, the control class obtained the lowest score of 22, the highest post-test score was 32, the average score was 27,410 and a deviation score was 2,763. Jaldi, it was concluded that there were deviations in the problem-solving ability scores behind the experimental and control levels that occurred. However, if we compare the overall scores, the problem-solving abilities of students from the experimental class are higher than those from the control class. This is because the application of project-based learning can improve students' ability to solve problems, and make students more interactive and able to solve complex problems (Supiyanto, 2022).

Hypothesis testing was carried out using the independent sample t-test with a significant ratio of $\alpha \geq 0.05$. The results of the test regarding the hypothesis obtained a significance value (Sig 2-taliled) which was 0.000 smaller than the significance ratio of 0.05, so the results were concluded. This was accepted and Ho was rejected. This means that there is a difference in the ability of students to solve natural problems who are given project-based learning as opposed to the ability to solve problems of students who are given direct learning. There are differences in students' problem-solving abilities, one of which is influenced by the learning model factors applied by lecturers in class, especially the project-based learning model. This is because the learning steps contained in project-based learning such as the stages of determining topics, project planning and scheduling, investigation processes, and data analysis can influence students' high-level thinking abilities including problem-solving abilities. (Hamidah et al., 2020)

When studying project-based learning, students will focus on solving problems given by the lecturer as the main goal of learning (Nurfitriyanti, 2016). Therefore, the application of project-based learning begins by providing a problem in the form of a project that students must work on in groups consisting of 4-5 people in each group. The group formed is a heterogeneous group based on ability, ethnicity, and race. Students then discuss with their respective groups and also carry out investigations in completing the projects given by the lecturer. In the investigation process, students will collaborate with their group friends in collecting information and data, discussing, building hypotheses, and drawing conclusions from a problem. Apart from that, students also prioritize their ability to solve existing problems using the help of technology to produce a product or work. This is reinforced by the statement by (Rusydan & Sujatmiko, 2020) that the application of the project-based learning model has a distinctive characteristic, namely that learning is based on collaboration in the application of technology in learning and student learning independence in completing projects given by the lecturer. The lecturer's job here is only to act as a facilitator and supervise the discussion process.

Next, each group presented the results of their discussion in front of the class in turn while the other groups provided input and responses. In the final stage, students and lecturers make a summary and evaluation of the material they have studied. These project-based learning steps make students actively involved in learning. Apart from that, students also become trained in solving the problems given which influences students' ability to solve problems and their learning outcomes. (Amin et al., 2023) stated that the project-based learning model can provide students with a much more meaningful learning experience because students can construct their knowledge independently in order to produce products through the projects given. Students

will be faced with various problems presented in projects given by the lecturer which must be completed and this process will train students' problem-solving abilities.

Furthermore, the application of the direct learning model is different from the project-based learning model. The role of students is very minimal in conveying this learning material. This is because students only listen to explanations from the lecturer regarding the material being studied, take notes, and work on practice questions given by the lecturer. These activities tend to make learning monotonous. Apart from that, students are also not given the freedom to express their ideas or opinions in learning. As stated by Sanjaya, the direct learning model emphasizes one-way communication so that students' mastery of the material is limited to the lecturer's explanation. This will prevent students' creativity in solving problems from developing optimally (NH & Winata, 2016)

Based on the discussion above, it can be concluded that there is an influence of the application of project-based learning on students' problem-solving abilities. The problem-solving abilities of students who apply the project-based learning model are better than the problem-solving abilities of students who apply direct learning.

The results of this research are also following several previous relevant research results, such as the research results of (Rani et al., 2021) that there is an influence of the project-based learning model on mathematical problem-solving abilities. (Mardin & Zainil, 2019) research shows that there is a significant influence of the Project Based Learning (PjBL) model on students' problem-solving abilities where the problem-solving abilities of students given the Project Based Learning (PjBL) model are better than the problem-solving abilities of students on control class which were not given the Project Based Learning (PjBL) model. Furthermore, research by (Susanto et al., 2020) stated that the results of this research showed that the application of the project-based learning model affected students' problem-solving and critical thinking abilities in basic statistics learning. The difference in the results of this research compared to previous research is that the application of the project-based learning model in this research uses technological assistance in the form of applications to complete the given project and also to produce products in the form of learning videos and modules. The process of completing projects assisted by the use of technology will make students more active and successful in solving various complex problems. This will influence students' problem-solving abilities.

Conclusion

This research concludes that there is a significant influence of the application of the project-based learning model on students' problem-solving abilities. Therefore, researchers recommend the project-based learning model to be applied by lecturers in classroom learning.

Declarations

Author Contribution   :   LDA: Conceptualization, Writing-Original Draft, Supervision.

EKH: Methodology, Formal Analysis, Investigation.

PAL: Review & Editing, Visualization.

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