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# APPLICATION OF THE PROJECT-BASED LEARNING MODEL ON PROKARYOTIC MATERIAL TO IMPROVE COGNITIVE, AFFECTIVE, AND PSYCHOMOTOR LEARNING OUTCOMES OF GRADE

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**ABSTRACT**

*This study aimed to determine the effect of the Project-Based Learning (PjBL) model on students' cognitive, affective, and psychomotor learning outcomes in learning prokaryotic material. The research was conducted at SMA Kesatrian 2 Semarang using a quasi-experimental method with a nonequivalent control group design. The final sample consisted of 25 students in the experimental class and 29 students in the control class, selected through purposive sampling. The research instruments included cognitive learning outcome tests, affective observation sheets, and psychomotor observation sheets. Data were analyzed using the Shapiro–Wilk normality test, Levene's homogeneity test, the Mann–Whitney U test, the independent samples t-test, and the N-Gain test. The results showed a significant difference in cognitive learning outcomes ($p < 0.001$) and affective learning outcomes ($p = 0.044$) between the experimental and control groups. However, no significant difference was found in psychomotor learning outcomes ($p = 0.282$). The average N-Gain scores were 0.63 for the experimental group and 0.69 for the control group, both categorized as moderate. Because the two groups differed significantly in their initial abilities before the intervention, the findings should be interpreted with caution.*

## INTRODUCTION

Education plays a crucial role in nation-building by improving social welfare and national progress (Mardiah et al., 2021). In the age of globalization, there is a need for

education to enhance the standard of learning to produce students with the best possible learning outcomes. Learning outcomes serve as the primary measure for evaluating the effectiveness of the educational process; therefore, they require advancements in teaching methods that can enhance student participation and enrich their understanding of concepts. (Aini Qolbiyah et al., 2022) argue that 21st-century learning is an implication of societal development over time.

Learning outcomes are one of the main indicators used to evaluate the effectiveness of the learning process. Improving students' learning outcomes requires learning strategies that actively engage students in constructing knowledge rather than relying solely on teacher-centered instruction (Handayani, 2021; Mona et al., 2023). However, preliminary observations at SMA Kesatrian 2 Semarang revealed that students' biology learning outcomes remained unsatisfactory. Of the 27 students in class X-1, only 37% achieved the Minimum Mastery Criterion (KKM), while 63% did not meet the expected standard. In addition, classroom observations showed that students tended to be passive during lessons because conventional teacher-centered approaches still dominated the learning process.

One of the biology topics that students find particularly challenging is prokaryotic material. Students experience difficulties because the topic involves microscopic organisms that cannot be directly observed, contains numerous scientific terms, and requires abstract conceptual understanding. These challenges often lead to misconceptions and low academic achievement. Previous studies have also reported that many students have not achieved the Minimum Mastery Criterion (KKM) in learning Archaebacteria and Eubacteria (Riza et al., 2019; Hermawan, 2020; Hidayatussadah et al., 2016).

Project-Based Learning (PjBL) has been widely recognized as an innovative learning model that encourages students to actively construct knowledge through collaborative project activities, problem-solving, and authentic learning experiences. Previous studies have demonstrated that PjBL can improve students' learning outcomes and scientific literacy in biology learning (Permatasari et al., 2023). However, most previous studies have focused primarily on cognitive learning outcomes or have examined different biology topics. Studies investigating the effectiveness of Project-

Based Learning in improving cognitive, affective, and psychomotor learning outcomes simultaneously for prokaryotic material at the senior high school level remain limited.

Therefore, this study offers a different perspective by examining the implementation of Project-Based Learning on prokaryotic material while simultaneously evaluating students' cognitive, affective, and psychomotor learning outcomes. This study is expected to provide empirical evidence on the effectiveness of Project-Based Learning as an alternative instructional model for biology instruction in senior high schools, particularly for teaching abstract biological concepts such as prokaryotes. Based on this background, the objective of this study was to determine the effect of the Project-Based Learning model on the cognitive, affective, and psychomotor learning outcomes of Grade X students studying prokaryotic material.

## MATERIALS AND METHODS

### *Populations and samples*

All tenth-grade students of SMA Kesatrian 2 Semarang during the 2025–2026 academic year constituted the study population. Preliminary classroom observations in Class X-1 to identify learning problems revealed that students' biology learning outcomes and classroom participation remained relatively low. However, Class X-1 was not included as the research sample because it was used only for the initial needs analysis.

The research sample was selected using purposive sampling. The selection criteria included classes with relatively similar academic characteristics, comparable student numbers, and the biology teacher's recommendations regarding the feasibility of implementing the research. Based on these criteria, Class X-2 was designated as the experimental class, comprising 26 students, and Class X-3 as the control class, comprising 29 students.

Although 26 students were initially assigned to the experimental class, only 25 students completed both the pretest and posttest and were therefore included in the final statistical analysis. Consequently, the analyses presented in the Results section were based on data from 25 students in the experimental class and 29 in the control class.

The instruments used in this study included Project-Based Learning (PjBL)-based teaching modules, Student Worksheets (LKPD), pretest and posttest instruments, and observation sheets for learning implementation and student activities.

### *Research Instruments*

The instruments used in this study included learning tools such as Project-Based Learning (PjBL)-based teaching modules, student worksheets (LKPD), pretest and posttest instruments, and observation sheets to assess the implementation of learning and student activities.

### *Research Design*

This study employed a quantitative quasi-experimental design with a nonequivalent control group. The design involved two intact classes: an experimental group that received the Project-Based Learning (PjBL) model and a control group that received conventional learning. Both groups were administered a pretest before the learning intervention and a posttest after the intervention to measure changes in students' learning outcomes.

**Table 1.** The research design is presented as follows:

| Group | Pretest | Treatment | Posttest |
|---|---|---|---|
| Experiment | $O_1$ | X | $O_2$ |
| Control | $O_2$ | - | $O_2$ |

$O_1$ represents the pretest, X represents the implementation of the Project-Based Learning (PjBL) model, and $O_2$ represents the posttest.

Because this study employed a quasi-experimental design with intact classes and no random assignment, differences in students' initial abilities between groups may occur. Therefore, pretest scores were administered before the intervention to identify students' initial abilities and to support the interpretation of the posttest results.

The research was carried out in three stages: preparation, implementation, and evaluation. During the preparation stage, the learning tools, including the Project-Based Learning (PjBL)-based teaching module, Student Worksheets (LKPD), pretest and posttest instruments, and observation sheets, were developed and validated before being implemented in the classroom.

During the implementation stage, students in the experimental class participated in learning activities based on the Project-Based Learning (PjBL) model. The learning process began with a pretest to identify students' initial abilities. The implementation of

the PjBL model followed six main stages: (1) determining the driving question, (2) designing the project plan, (3) preparing the project schedule, (4) monitoring project implementation, (5) presenting the project results, and (6) evaluating the project. Throughout the learning process, students worked collaboratively to complete the assigned project related to prokaryotic material. At the same time, the teacher acted as a facilitator by guiding discussions, monitoring project progress, and providing feedback. The control class received biology instruction using the conventional learning method routinely applied by the classroom teacher. At the end of the learning activities, both groups completed the posttest to measure students' learning outcomes.

During the evaluation stage, students' cognitive learning outcomes were analyzed using the pretest and posttest scores. In contrast, the implementation of the learning process and students' activities were evaluated using observation sheets completed during each learning session.

Several statistical tests were used to assess the data quantitatively. The N-Gain test was used to gauge the extent of improvement to students' learning outcomes. Furthermore, normality and homogeneity tests, as well as the Mann–Whitney test, were performed using SPSS.

## RESULTS AND DISCUSSION

This study aims to determine how students' learning outcomes in the subject of prokaryotic biology are affected by the use of the Project-Based Learning (PjBL) paradigm. Instrument test results and students' cognitive, emotional, and psychomotor learning outcomes were among the data evaluated.

### *Research Design*

Normality Test

**Table 2.** Normality Test

| Group | Kolmogorov Smirnov test sig. | Shapiro Wilk sig. | Information |
|---|---|---|---|
| Experiment | 0.200 | 0.051 | Normally distributed |
| Control | 0.027 | 0.012 | Nor Normally distributed |

Based on Table 2, the normality test was performed on the pretest scores to determine the distribution of students' initial abilities before the learning intervention.

Since each group had fewer than 50 students, the Shapiro–Wilk test was used to assess normality. The experimental group's pretest scores were normally distributed (Shapiro–Wilk, p = 0.051), whereas the control group's pretest scores were not normally distributed (Shapiro–Wilk, p = 0.012).

**Table 3.** Posttest Normality Test

| Group | Kolmogorov Smirnov test sig. | Shapiro Wilk sig. | Information |
|---|---|---|---|
| Experiment | 0.002 | 0.004 | Abnormal |
| Control | 0.000 | 0.012 | Abnormal |

Based on Table 3, the normality test of the posttest scores indicated that the posttest data for both the experimental and control groups were not normally distributed, as indicated by the Shapiro–Wilk test (experimental: p = 0.004; control: p = 0.012). Since the sample size in each group was fewer than 50 students and the data were not normally distributed, the Mann–Whitney test was used for the subsequent hypothesis testing.

**Table 4.** Mann-Whitney Pretest Results

| Statistic | Mark |
|---|---|
| Mann-Whitney University | 87.000 |
| Z | -4.790 |
| Sig (2 Tailed) | 0.000 |

Based on Table 4, the Mann–Whitney test on the pretest scores showed a significant difference between the experimental and control groups (U = 87.000, Z = -4.790, p < 0.001). These results indicate that the two groups were not equivalent in terms of their initial abilities before the learning intervention.

**Table 5.** Mann-Whitney Pretest Results

| Statistic | Mark |
|---|---|
| Mann-Whitney University | 113.000 |
| Z | -4.343 |
| Sig (2 Tailed) | 0.000 |

Based on Table 5, the Mann–Whitney test revealed a significant difference in the posttest scores between the experimental and control groups (Mann–Whitney U = 113.000; Z = -4.343; Sig. (2-tailed) = 0.000). These findings indicate that the posttest learning outcomes differed significantly between the two groups after the learning intervention. However, because the pretest analysis showed that the groups were not equivalent at baseline, the posttest differences should be interpreted with caution.

**Table 6.** N-Gain Test Results`

| Class | N | Minimum | Maximum | Mean | Category |
|---|---|---|---|---|---|
| Experiment | 25 | -0.14 | 0.92 | 0.63 | Currently |
| Control | 29 | -0.90 | 0.62 | 0.69 | Currently |

Based on Table 6, the average N-Gain score of the experimental group was 0.63, while the control group obtained an average N-Gain score of 0.69. According to the standard N-Gain classification, both groups were categorized as having a medium level of improvement. Although the statistical analysis showed a significant difference between the two groups, these findings should be interpreted with caution because the experimental and control groups differed significantly in their initial abilities before the learning intervention.

**Table 7.** Findings from the Affective Learning Outcomes Normalcy Test

| Class | Kolmogorov Smirnov test sig. | Shapiro Wilk sig. |
|---|---|---|
| Experiment | 0.134 | 0.154 |
| Control | 0.108 | 0.056 |

According to Table 7, the Shapiro-Wilk significance value for the experimental group is 0.154, while that for the control group is 0.056. It may be deduced that the affective learning outcome data for both groups follow a normal distribution because both p-values are> 0.05 (Sig. > 0.05).

**Table 8.** Results of the Homogeneity Test for Affective Learning Outcomes

| Affective data | Leven Sig. |
|---|---|
| Mark | 0.020 |

It can be inferred that the data is not homogeneous because the significance value obtained is 0.020 < 0.05.

**Table 9.** Results of the Independent Sample T-Test.

| Variabel | Experimental (N, Mean ± SD) | Control (N, Mean ± SD) | Levene's Sig. | t (Equal Variances Not Assumed) | df | p-value |
|---|---|---|---|---|---|---|
| Affective learning outcomes | 25; 24.24 ± 3.67 | 29; 22.28 ± 4.19 | 0.020 | 2.072 | 48.734 | 0.044 |

Table 9 presents the descriptive statistics and the results of the independent samples *t*-test for students' affective learning outcomes. The experimental group consisted of 25 students (Mean = 24.24, SD = 3.67), whereas the control group consisted of 29 students (Mean = 22.28, SD = 4.19). Affective learning outcomes were assessed using an

observation rubric comprising seven indicators: responsibility in completing assigned tasks, active participation in group discussions and collaborative activities, respect for peers' and teachers' opinions, adherence to classroom rules and time management, consistency in demonstrating positive learning attitudes, receptiveness to feedback, and concern for the success of group activities or projects.

The homogeneity of variance assumption was examined using Levene's test, which yielded a p-value of 0.020, indicating that the assumption of equal variances was not satisfied. Consequently, the Equal Variances Not Assumed (Welch's *t*-test) results were used for hypothesis testing. The analysis yielded a significance value (*p*) of 0.044, which was lower than the predetermined significance level of 0.05. Accordingly, the null hypothesis ($H_0$) was rejected, indicating a statistically significant difference in affective learning outcomes between students in the experimental and control groups. The higher mean score of the experimental group suggests that implementing the Project-Based Learning (PjBL) model led to more favorable affective learning outcomes than those achieved through conventional instruction.

**Table 10.** Results of the Normality Test for Psychomotor Learning Outcomes

| **Class** | Shapiro Wilk<br>sig. |
|---|---|
| Experiment | 0.373 |
| Control | 0.028 |

According to Table 10. The significance value for the experimental group was 0.373, exceeding 0.05, indicating that the data are normally distributed. The control group, on the other hand, showed a significance value of 0.028, which was less than 0.05, suggesting that the data did not follow a normal distribution. Therefore, it may be concluded that the dataset as a whole was not totally regularly distributed.

**Table 11.** Results of Homogeneity Test of Psychomotor Learning Outcomes

| **Data** | **Levene Sig.** |
|---|---|
| Mark | 0.000 |

Table 11 presents the results of Levene's test for the equality of variances. The analysis yielded a p-value of 0.000, which is lower than the significance level of 0.05. This result indicates that the assumption of homogeneity of variances was not met, suggesting that the variances between the comparison groups were significantly different. Consequently, the statistical analysis was interpreted using the Equal Variances Not

Assumed results to ensure that the hypothesis testing remained appropriate despite the unequal group variances.

**Table 12.** Results of the Man-Whitney U Test for Psychomotor Learning Outcomes

| Varabel | Mann-Whitney U | Wilcoxon W | Z | Asymp. Sig. (2-tailed) |
|---|---|---|---|---|
| Psychomotor learning outcomes | 301.000 | 736.000 | -1.075 | 0.282 |

Table 12 presents the results of the Mann–Whitney U test for psychomotor learning outcomes. Since the psychomotor data did not meet the assumptions of normality and homogeneity of variance, the Mann–Whitney U test was employed to compare the psychomotor learning outcomes between the experimental and control groups. The analysis yielded a Mann–Whitney U value of 301.000, a Wilcoxon W value of 736.000, a Z value of −1.075, and an Asymp. Sig. (2-tailed) value of 0.282. Because the p-value was greater than 0.05, the null hypothesis ($H_0$) was not rejected, indicating that there was no statistically significant difference in psychomotor learning outcomes between the experimental and control groups. Although the experimental group showed a descriptively higher average psychomotor score, the difference was not statistically significant. These findings suggest that, within the duration and conditions of this study, the implementation of the Project-Based Learning (PjBL) model did not produce significantly different psychomotor learning outcomes compared with the conventional learning approach.

***Students' Cognitive Learning Outcomes***

According to the normality assessment, the pretest data for the experimental group were normally distributed. In contrast, the information for the control group did not show a normal distribution. In contrast, the posttest data for both groups exhibited non-normal distributions. Statistically, a dataset is considered normal when the significance value (Sig.) exceeds 0.05; when Sig. is less than 0.05, the dataset is classified as not normally distributed (Kim, 2021).

When comparing the experimental and control groups, the study's data show substantial differences in students' competencies and starting skills. The preliminary results of the Mann-Whitney test support this finding. which showed a significance level of 0.000. This situation shows that the two groups were not similar at the outset. As noted by Ningsih et al. (2022), variations in baseline abilities may influence students' academic

performance and should be taken into account when analyzing research findings. The analysis used the nonparametric Mann-Whitney test, which does not require normality of the data, because the data were not normally distributed (Fay & Proschan, 2021). The results of the Mann-Whitney test conducted after the intervention yielded a p-value of 0.000.

This variation suggests that the use of the Project-Based Learning (PjBL) approach influences students' educational outcomes. This is because PjBL actively involves students in the learning process through project-based activities, enabling them to understand better the concepts being learned. This is in line with research indicating that project-based learning can significantly improve learning outcomes and student engagement (Mona et al., 2023; Nurwahyunani, 2023; Sari et al., 2023; Permatasari et al., 2023; Mulyadi et al., 2023). The findings of this investigation are corroborated by the work carried out by Lema et al. 2023), which indicated that Project-Based Learning has the potential to enhance students' educational results by fostering engagement, teamwork, and relevant learning experiences. Moreover, these results align with the research conducted by Agussalim et al. 2025), which demonstrated that Project-Based Learning improves student participation and educational success via dynamic and contextual learning experiences.

The N-Gain analysis indicated that both groups achieved improvements in cognitive learning outcomes within the moderate category. The experimental group obtained an average N-Gain score of 0.63, whereas the control group achieved a slightly higher average score of 0.69. Although the control group demonstrated a marginally greater improvement descriptively, this difference should be interpreted with caution. Several factors may have contributed to this finding, including differences in students' initial academic abilities, the adjustment process required for students to engage effectively with the Project-Based Learning (PjBL) model, the relatively limited duration of the intervention, and variations in the quality of classroom implementation. These factors may have influenced the extent to which students benefited from the learning activities.

Nevertheless, the inferential statistical analysis revealed a significant difference between the experimental and control groups. Therefore, while the descriptive N-Gain results do not indicate greater improvement in the experimental group, the overall

findings suggest that implementing the Project-Based Learning (PjBL) model contributed to differences in students' cognitive learning outcomes. Further studies with a longer intervention period and more controlled implementation are recommended to provide a more comprehensive evaluation of the PjBL model's effectiveness.

***Affective Learning Outcomes***

According to the normality assessment, the data on affective learning outcomes in both the experimental and control groups were normally distributed, as the significance values from the Shapiro-Wilk test exceeded 0.05. This suggests that the data fulfilled the criteria for normality. On the other hand, the results from the homogeneity assessment revealed a significance value of 0.020 (<0.05).

Even though the information is not uniform, it is still possible to perform an analysis using the Independent Samples T-Test, assuming unequal variances. The test results indicate a significance level of 0.044.

These findings suggest that implementing the Project-Based Learning (PjBL) model contributed to improved **affective learning outcomes**. Based on the observation data, students in the experimental group demonstrated greater responsibility in completing project tasks, more active participation during group discussions, better respect for peers' and teachers' opinions, improved discipline in following classroom procedures, greater consistency in maintaining positive learning attitudes, increased willingness to accept feedback, and stronger concern for the success of their group activities. These findings indicate that collaborative, project-oriented learning experiences provided through the PjBL model supported the development of students' affective learning outcomes during instruction.

PjBL gives students opportunities to collaborate, communicate, and take responsibility in completing projects, which in turn enhances their positive attitudes toward learning. As noted by Nurwahyunani (2022), engaging in project-based learning in biology not only enhances intellectual capabilities but also cultivates significant scientific attitudes among students, including teamwork, accountability, and inquisitiveness. Additionally, current studies indicate that PjBL effectively enhances students' interpersonal skills and positive learning attitudes through cooperative tasks (Putri et al., 2021). The results align with the investigation by A. A. Suryani et al. (2023), which found that the Project-Based Learning model not only enhances academic

performance but also cultivates important scientific attitudes among students, including teamwork and accountability.

Furthermore, a study conducted by Putri et al. (2021) demonstrated that the Project-Based Learning (PjBL) approach effectively boosts students' social attitudes and involvement through group learning experiences. Consequently, it can be inferred that the Project-Based Learning (PjBL) model plays a crucial role in improving students' emotional learning outcomes. Consequently, it can be asserted that the Project-Based Learning (PjBL) approach positively influences students' emotional learning outcomes.

***Psychomotor Learning Outcomes***

The results of the normality test showed that the psychomotor learning outcome data were normally distributed in the experimental group (Sig. = 0.373) but not in the control group (Sig. = 0.028). Furthermore, the homogeneity test yielded a significance value of 0.000, indicating that the assumption of homogeneity of variances was not satisfied. Since the psychomotor data did not meet the assumptions required for parametric analysis, the differences between the experimental and control groups were analyzed using the Mann–Whitney U test.

The Mann–Whitney U test produced a Mann–Whitney U value of 301.000, a Z value of −1.075, and an Asymp. Sig. (2-tailed) value of 0.282. As the significance value exceeded 0.05, no statistically significant difference was found in psychomotor learning outcomes between the experimental and control groups. Although the experimental group had a higher mean psychomotor score than the control group, the difference was not statistically significant.

One possible explanation for this finding is that the duration of the intervention may not have been sufficient to produce measurable improvements in psychomotor performance. In addition, students required time to adapt to project-based learning activities, particularly those involving collaboration, practical tasks, and project implementation. Variations in students' initial practical skills and classroom implementation may also have influenced the psychomotor outcomes observed in this study.

Nevertheless, students in the experimental group demonstrated active participation in project activities, collaborative work, and practical learning experiences throughout the instructional process. These learning experiences are consistent with the characteristics

of the Project-Based Learning (PjBL) model, which emphasizes hands-on activities and student engagement. Similar findings have been reported by Sudarmin (2020), who suggested that project-based learning facilitates the development of practical and science process skills. However, the effectiveness of PjBL may vary depending on factors such as the learning context, implementation quality, and duration of the intervention, as also reported by Chen and Yang and Biologi (2025). Therefore, although PjBL provided meaningful practical learning experiences, the present study did not demonstrate a statistically significant improvement in psychomotor learning outcomes compared with conventional instruction.

## CONCLUSION

The implementation of the **Project-Based Learning (PjBL)** model produced different outcomes across the cognitive, affective, and psychomotor domains. In the cognitive domain, inferential statistical analysis revealed a significant difference between the experimental and control groups. However, the descriptive N-Gain analysis showed a slightly greater improvement in the control group than in the experimental group. Therefore, these findings should be interpreted cautiously, as differences in students' initial abilities, the relatively short duration of the intervention, and students' adaptation to the PjBL model may have influenced the results. In the affective domain, students who learned through the PjBL model demonstrated significantly better affective learning outcomes than those who received conventional instruction. The implementation of project-based learning encouraged students to develop positive learning attitudes, including responsibility, cooperation, active participation, discipline, and respect for others during the learning process. In contrast, the psychomotor domain did not show a statistically significant difference between the experimental and control groups based on the Mann–Whitney U test. Although students in the experimental group demonstrated active involvement in project activities and obtained descriptively higher psychomotor scores, the observed differences were not statistically significant.

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