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The Effect of Project-Based Learning (PjBL) on Mathematical Logic Learning Results

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Abstract

This research is motivated by the fact that many students still have difficulties in mastering mathematical logic, one of which is caused by conventional learning methods that are theoretical and do not involve practical activities. This condition is supported by the low initial test results in the discrete mathematics course, where almost 50% of students show difficulty in solving mathematical logic problems. This study aims to analyze the effect of the application of Project-Based Learning (PjBL) on the learning outcomes of mathematical logic in students. The method used in the research is pre-experiment with one group pretest-postest design. The research subjects were 69 students majoring in informatics engineering in Jakarta. The instruments used were math logic pretest and posttest. The results showed that the application of Project-Based Learning affected the learning outcomes of mathematical logic. This can be seen from the increased percentage (P) which is 72.95% (pretest) and 86.84% (posttest). The results of statistical hypothesis testing with the Wilcoxon test obtained a sig value of 0.000 <0.05 which means that there is an increase in students' mathematical logic learning outcomes. PjBL has a significant effect on students' math logic learning outcomes.

Keywords: Project-Based Learning (PjBL), Learning Outcomes, Math Logic

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INTRODUCTION

Mathematical logic plays a very important role in education in the field of informatics engineering and computer science in general. As a basis of knowledge and understanding for students to understand discrete mathematics, programming, automata theory and other courses. It is a function that becomes the main basis in developing analytical and systematic thinking skills needed in solving various computational problems. Optimal learning outcomes are an important goal of the learning process. Learners' understanding of mathematical logic will be reflected in learning outcomes. The extent to which students understand, analyze and apply the concepts that are the basis in the field of informatics engineering. However, in reality there are still many students who have difficulty in mastering mathematical logic. One of the factors causing this is the conventional learning method that is theoretical and teacher centered and the lack of student involvement in the learning process in the classroom. Data obtained from pretest results at the beginning of discrete mathematics lectures, almost 50% of students have difficulty solving mathematical logic problems. Furthermore, the results of interviews with students obtained that mathematical logic is one of the difficult courses because many problems contain the process of proving with truth tables and how to formulate conclusions.

This issue encourages lecturers to re-evaluate the learning methods used in class. One of them is using various approaches so that the learning process is more active and meaningful for students. One approach that can be effectively implemented in learning is project-based learning (PjBL). Project-based learning (PjBL) is an approach that can accommodate students in carrying out activities and being actively involved more dominantly than lecturers. Learners are given the opportunity to discuss with the team in completing the project given to the team so that it can be completed according to the project collection limit. Learners learn how to communicate in conveying ideas and how to deal with differences of opinion in the team. Learners also determine what the completion process will be like for project completion, such as the division of tasks of team members, what tools and materials are needed, sources for obtaining project-related information and learning to share knowledge within the team. This approach encourages students to be active and intensive to communicate both among students and with lecturers so that more interactive learning is formed. Then (Requies, J.M. et al., 2018) also stated the results of his research that the relationship and communication between students and lecturers were closer after using Project-based learning (PjBL).

Various studies support the effectiveness of Project-based learning (PjBL) in improving the learning outcome process. Previous research conducted (Guo et al., 2020) and (Syahril et al., 2021)

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concluded that the application of Project-based learning (PjBL) can improve learning to be of higher quality overall. Furthermore, (Fitriyani et al., 2023) and (Jannah, 2024) showed the results of their research that the learning outcomes and activities of students increased with the use of Project-based learning (PjBL). Project-based learning (PjBL) has the potential to solve real problems as mentioned (Syahril et al., 2021) and that is the reason for choosing this approach to be implemented in learning mathematical logic in informatics engineering.

The importance of the role of mathematical logic in the basic knowledge of students to understand basic programming and analysis, and the lack of research that examines the effect of Project-based learning (PjBL) specifically in learning mathematical logic in informatics engineering. Therefore, this research was conducted to fill the void. The use of Project-based learning (PjBL) is expected to improve the learning outcomes of mathematical logic significantly from before. This research aims to provide better changes in the development of learning methods in improving the quality and learning outcomes of students in an increasingly advanced digital age.

Although, a number of studies that have examined Project-based learning (PjBL) resulted in an increase in mathematics learning outcomes in general (Fitriyani et al., 2023); (Mursyidah et al., 2024); (Wu, 2024), especially the category of problem solving and collaboration (Syahril et al., 2021); (Requies, J.M. et al., 2018), there is still a lack of research that specifically examines the application of Project-based learning (PjBL) to improve mathematical logic learning outcomes in informatics engineering majors, there is still a lack of research that specifically examines the application of Project-based learning (PjBL) to improve learning outcomes of mathematical logic in informatics engineering majors. Based on the unique and complex characteristics of mathematical logic, the right learning approach is needed (Anugrahana, 2021). Therefore, this study aims to determine the effect of Project-based learning (PjBL) on learning outcomes of mathematical logic. The novelty of this research is seen in its focus, namely applying Project-based learning (PjBL) to mathematical logic courses in informatics engineering.

RESEARCH METHOD

This type of research is pre-experiment research. The method used is one-group pretest-postest design. The research design can be seen in the following figure (Duwila et al., 2019)

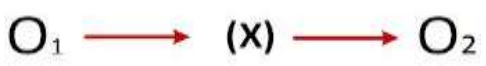


Figure 1. One Group Pretest and Postetest

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Description:

O_1 = Pretest in the experimental class

X = class that gets treatment

O_2 = Post-test in the experimental class

This study involved 77 students in the second semester of the informatics engineering study program in the 2023/2024 academic year. The group selection was done specifically (purposive sampling) because the focus of the research was to evaluate how successful the use of project-based learning (PjBL) was in my class. The selection of classes was done intentionally (not randomly). However, the selection of classes was based on the suitability of achieving optimal research objectives. Students in this class directly participated in the application of project-based learning (PjBL) during mathematical logic learning so that the data obtained was more in-depth and meaningful.

The following is a research process design that illustrates the effect of project-based learning (PjBL) on student learning outcomes in mathematical logic courses.



Figure 2. Research Activity Design

Pretest and postest were used as research data collection. Both were given to students in the form of 3 essay questions. Learners were given pretest questions at the beginning before the application of project-based learning (PjBL). This is done to determine the initial ability of students. Furthermore, students will be given a posttest question after the application of project-

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based learning has been carried out so that these results can determine the extent to which the results of the learning evaluation have been achieved. The research data were analyzed using the formula for the percentage of scores obtained by students. The following is the percentage score formula:

$$P = \frac{Average\ score}{Maximum\ score} \times 100\%$$

Source: (Duwila et al., 2019)

Furthermore, categorizing the percentage results with the Benchmark Guidelines (PAP) which consists of a scale of five as follows:

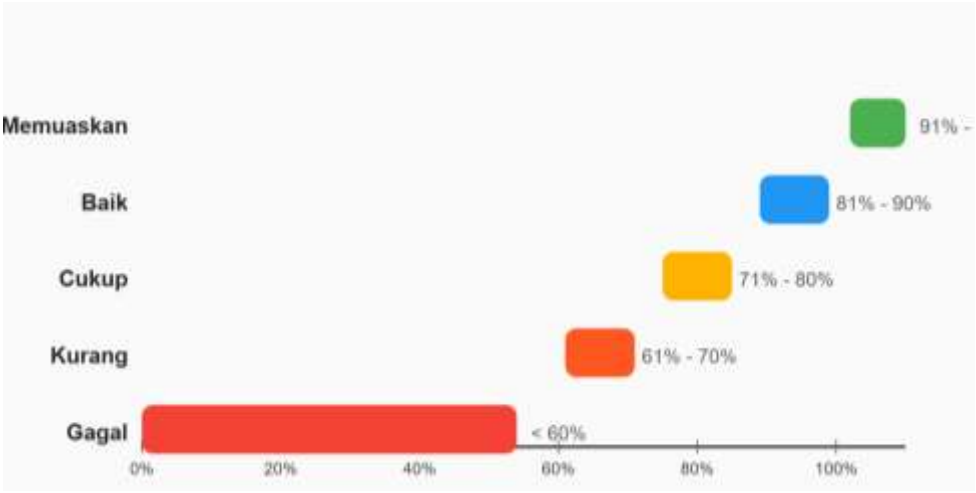


Figure 3. Benchmark Guideline
Source: (Duwila et al., 2019)

Before the data analysis process, it is necessary to conduct a prerequisite test by conducting a normality test using the shapiro-wilk method with the help of SPSS software version 24. This test is used because the number of samples is more than 50 students. Data is considered normally distributed if the significance value (P) is greater than 0.005 (P> 0.005) (Aziz et al., 2021). Furthermore, hypothesis testing is carried out using paired-sample t-test if the data is normally distributed. However, if the pretest or postest data is not normally distributed, then the next step is to conduct a non-parametric wilcoxon test. Hypothesis testing criteria are if the significance value (2-tailed) <0.05, then the alternative hypothesis (H_a) is accepted and the hypothesis (H_o) is rejected. Conversely, if the significance value (2-tailed) > 0.05, the hypothesis (H_o) is accepted and

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the alternative hypothesis (H_a) is rejected (Astuti & Julaeha, 2021). Thus, this research method is designed in order to analyze the effect of project-based learning in improving students' learning outcomes in mathematical logic courses.

RESULT AND DISCUSSION

Research result

A significant increase in the percentage of scores was obtained from the results of pretest and posttest data of students who had participated in project-based learning and worked on mathematical logic problems. This can be seen from the pretest value of 72.95% and the postest value of 86.84%. Based on the Benchmark Guidelines (PAP), the pretest score is in the sufficient category with a range of 71% - 80%. While the postest score is in the good category with a range of 81% - 90%.

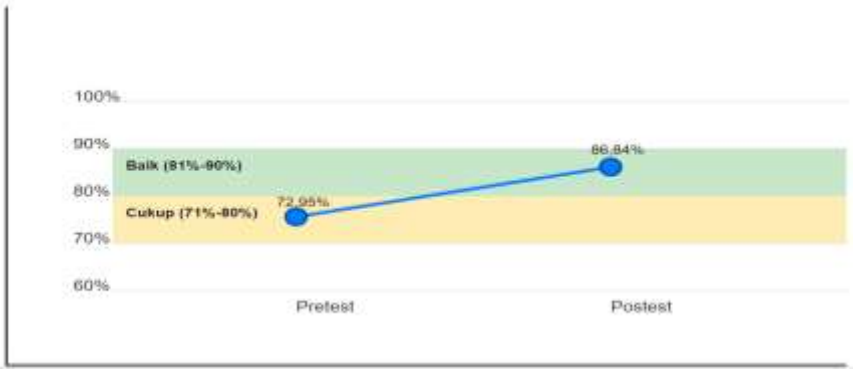


Figure 4. Graph of Pretest and Posttest Scores Based on PAP

Prerequisite tests in conducting data analysis for normality tests using shapiro-wilk. Data criteria are considered normal if the significance value (P) is greater than 0.05 (P> 0.05). The normality test results show that the data is not normally distributed because the significance value obtained from the pretest is 0.10 and the posttest is 0.00. The data is not normally distributed because the P value is greater than 0.05. Data that are not normally distributed may be caused by uneven data distribution (Rahmawati, 2015). Therefore, it is necessary to do the Wilcoxon test. The criteria for this study are if the results of the hypothesis test show a significance value (2-tailed) smaller than the alpha / significance level of 0.05, then Ha is accepted and Ho is rejected. The following data were obtained based on the results of measuring the pretest and posttest learning scores of mathematical logic with the application of project-based learning (PjBL).

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Table 1. Wilcoxon Test Results

	N	Mean Rank	Sum of Ranks
Negative Ranks	7[a]	25.36	177.50
Positive Ranks	69[b]	39.83	2748.50
Ties	1[c]		

Based on table 1, it can be seen that 69 students showed an increase (positive rank) by comparing the posttest and pretest. This can be interpreted that there are 69 students experiencing an increase in learning outcomes in mathematical logic through PjBL from pretest to posttest. Then there are 7 students who show a decrease (negative ranks). This means that there are 7 students experiencing a decrease in learning outcomes in mathematical logic through PjBL from pretest to posttest. It should be noted that this increase is not only in larger numbers, but also more meaningful when viewed from the average rank (Mean Rank) and the total number of ranks (Sum of Ranks), where positive ranks have a higher average rank (39.83) and a much larger total number of ranks (2,748.50) compared to negative ranks (25.36 for Mean Rank and 177.50 for Sum of Ranks). Furthermore, Ties, which show similarities between pretest and posttest results, were recorded as many as 1 learner. This indicates that there is one learner who gets the same score on the pretest and posttest or it can be interpreted that there is only one learner where there is no change between the pretest and posttest results. Thus, these results show that in general, there was a significant improvement from pretest to posttest results, with only a few cases showing a decrease or no change at all.

Table 2. Wilcoxon Statistical Test

Statistic	Value
Z	-6.657b
Asymp. Sig. (2-tailed)	.000

The basis for decision making in the Wilcoxon test:

1. If the Asymp.Sig (2 tailed) value is smaller than < 0.05, then Ha is accepted.

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2. Conversely, if the Asymp.Sig (2 tailed) value is greater than > 0.05, then Ha is rejected.

Based on the existing output, it is known that Asymp.Sig (2 tailed) is obtained 0.000 which is smaller than 0.05 so that Ha is accepted. This can be interpreted that there is an increase between the learning outcomes of mathematical logic for pretest and postest so that there is an effect of PjBL in improving students' mathematical logic learning outcomes. Learning implemented with PjBL has an effect on learning outcomes of mathematical logic. The pretest and posttest instruments used are quantitative data. The lowest scores of pretest and posttest results are 5 and 41, which is a difference of 36. Then seen from the average learning outcomes obtained for pretest and posttest, namely 69.73 and 86.84. The average difference from pretests and postests is as much as It shows that the learning outcomes of students increase through the application of PjBL. This is in accordance with some previous research results, namely (Mayangsari, 2017; Widiastutik et al., 2023; Amrilizia et al., 2023) which state that PjBL can improve student learning outcomes.

Judging from the results of students' math logic pretest and posttest answers, PjBL can have an influence on math logic learning outcomes. If analyzed for the results of pretest and posttest student answers after the application of PjBL in mathematical logic. The following is an example of solving pretest and posttest questions done by students.

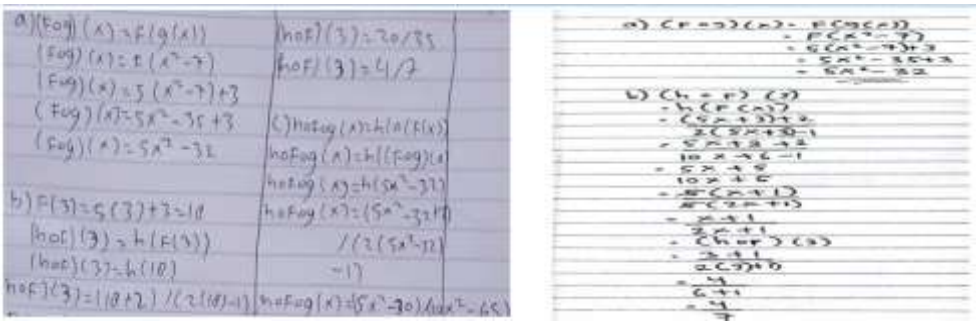


Figure 5. Answers to Pretest and Posttest Question 1

In Figure 5. it can be seen that the results of students' answers in the pretest in solving function composition problems are still not systematic from abstract to real. There is a completion process that is not visible. students do the completion process by directly finding the value of f(3) and entering the results into h(x). Learners should determine fog(x) first before solving fog(3) so that the completion process will look systematic. Learners only focus on the result of fog(3). Whereas in the posttest answers, students solve the function composition

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problem starting from determining fog(x) and continuing with fog(3). Students solve the problem systematically so that it can be seen the process of getting fog (x) to get fog (3). Furthermore, the solution to question 2 can be seen in Figure 6 below.

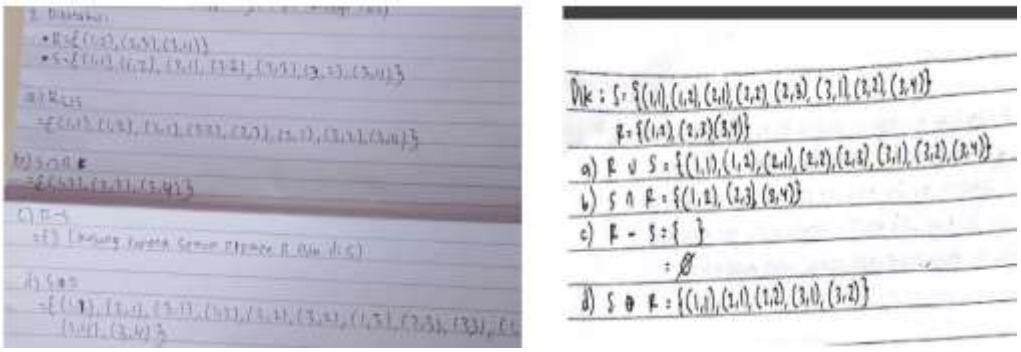


Figure 6. Results of Pretest and Posttest Answers to Question 2

In Figure 6. it can be seen that the results of students' answers in the pretest in solving the relation combination problem still found errors in using operations on relation combinations. In the pretest answers, students already understand the concept of solving the combination of relations with conjunction, disjunction and difference operations. However, students still misunderstand the concept of solving symmetric difference operators. In the symmetric difference operator, students should combine the results of (R-S) with (S-R) and not include the R slice of S. However, students write the slices of R and S, namely (1,2), (2,3) and (3,4). Furthermore, in the posttest answers, students can complete the process of solving combination relation problems correctly, both conjunction, disjunction, difference and symmetrical difference.

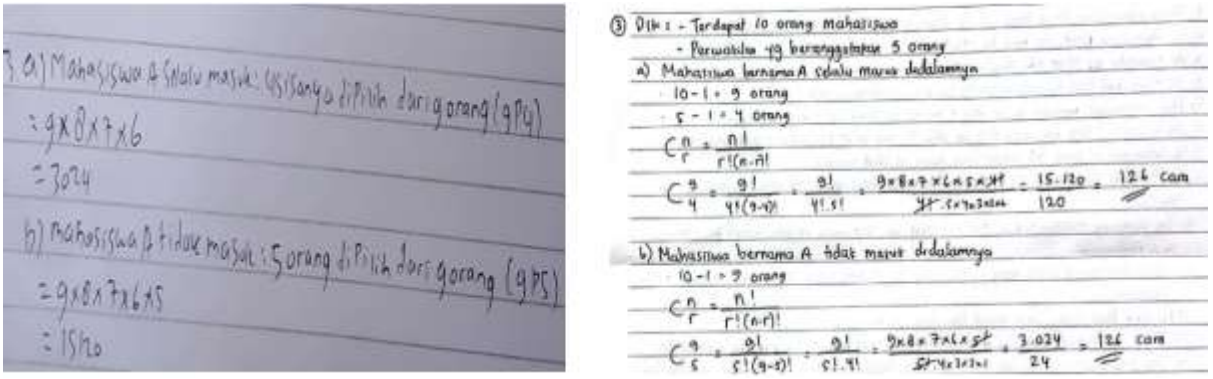


Figure 7. Results of Pretest and Posttest Answers to Question 3

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In Figure 7. it can be seen that the results of students' answers in the pretest in solving combination problems are still found errors. Learners do not understand the concept of combination so they make the wrong solution. Whereas in the posttest, students were able to explain the steps to solve the problem systematically and clearly. Understanding the concept of good material will show a coherent and clear solution process.

DISCUSSION

This study proves that the application of the Project-Based Learning (PjBL) learning model contributes significantly to improving student learning outcomes in Mathematical Logic material. This can be seen from the comparison of pretest and posttest scores which experienced a considerable increase, from 72.95% (fair category) to 86.84% (good category). Statistical analysis using the Wilcoxon test also supports this finding, with an Asymp. Sig. (2-tailed) of 0.000, which is smaller than the significance level of 0.05. Thus, the alternative hypothesis (Ha) is accepted, which means there is a significant difference between learning outcomes before and after the application of PjBL. These results indicate that the project-based learning method is effective in improving students' understanding of the material studied. This is in line with the findings of research conducted by (Widiastutik et al., 2023) which found that PjBL can improve concept understanding ability in mathematics. Furthermore (Mayangsari, 2017) also found that PjBL was effective in improving student learning outcomes. (Amrilizia et al., 2023) also found that PjBL can improve problem solving skills.

In addition, the analysis of students' answers on the pretest and posttest showed an improvement in their mindset and problem-solving approach after the application of PjBL. In the function composition problem (Figure 4), before the application of PjBL, students tended to directly find the final result without going through a systematic solution process, so the steps were less structured. However, after participating in project-based learning, they understood the importance of arranging the solution in stages, namely by determining fog(x) first before solving fog(3). The same can be seen in the relation combination problem (Figure 5), where before the application of PjBL, students still experienced errors in understanding the concept of symmetric difference operator, because they included the result of $R \cap S$, which is not actually included in the operation. After being given project-based learning, they were able to understand the concept better and apply it correctly. Similarly, in the combination problem (Figure 6), before the application of PjBL, students still have difficulty in understanding the concept of combination so that the solutions they make are less precise. However, after participating in project-based

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learning, they were able to explain the solution steps more systematically and accurately.

Overall, the results of this study are consistent with previous research which states that the application of Project-Based Learning (PjBL) can improve student learning outcomes. This learning model provides opportunities for students to be more active in exploring concepts, understanding the relationship between theory and practice, and practicing critical thinking skills in solving problems. In addition, PjBL also encourages students to be more independent in finding solutions to the problems given, so that their understanding of the concepts learned becomes deeper. Thus, the application of PjBL in learning Mathematical Logic is proven effective in improving learning outcomes, both in terms of academic achievement and skills in structuring problem solving in a more systematic and structured manner.

The novelty of this research is seen from the use of Project-Based Learning (PjBL) with mathematical logic in informatics engineering. The results of this study are expected to provide a significant empirical contribution for lecturers in improving the quality of mathematical logic learning. This research has limitations in terms of its implementation which is carried out on a small scope of students in informatics engineering. This research is still limited in discussing the learning outcomes of mathematical logic and has not discussed the product results of the project. Therefore, this research can be developed again in various existing courses so that it can be seen the effectiveness and influence of Project-Based Learning (PjBL) on student learning outcomes. Recommendations for future researchers to be able to integrate Project-Based Learning (PjBL) assisted with various types of interactive media to see motivation, activity, mathematical ability, numeracy literacy and digital literacy as well as learning outcomes of mathematical logic and other courses in informatics engineering. in addition, researchers can see how numeracy literacy and digital literacy of students on the products produced.

CONCLUSION

The application of project-based learning (PjBL) in informatics engineering is proven to improve student learning outcomes in mathematical logic courses, with an increase in the average score from 72.95% (good category) in the pretest to 86.84% (good category) in the posttest. This means that the greater the influence of PjBL, the better the learning outcomes of students' mathematical logic. Recommendations for further research are to examine the effect of students' self-efficacy on students' mathematical logic learning outcomes. The study is also expected to see how the improvement of students' mathematical logic learning outcomes. Furthermore, studies on the effect of PjBL in numeracy literacy and digital literacy and so on.

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