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THE EFFECT OF PROJECT-BASED LEARNING ON STUDENTS COLLABORATIVE SKILLS AND LEARNING OUTCOMES ON VIRUS MATERIAL

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ABSTRACT: This study aims to determine the effect of Project-Based Learning (PjBL) on students' collaboration skills and cognitive learning outcomes in biology, specifically on virus topics, among 10th grade students at SMA Negeri 1 Tanjungtiram. A quasi-experimental design with a pretest-posttest control group was employed, involving 72 students from two classes selected through random sampling. The experimental class implemented PjBL, while the control class used conventional learning. Collaboration skills were measured using observation sheets, and cognitive learning outcomes were assessed using multiple-choice tests. The results showed that the experimental class achieved a mean collaboration skill score of 84.66% (very skilled category), significantly higher than the control class at 64.05% (skilled category). Cognitive learning outcomes also improved substantially, with the experimental class reaching an N-gain of 0.72 (high category) compared to 0.46 (medium category) in the control class. Mann-Whitney U test results confirmed a significant effect of PjBL on both variables ($p < 0.05$). These findings suggest that PjBL is an effective instructional model for developing students' collaboration skills and improving their learning outcomes in biology, particularly on virus topics.

Keywords: Collaboration Skills, Learning Outcomes, Project-Based Learning.

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INTRODUCTION

In the field of education, the Fourth Industrial Revolution of the 21st century poses significant problems. Education must be able to mold people with productive, inventive, and creative personalities who can solve problems and contribute to society (Widiyono & Millati, 2021). According to the National Education Standards Agency (BNSP), students must grasp the 4Cs: Critical Thinking, Communication, Collaboration, and Creativity. Collaboration is one of these characteristics that is very important since it helps students develop good group skills and steer clear of individualistic thought patterns (Khumaerah et al., 2023).

Collaboration skills are essential in group problem solving processes. According to Sugiyarti & Arif (2018), students are expected not only to understand the material but also to build social interactions while learning together. Riyadi (2019) further identifies six key indicators of collaboration skills:

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contributing to the group, helping fellow group members, being flexible toward others' opinions, respecting individual differences, being responsible, and completing tasks on time. These skills are considered fundamental competencies in both academic and professional contexts.

Learning outcomes, which encompass cognitive, affective, and psychomotor domains, are influenced by internal factors such as initial abilities and motivation, external factors such as learning environment and facilities, and the instructional approach applied (Asrori, 2020). The learning model used by teachers has a significant influence on student outcomes, as it directly affects student engagement and motivation (Yanni, 2018). In the era of Education 4.0, students also need to be equipped with the ability to innovate, collaborate, communicate, and utilize technology effectively (Lubis, 2019).

However, a gap between expectations and reality was identified through pre-research observations and interviews conducted at SMA Negeri 1 Tanjungtiram. The findings revealed that students' collaboration skills were underdeveloped, with the learning process remaining largely teacher-centered rather than student-centered. The conventional lecture-based approach resulted in low student engagement and suboptimal cognitive learning outcomes, with most students scoring below the minimum competency threshold. This finding is consistent with Efendi & Safnowandi (2016) and Khumaerah et al. (2023), who reported similar challenges in biology classrooms where conventional learning methods failed to promote meaningful collaboration and resulted in low learning outcomes. Riastuti & Febrianti (2021) also noted that passive learning environments hinder students' ability to understand material deeply and achieve satisfactory results.

Project-Based Learning (PjBL), an educational approach that actively includes students in resolving real world issues through group project work, is one potential remedy for these issues (Trianto, 2020). Numerous empirical investigations have proven its efficacy. In a biology classroom action research study, Suaidiah et al. (2024) discovered that PjBL deployment continuously enhanced learning outcomes and teamwork abilities throughout cycles. Between Cycle I and Cycle II, learning outcomes significantly improved; the lowest score increased from 11 to 60, while the best score increased from 96 to 100. With a mean score that increased from 70% to 73% between cycles, collaboration skills also improved, moving from the somewhat effective group to the effective category. In a same vein, Khumaerah et al. (2023) found that, in comparison to traditional instruction, PjBL applied to virus content at SMAN 13 Makassar improved students' collaborative performance and learning results. All of these results point to PjBL as a viable paradigm for improving learning outcomes and cooperation abilities in biology classes.

The present study differs from previous research in three key aspects. First, in terms of research design, Suaidiah et al. (2024) used a Classroom Action Research (CAR) design with two cycles under a lesson study approach, which lacks a control group, while Khumaerah et al. (2023) employed a descriptive approach without a control group comparison. The present study adopts a quasi-experimental pretest-posttest control group design, enabling a more rigorous

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causal comparison between groups. Second, regarding subject matter, Suaidiah et al. (2024) focused on ecosystem material and Khumaerah et al. (2023) examined virus topics but did not measure collaboration skills using a standardized six-indicator rubric across C1-C6 cognitive levels. The present study addresses both variables simultaneously within the same virus topic context. Third, concerning sample size and setting, this study involved 72 students from two classes at SMA Negeri 1 Tanjungtiram, offering a broader and more controlled sample base than the single-class designs of both Khumaerah et al. (2023) and Suaidiah et al. (2024). These distinctions underscore the novelty of this study in providing more generalizable and methodologically rigorous evidence on PjBL's effectiveness for improving collaboration skills and learning outcomes in biology, particularly on virus topics.

Collaboration skills are among the essential competencies students must develop in the 21st century. The collaboration skills examined in this study are assessed based on six indicators proposed by Riyadi (2019): 1) contributing to the group; 2) being helpful to fellow group members; 3) being flexible toward the opinions of all members; 4) respecting individual differences; 5) being responsible; and 6) completing tasks on time. Developing these skills requires an instructional approach that actively engages students in meaningful group interactions rather than passive reception of information.

In this regard, Project-Based Learning (PjBL) has emerged as a promising model. PjBL aims to involve students in an active role in solving real-world problems through collaborative project work (Trianto, 2020). Empirical evidence supports its effectiveness across multiple outcomes. In terms of collaboration skill development, Suaidiah et al. (2024) reported that PjBL implementation in biology learning improved students' collaboration skills from the moderately effective to the effective category, with mean scores increasing from 70% to 73% across cycles. Regarding learning outcomes, Khumaerah et al. (2023) found that PjBL applied to virus material significantly enhanced students' learning outcomes compared to conventional instruction. Riastuti & Febrianti (2021) further confirmed that students who are actively involved in project-based discussions and collaboration demonstrate deeper understanding of material and achieve higher learning outcomes. These findings collectively suggest that PjBL is effective in simultaneously fostering collaboration skills and improving cognitive learning outcomes in biology classrooms.

Despite this growing body of evidence, a research gap remains. Most existing studies either focus on a single outcome variable, employ non-experimental designs, or are conducted in different subject matter contexts. The present study therefore investigates the effect of PjBL on both collaboration skills and cognitive learning outcomes simultaneously, using a quasi-experimental design with virus topics as the learning context at SMA Negeri 1 Tanjungtiram.

Based on the above description, this study investigates the effect of Project-Based Learning (PjBL) on students' collaboration skills and cognitive learning outcomes in biology, specifically on virus topics, among Grade X students at SMA Negeri 1 Tanjungtiram. This study is guided by two research objectives: first, to analyze the effect of PjBL on students' collaboration skills

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compared to conventional learning, and second, to analyze the effect of PjBL on students' cognitive learning outcomes compared to conventional learning. With regard to collaboration skills, the null hypothesis (H_{01}) states that there is no significant effect of PjBL on students' collaboration skills on virus topics in Grade X at SMA Negeri 1 Tanjungtiram, while the alternative hypothesis (H_{a2}) states that there is a significant effect. Similarly, with regard to cognitive learning outcomes, the null hypothesis (H_{01}) states that there is no significant effect of PjBL on students' cognitive learning outcomes on virus topics in Grade X at SMA Negeri 1 Tanjungtiram, while the alternative hypothesis (H_{a2}) states that there is a significant effect. The findings of this study, entitled 'The effect of project-based learning on students' collaborative skills and learning outcomes on virus material', are expected to provide empirical evidence and practical insights for biology teachers in selecting effective instructional models that promote both collaborative competencies and academic achievement.

METHOD

The research method used in this study was a quasi-experiment or experimental research using a semi-experimental method. The research design in this study is a pretest-posttest control group design. This research was conducted from August to October 2025 at SMA Negeri 1 Tanjungtiram. The procedure began with administering a pretest to both the experimental and control groups to control for differences in their initial conditions and to ensure the comparability of both groups prior to treatment. The research was carried out over four meetings for each class. In the first meeting, the pretest was administered, followed by an introduction to virus material and the presentation of fundamental questions relevant to students' daily lives to stimulate project ideas. In the second and third meetings, the experimental group implemented the PjBL model through a series of structured stages, namely: developing a project plan, setting a completion schedule, and actively working on the assigned project which involved designing virus demonstration tools and virus posters in groups. During these meetings, observers monitored students' collaboration skills using observation sheets based on six indicators.

The control group, meanwhile, followed conventional learning through lectures and group discussions without producing any project-based products. In the fourth and final meeting, students in the experimental class presented their completed projects, followed by a reflection session where both teachers and students evaluated the learning experience. Subsequently, a posttest was administered to both groups to measure cognitive learning outcomes after the treatment. The researchers then examined the differences between the pretest and posttest scores of both groups to determine the effect of the PjBL model on collaboration skills and learning outcomes.

The study's population comprised 252 students from seven classes in Grade X at SMA Negeri 1 Tanjungtiram during the 2025/2026 academic year. Two classes were chosen at random from the total population of Grade X classes in order to create the sample. This method was used to reduce selection bias by guaranteeing that each class had an equal chance of being chosen. A total of 72

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students made up the sample size after the chosen classes were randomly assigned as the experimental class and the control class, each with 36 students. While the control group got traditional instruction, the experimental group was given Project-Based Learning (PjBL). In addition to ensuring that all courses had similar starting features in terms of academic ability and learning environment, the study's use of random sampling made them appropriate for comparison within a quasi-experimental design.

A cognitive learning outcomes and an observation sheet for collaborative skills made up the research tools. Twenty multiple choice questions covering cognitive levels C1-C6 according to Bloom's Taxonomy made up the cognitive exam. Two professional validators a biology education lecturer and an experienced biology teacher tested the instrument's content validity prior to its deployment, and it was deemed valid after changes based on their suggestions. The Kuder-Richardson 20 (KR-20) formula was used to evaluate reliability; the result was a coefficient of 0.8784, which indicates extremely good reliability.

The collaboration skill observation sheet was developed based on six indicators proposed by Riyadi (2019): Contributing to the group, helping fellow group members, being flexible toward others' opinions, respecting individual differences, being responsible, and completing tasks on time. Each indicator was assessed using a structured descriptive rubric, enabling observers to evaluate students' collaboration skills systematically during group project activities.

Table 1. Quasi-Experimental Pretest-Posttest Control Group Design.

Group	Pretest	Treatment	Posttest
Experimental	O_1	X_1	O_2
Control	O_3	X_2	O_4

(**Source:** Sugiyono, 2019).
Description:
O_1 = Pretest measurement in the experimental class;
O_2 = Posttest measurement in the experimental class;
O_3 = Pretest measurement in the control class;
O_4 = Posttest measurement in the control class;
X_1 = PjBL treatment applied to the experimental class; and
X_2 = Conventional learning applied to the control class.

The following is an index of collaboration skill criteria presented in Table 2 below.

Table 2. The Criteria for Collaboration Skills.

Percentage (%)	Criteria
81-100	Very Skilled
61-80	Skilled
41-60	Moderately Skilled
21-40	Less Skilled
0-20	Unskilled

(**Source:** Nuriyani et al., 2021).

The Shapiro-Wilk test was used to assess normality, and the results showed that the data for both variables were not normally distributed. Levene's

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Test was used to evaluate homogeneity and verify that variances were similar in both classes. The non-parametric Mann-Whitney U test was used for hypothesis testing at a significance level of $\alpha = 0.05$ because the normality assumption was not satisfied. The average pretest, posttest, and N-gain scores between the experimental and control groups were compared in order to do a quantitative analysis. To measure the improvement of collaboration skills in both classes, the N-gain score was calculated using this formula:

$$\text{N-gain} = \frac{\text{Posttest Score} - \text{Pretest Score}}{\text{Maximum Score} - \text{Pretest Score}}$$

(**Source:** Arikunto, 2016).

The N-gain scores were interpreted based on a set of classification criteria to determine the category of improvement achieved by each class. The criteria usedto classify the N-gain scores in this study can be seen in Table 3 below.

Table 3. N-gain Level Criteria.

N-gain Value	Category
G > 0.7	High
0.3 ≤ G ≤ 0.7	Medium
G < 0.3	Low

(**Source:** Arikunto, 2016).

RESULTS AND DISCUSSION

Results

This study examined the effect of Project-Based Learning (PjBL) on students' collaboration skills and cognitive learning outcomes in biology on virus topics. The results are presented in two parts: collaboration skills and cognitive learning outcomes.

Collaboration Skill

An observation sheet based on six variables suggested by Riyadi (2019) was used to evaluate collaboration skills. For both the experimental and control groups, observations were made twice: once prior to treatment (the initial observation) and once following treatment (the final observation). Table 4 displays the data from the initial observations, and Table 5 displays the data from the final observations. The results of the collaboration skills assessment for both the experimental class and the control class are presented in Table 4 below. The data reflects the overall performance of students based on the observed indicators during the learning process.

Table 4. Initial Observation Data on Collaboration Skill.

No.	Indicator	Experimental Class		Control Class	
		Indicator	Category	Indicator	Category
1	Contribute to the Group	45.49%	Moderately Skilled	44.44%	Moderately Skilled
2	Be Helpful to Fellow Group Members	46.18%	Moderately Skilled	45.49%	Moderately Skilled
3	Be Flexible Towards the Opinions of All Members	47.57%	Moderately Skilled	46.88%	Moderately Skilled
4	Respect Individual	48.28%	Moderately	47.57%	Moderately

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No.	Indicator	Experimental Class		Control Class	
		Indicator	Category	Indicator	Category
	Differences		Skilled		Skilled
5	Be Responsible	45.49%	Moderately Skilled	45.49%	Moderately Skilled
6	Complete Tasks on Time	47.57%	Moderately Skilled	44.44%	Moderately Skilled
	Mean	46.76%		45.72%	

Based on Table 4 shows that the experimental and control groups' initial average cooperation skill scores were 46.76% and 45.72%, respectively, placing them in the moderately skilled range. The two classes' initial collaboration skill levels were similar before treatment, as seen by the average difference between them of just 1.04%.

Table 5. Final Observation Data on Collaboration Skills.

No.	Indicator	Experimental Class		Control Class	
		Indicator	Category	Indicator	Category
1	Contribute to the Group	85.42%	Very Skilled	62.85%	Skilled
2	Be Helpful to Fellow Group Members	83.33%	Very Skilled	65.63%	Skilled
3	Be Flexible Towards the Opinions of All Members	85.07%	Very Skilled	64.50%	Skilled
4	Respect Individual Differences	83.33%	Very Skilled	64.24%	Skilled
5	Be Responsible	84.72%	Very Skilled	63.54%	Skilled
6	Complete Tasks on Time	86.11%	Very Skilled	65.63%	Skilled
	Mean	84.66%		64.05%	

According to Table 5 there was a significant difference between the final collaboration skills of the two classes. The initial average collaboration skill of the experimental class was 46.76%. After the treatment, the average collaboration skill of the experimental class increased to 84.66%, with a difference in the average collaboration skill of the experimental class of 37.9%. In the control class, the initial average collaborative skills score was 45.72%, and the final average collaborative skills score was 64.05%, with a difference of 18.33%. The final results for collaboration skills in the experimental class reached an average of 84.66% in the highly skilled category, while the control class achieved 64.05% in the skilled category. The difference of 20.61% indicates a greater improvement in collaboration skills in the experimental class compared to the control class.

Student cognitive learning outcomes were obtained from pretest and posttest scores, then the average score and standard deviation were calculated for each class, namely the experimental class with the Project-Based Learning (PjBL) model and the control class with the conventional model. The average cognitive learning outcomes of students obtained from the pretest and posttest scores can be seen more clearly in Figure 1 below.

Cognitive Learning Outcomes

Cognitive learning outcomes were measured using a 20-item multiple-choice test administered as pretest and posttest to both classes. The test items were designed to assess students' understanding across various cognitive levels,

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including comprehension, application, and analysis. The average pretest, posttest, and N-gain scores for each class are summarized in Table 6 and illustrated in Figure 1.

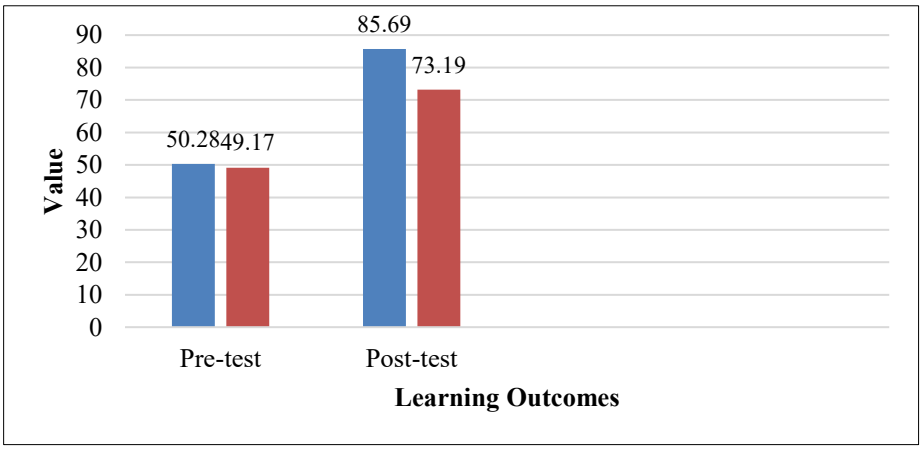

Figure 1. Bar Diagram Showing the Average Pretest and Posttest Scores for the Experimental Class and Control Class.

The standard deviation, Mann-Whitney U test results and N-gain of the experimental and control classes in this study are presented in Table 6.

Table 6. Standard Deviation, Mann-Whitney U Test Results and N-Gain.

Class	N	Standard Deviation		Mann-Whitney U Test	N-gain
		Pretest	Posttest		
Experimental	36	8.860	7.574	0.000	0.72
Control	36	8.238	5.366		0.46

Based on Figure 1 and Table 6 above, it is known that the average pretest score for the experimental class was 50.28 (SD = 8.860), while for the control class it was 49.17 (SD = 8.238). This indicates that the average pretest scores in the experimental and control classes have a difference or average difference of 2.26. There is no significant difference between the average pretest scores of the experimental and control classes. This means that the experimental and control classes have the same initial cognitive abilities.

The experimental class achieved a pretest mean score of 50.28, which increased to 85.69 in the posttest, representing a gain of 35.41 points (70.44%). The control class showed a pretest mean of 49.17 and a posttest mean of 73.19, reflecting an increase of 24.02 points (48.86%). Although both classes demonstrated improvement, the experimental class showed substantially greater growth compared to the control class. The posttest mean difference between the two classes was 12.50 points (17.08%), with the experimental class consistently outperforming the control class.

Prior to hypothesis testing, normality was assessed using the Shapiro-Wilk test, which revealed that the data for both classes were not normally distributed. As the normality assumption was not satisfied, the non-parametric Mann-Whitney U test was employed as the appropriate hypothesis testing method. The Mann-Whitney U test yielded a significance value of p = 0.000, which is below the

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predetermined significance level of $\alpha = 0.05$. This result indicates that H_0 is rejected and H_1 is accepted, meaning that there is a statistically significant difference in cognitive learning outcomes between students taught using PjBL and those taught using conventional learning. The experimental class had a higher average than the control class. Learning using the Project-Based Learning (PjBL) model was more significant in improving learning outcomes than using the conventional learning model.

Discussion

This study examined the effect of Project-Based Learning (PjBL) on students' collaboration skills and cognitive learning outcomes in biology on virus topics. The discussion is organized around two main findings: the improvement of collaboration skills and the improvement of cognitive learning outcomes.

Collaboration Skills

The results demonstrated that students in the experimental class who were taught using PjBL achieved significantly higher collaboration skill scores compared to those in the control class. This improvement can be attributed to the nature of PjBL, which requires students to actively engage in group-based project work through six structured syntaxes: determining fundamental questions, developing a project plan, setting a schedule, monitoring progress, assessing results, and evaluating experiences (Trianto, 2020). Throughout these stages, students were consistently required to contribute ideas, divide tasks, negotiate decisions, and support one another directly exercising all six collaboration indicators assessed in this study. In contrast, students in the control class engaged only in conventional group discussions without producing any tangible project output, resulting in lower levels of active participation and group cohesiveness.

These findings are consistent with previous research. Suaidiah et al. (2024) reported that PjBL implementation in biology learning improved students' collaboration skills from the moderately effective to the effective category. Similarly, Khumaerah et al. (2023) found that PjBL applied to virus material at SMAN 13 Makassar enhanced students' collaborative performance compared to conventional instruction. The present study extends these findings by demonstrating that PjBL produces very skilled collaboration levels (84.66%) when implemented with a standardized six-indicator rubric in a quasi-experimental design, providing more methodologically rigorous evidence than previous classroom action research studies.

Cognitive Learning Outcomes

Additionally, the experimental class showed significantly better cognitive l earning outcomes than the control group, as evidenced by the higher N-gain value experimental class (0.72) with control class (0.46) and posttest experimental test mean (85.69) control class posttest mean (73.19). The active and relevant learning processes that PjBL facilitates can account for this improvement. Students were inspired to completely comprehend the subject matter in order to effectively finish their projects when they were given real-world issues, particularly different illnesses brought on by viruses in daily life.

As Suaidiah et al. (2024) PjBL provides learners with the opportunity to explore, making learning meaningful and improving learning outcomes. Students

who are actively involved in discussions, project planning, and collaborative problem solving develop a deeper understanding of the material, which enables them to perform better on posttest assessments (Riastuti & Febrianti, 2021). By contrast, students in the control class received material through conventional lectures and discussions without producing project-based outputs. This passive learning environment limited their engagement and resulted in lower learning outcomes, consistent with findings by Yanni (2018), which notes that conventional teaching methods can reduce students' motivation and involvement.

Despite promising results, this study has several limitations. First, it employed a quasi-experimental design without random assignment, as intact classes were used, which may introduce selection bias despite similar baseline scores. Second, collaboration skills were assessed using a rubric, but the presence of observers may have influenced student behavior (hawthorne effect), and no inter-rater reliability was reported, potentially affecting assessment consistency. Third, the study was conducted in a single school, limiting generalizability across different educational contexts. Future research should adopt stronger experimental designs, ensure inter-rater reliability, and replicate the study in diverse settings.

CONCLUSION

Project-Based Learning (PjBL) has a significant effect on students' collaboration skills in learning about viruses in grade X of SMA Negeri 1 Tanjungtiram the 2025/2026 academic year ($p < 0.05$). The average collaboration skills of the experimental class reached 84.66% (very skilled category), higher than the control class, which reached 64.05% (skilled category). The Project-Based Learning (PjBL) model had a significant effect on students' cognitive learning outcomes on virus material in grade X of SMA Negeri 1 Tanjungtiram in the 2025/2026 academic year ($p < 0.05$). The experimental class showed an increase in learning outcomes with an N-gain of 0.72 (high category), which was greater than the control class with an N-gain of 0.46 (moderate category).

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