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THE EFFECT OF THE PROJECT BASED LEARNING MODEL ON THE IMPLEMENTATION OF DEEP LEARNING IN IMPROVING MATHEMATICS LEARNING OUTCOMES

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ABSTRACT

This research is focused on enhancing the mathematics achievement of students in eleventh grade in the area of Statistics by utilizing Project Based Learning to facilitate deep learning. The approach adopted is a quasi-experimental design with pre-tests and post-tests involving two groups of 72 students (with XI-1 as the experimental group and XI-4 as the control group) employing essay assessments and observational methods at SMA Negeri 1 Aek Natas. Findings revealed that the average post-test score for the experimental group improved by 19.17, surpassing the control group's score of 17.08. The independent sample t-test yielded a significant value of 0.007 (<0.005), indicating a notable difference between the two groups. Furthermore, the N-gain for the experimental group was 41.19% (medium category), significantly greater than the 5.8% (low category) recorded for the control group. In summary, the utilization of Project Based Learning (PJBL) in the experimental class effectively contributes to the enhancement of mathematics learning outcomes and promotes student participation in mathematics education within secondary schools.

Keywords: Project Based Learning, Deep Learning, Mathematics Achievement.

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PRELIMINARY

Mathematics education in Indonesia still faces many obstacles due to its abstract nature, particularly in statistics, which negatively impacts student learning outcomes (Sulistyo & Alyani, 2021; Wahyuni & Sholichah, 2022). Various studies have shown that learning models dominated by lectures and routine exercises tend to make students bored and ultimately lose focus on the lessons being studied (Pabesak et al., 2023). Conversely, the Project-Based Learning (PJBL) model, in the implementation of deep learning, has been shown to increase student engagement and mathematics achievement in high school. Project-Based Learning (PJBL) in mathematics learning increased student learning outcomes by 18% compared to traditional methods(Niswara et al., 2019; Nurhayati et al.,

2019). These findings suggest the need for teachers to redesign more meaningful project-based mathematics learning without neglecting the demands of learning outcomes(Sumardi, 2024).

A similar condition is seen in mathematics learning at SMAN Negeri 1 Aek Natas in grade XI. The evaluation results show that the average student score does not touch the minimum completion criteria (KKM) applied in schools, this is known from the semester exam scores for mathematics lessons so that the average score for grade XI is between 60 and 68 while the highest score is 88 and the lowest score is 65, with 15 out of 36 students completing the course. So it can be concluded that there are 21 students whose scores do not reach the KKM. More than 55% of Indonesian students experience difficulties in solving reasoning-based questions and contextual problem solving (Yumna Durrotul Hikmah, 2024). This shows that learning still emphasizes memorizing formulas and procedures without conceptual understanding (Mulyono, 2018). Thus, an approach is needed that can bridge the characteristics of children's reasoning development that is close to in-depth learning so that students not only know the basic concepts but also direct students to be more active in working on questions and collaborating with each other(Inayah et al., 2025).

In this context, various studies recommend learning methods as a strategy to concretize mathematical concepts and foster student learning motivation (Suhermi, 2025). A study (Nurhadiyati et al., 2020) found that Project-Based Learning (PJBL) can strengthen students' sense of responsibility and collaboration in completing contextual mathematics projects. More specifically, a study (Irfan Masrur, 2025) emphasized that Project-Based Learning (PJBL) can foster metacognitive abilities because students learn to process projects, make decisions, and reflect on the in-depth learning process that aligns with the principles of deep learning in an educational context(Raisah et al., 2024).

On the other hand, (Fadhilla, Y. U., & Afri, 2024) explained that deep learning encourages students to search for meaning, connect ideas, and apply concepts in new situations. In mathematics learning, this means students not only understand formulas mechanically but are also able to explain why and how a mathematical concept applies in a particular context. The integrity of Project Based Learning (PJBL) and deep learning provides a great opportunity to create learning experiences that not only improve learning outcomes but also foster critical thinking and complex problem-solving skills(Fitriyah & Ramadani, 2021; Nurhadiyati et al., 2020).

Similarly, research conducted by (Saabighoot, 2023) revealed that 72% of schools in Indonesia still face challenges in supporting project-based learning facilities, such as collaborative spaces and digital learning resources. This obstacle stems from students' learning culture, which is still accustomed to passively receiving information. These challenges highlight the gap between the theory and practice of implementing Project-Based Learning (PJBL) and deep learning in the field(Krisjayanti et al., 2024).

Similarly, based on the above research, there are still limited studies that specifically examine the application of the Project Based Learning (PJBL) model to the implementation of deep learning to improve students' mathematics learning outcomes in statistics material for grade XI in senior high schools in the context of the Indonesian curriculum(Abdullah & Munawwaroh, 2024). Based on this gap, this study aims to improve mathematics learning outcomes for grade XI students in statistics material through the application of the Project Based Learning (PJBL) model with a deep learning approach. Specifically, this study seeks to describe the improvement in students' mathematics learning outcomes and provide practical recommendations for teachers in developing optimal learning to align with the principles of deep learning that emphasize in-depth understanding, reflection, and application of concepts.

METHODS

This study uses a quasi-experimental research design with a pre-test and post-test control group design approach that appliestreatment(treatment) in 2 classes, namely the control and experimental classes(Abraham & Supriyati, 2022; Yandiana & Ariani, 2020). The sample selection technique used is simple random sampling. The research subjects were 72 students of class XI-1 (experimental class) consisting of 36 students and class XI-4 (control) consisting of 36 students withsimple random sampling techniqueat SMA Negeri 1 Aek Natas in the 2025/2026 academic year. The focus of the action is the implementation of the Project Based Learning (PJBL) model with a deep learning approach to statistics material. The Project-Based Learning (PJBL) model in this study was implemented through structured stages that included defining contextual problems, planning and implementing statistics projects, presenting results, and reflecting on learning that emphasized the connection between concepts and students' real-life experiences. Through these stages, PJBL was designed to encourage active engagement, collaboration, and in-depth conceptual understanding, enabling students to develop analytical, reasoning, and critical thinking skills in statistics.

The instruments used include: (1) pretest and posttest containing 5 essay-style questions, (2) direct observation at school. All instruments have undergone content validity testing using Aiken's V formula and reliability testing using Cronbach's Alpha, so they are suitable for use as data collection tools Selafia, S., (2025).

Validity testing using Aiken's V formula

$$V = \frac{\sum 8}{N(c-1)} \quad (1)$$

Reliability testing using Cronbach's Alpha

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum \sigma_i^2}{\sigma_t^2}\right) \quad (2)$$

The posttest was structured in the form of 5 essay questions that referred to the indicators of mathematics learning outcomes and the principles of deep learning, namely, (1) conceptual understanding, (2) data analysis and processing skills, (3) reasoning and drawing conclusions, (4) application of concepts in the context of real problems. The action procedure involves preparing a lesson plan based on Project Based Learning (PJBL) with a deep learning approach, determining the research sample. During the action, students work collaboratively to plan, implement, and present a statistics project relevant to everyday life. The researcher acts as the teacher, while the observer observes the learning process. Data analysis was conducted quantitatively by calculating the average value, percentage, and N-gain score to determine the improvement in student learning outcomes. Prior to hypothesis testing, the data were tested for normality using the Kolmogorov–Smirnov test and for homogeneity using the Levene test. Furthermore, hypothesis testing was conducted using paired sample t-tests and independent sample t-tests with a significance level of 5%.

RESULT AND DISCUSSION

This research was conducted at SMA Negeri 1 Aek Natas in the even semester of the 2025/2026 academic year, involving two sample classes: class XI-1 as the experimental class and class XI-4 as the control class. The experimental class was given treatment in the form of the application of the Project Based Learning (PJBL) model oriented to the

principles of deep learning, while the control class was given conventional learning using lecture methods and practice questions.

Student learning outcomes were obtained from the posttest scores given after the implementation of the Project Based Learning (PJBL) model in the experimental class. The posttest was structured in the form of 5 essay questions that referred to the indicators of mathematics learning outcomes and the principles of deep learning, namely, (1) conceptual understanding, (2) data analysis and processing skills, (3) reasoning and drawing conclusions, (4) application of concepts in the context of real problems. Based on the results of the posttest score calculations, the percentage variations in student learning outcomes were obtained below.

Table 1. Description of Student Learning Outcomes

Percentage Value (%)	Number of Students	Student Presentation	Information	Question number
100	7	18%	All indicators achieved	1,2,4
67	2	6%	Almost all indicators were achieved	2,4
50	3	8%	Key indicators achieved	2,5
40	1	3%	Conceptual understanding and initial analysis	1,4
33	1	3%	Understanding basic concepts	2,3
25	3	8%	Partial understanding of the concept	1,2
22	2	6%	Limited conceptual understanding	3,1
21	1	3%	Limited conceptual understanding	1,5
20	4	11%	Initial understanding	2
18	3	8%	Initial understanding	1
17	2	6%	Initial understanding	1
15	3	8%	Very limited understanding	3
14	2	6%	Very limited understanding	3
13	1	3%	Very limited understanding	3

Percentage Value (%)	Number of Students	Student Presentation	Information	Question number
Amount	36	100%		

Based on table 1, it is known that each student obtained a different percentage of post-test scores according to the level of achievement of the mathematics learning outcome indicators 7 students (18%) got 100%, which indicates that the student is able to meet all learning outcome indicators, starting from conceptual understanding, the ability to analyze and process data, reasoning in drawing conclusions, to the application of concepts in the context of real problems. Meanwhile, students who obtain a percentage of the value 67% and 50% shows that most of the learning outcome indicators have been achieved, especially the indicators of understanding concepts and data analysis, although there are still shortcomings in the aspect of advanced reasoning or accuracy in drawing conclusions, furthermore, students with a percentage of grades 40% and 33% have generally achieved the indicator of understanding basic concepts, but have not been fully able to relate the concept to contextual problems. Next, students who obtain25% to 20%This indicates that the learning outcomes are still at the initial understanding stage. In this category, the dominant indicator achieved is partial conceptual understanding, while analytical, reasoning, and conceptual application skills have not developed optimally. Meanwhile, students with a percentage of grades18% to 13%indicates that the mathematics learning outcome indicators have not been optimally achieved. Students in this category are generally only able to identify basic information from the problem, but have difficulty analyzing data, drawing conclusions, and applying statistical concepts appropriately. The results show that each student's posttest score percentage reflects a different level of achievement of the mathematics learning outcome indicators. In general, the implementation of the Project Based Learning (PJBL) model can encourage some students to achieve the learning outcome indicators fully, while helping others begin to develop a deeper understanding.

Table 2. Results of the Kolmogorov-Smirnov Normality Test

Class	Measurement	Sig.	Results
Control	Pretest	0.136	Data Normal
	Posttest	0.137	Data Normal
Experiment	Pretest	0.103	Data Normal
	Posttest	0.060	Data Normal

According to the findings from the normality assessment conducted with the Kolmogorov-Smirnov approach, the significance figures for the control group were 0.136 during the pretest and 0.137 following the posttest. In the experimental group, these values were 0.103 for the pretest and 0.060 for the posttest. Every significance value surpassed 0.05, which leads to the conclusion that the data for both groups were considered to follow a normal distribution. These findings suggest that the distribution of the results from students' learning, both prior to and after the treatment, has satisfied the criteria for normality, making it suitable for evaluation through parametric statistical methods.

Table 3. Homogeneity Test Results

Score	Levene Statistic	Sig.	Results
Posttest Control & Experiment	0.223	0.638	Homogeneous

Moreover, the outcomes of the homogeneity assessment conducted through Levene's test revealed a significance figure of 0.638, exceeding the threshold of 0.05, thus confirming that the variance in the posttest results for both the control and experimental classes is homogeneous. This result signifies that the data variability within both groups is fairly alike. Given that both the assumptions of normality and homogeneity have been satisfied, the comparison of academic achievements between these two classes can proceed utilizing parametric tests.

Table 4. Paired Sample T Test for Control Class

Measurement	Mean	Sig.	Results
Pretest	17.03	0.535	No Different
Posttest	17.08		

According to the findings of the paired sample t-test conducted in the control group, the mean score for the pretest stood at 17.03, while the mean score for the posttest was 17.08, suggesting a marginal increase in scores. The obtained significance level was 0.535, which exceeds 0.05, indicating that the variation between the pretest and posttest scores lacked statistical significance. Therefore, the null hypothesis (H0) was upheld while the alternative hypothesis (H1) was dismissed, signifying that there was no noteworthy difference in educational outcomes prior to and following traditional teaching methods. This result suggests that traditional approaches utilized in the control class have not succeeded in significantly enhancing mathematics learning achievements.

Table 5. Paired Sample T Test for Experimental Class

Measurement	Mean	Sig.	Results
Pretest	17.28	0.000	Significantly Different
Posttest	19.17		

According to the outcomes from the paired sample t-test conducted in the experimental group, the average score on the pretest was recorded at 17.28, rising to 19.17 following the posttest. This rise suggests an enhancement in educational achievements after the introduction of the Project Based Learning (PJBL) approach. The obtained significance value was 0.000, which is less than 0.05, thus confirming that the variation between pretest and posttest scores is statistically noteworthy. Consequently, the null hypothesis (H0) has been dismissed while the alternative hypothesis (H1) has been upheld, indicating a significant disparity in educational results prior to and subsequent to the intervention. These results show that employing the Project Based Learning (PJBL) model effectively boosts students' mathematics learning outcomes related to statistical concepts.

Tabel 6. Uji Independent Sample T Test Posttest

Class	Mean	Sig.	Results
Control	17.08	0.047	Significantly Different
Experiment	19.17		

According to the findings from the independent sample t-test regarding the posttest results, the average educational performance of the control group was 17.08, whereas the experimental group achieved an average of 19.17. The significance level found was 0.047, which is less than 0.05, indicating a notable distinction between the two groups. Consequently, the null hypothesis (H0) is dismissed, and the alternative hypothesis (H1) is confirmed, suggesting there is a difference in mathematics educational performance among pupils engaged in traditional learning compared to those utilizing the Project Based Learning (PJBL) approach. These findings demonstrate that employing the PJBL model proves to be more effective than traditional teaching methods in enhancing students' performance in mathematics concerning statistical content.

Tabel 7. N Gain Score

Class	N Gain Score	Criteria
Control	5.8%	Low
Experiment	41.49%	Currently

According to the results derived from the N-gain calculations, the group that served as the control registered an increase of 5.8% in their learning results, a figure deemed low. This suggests that traditional teaching approaches, such as lectures, yield minimal improvements in educational outcomes and do not effectively aid students in comprehending statistical concepts at an optimal level. Conversely, the experimental group recorded an N-gain value of 41.4%, which is regarded as moderate. These findings imply that employing the Project Based Learning (PJBL) model leads to superior learning outcomes in comparison to the control group. Therefore, it can be inferred that the PJBL approach is more successful in enhancing students' mathematics learning achievements by fostering a more engaging, relevant, and meaningful educational experience.

Comparison of Learning Outcomes of Experimental Class and Control Class

A comparison of learning achievements between the experimental group and the control group was conducted to evaluate the impact of the Project Based Learning (PJBL) approach on the execution of learning, especially concerning deep learning. According to the findings from the analysis, the experimental group demonstrated superior learning outcomes in comparison to the control group, both in posttest scores and in the enhancement of learning results.

In the experimental group, the mean posttest score was found to be 19.17, supported by a thorough independent sample t-test analysis. In contrast, the control group displayed student learning outcomes that fell within the low to moderate range, averaging at 17.08, with a significance level of 0.047 (which is less than 0.05). These findings suggest that students who engaged with the Project Based Learning (PJBL) framework experienced improved learning outcomes, which facilitated greater student participation and fostered deeper learning skills when compared to those who learned through traditional methods. Therefore, it was established that the Project Based Learning (PJBL) approach was more effective in enhancing students' performance in mathematics.

Improving Learning Outcomes Based on N-Gain

Based on the N-Gain calculation, the increase in learning outcomes in the control class was 5.8%, categorized as low, while in the experimental class it was 41.49%*, categorized as medium. This difference indicates that the PJBL model has a greater impact on improving student learning outcomes. The N-Gain results reinforce the findings of previous statistical tests that project-based learning is able to improve students' conceptual understanding, critical thinking skills, and problem-solving skills compared to conventional learning.

CONCLUSION

Drawing from the findings and discussions, it is evident that the use of the Project Based Learning (PJBL) approach focused on deep learning in the context of statistics education at SMA Negeri 1 Aek Natas has effectively enhanced student performance. By engaging in structured PJBL phases, learners take part in authentic data analysis, teamwork, and reflective learning, which allows them to grasp statistical concepts in a more profound and practical manner. The incorporation of deep learning strategies motivates students to go beyond memorization of formulas, fostering a true understanding of their significance and real-world applications. The marked difference in academic performance observed between the experimental group and the control group, evident in both posttest results and advancements in N-gain, indicates that PJBL significantly supports deep learning and boosts students' achievements in mathematics.

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