The Influence Of Paikem Based On The Project-Based Learning (Pjbl) Learning Model On Learning Outcomes of Students At SMAN 2 Rantau Utara

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Abstract.
Biology learning that is still dominated by conventional teaching approaches tends to reduce student involvement in the learning process, which may affect learning achievement. Meanwhile, the implementation of the Active, Innovative, Creative, Effective, and Enjoyable Learning (PAIKEM) approach integrated with Project Based Learning (PjBL) on Biodiversity topics requires further investigation to determine its effectiveness in improving students' learning outcomes. This study aimed to analyze the effect of the PAIKEM approach based on Project Based Learning on students' learning achievement in the Biodiversity topic at SMA Negeri 2 Rantau Utara. This research employed a quantitative approach with a quasi-experimental method using a pretest-posttest control group design. The sample consisted of 70 students divided into an experimental class and a control class, with each class consisting of 35 students. Data were collected using a learning achievement test instrument that had been tested for validity and reliability. Data analysis was conducted through prerequisite tests, including normality and homogeneity tests, followed by hypothesis testing using the Independent Samples t-test with the assistance of IBM SPSS Statistics version 25. The results showed a significant difference in students' learning achievement between the experimental class implementing PAIKEM-based Project Based Learning and the control class using conventional learning methods. The hypothesis test results indicated a significance value (Sig. 2-tailed) of 0.000 ($p < 0.05$) with a t-value of -6.008, indicating that H_0 was rejected and H_1 was accepted. These findings demonstrate that the implementation of PAIKEM-based Project Based Learning enhances student engagement through investigation, group discussion, project development, presentation, and reflection activities, resulting in more meaningful learning experiences. The implication of this study suggests that the PAIKEM approach integrated with Project Based Learning can be used as an alternative Biology learning strategy to improve students' learning achievement and active participation, particularly in Biodiversity topics.

Keywords*: PAIKEM; Project Based Learning; learning achievement; Biology learning and Biodiversity.*

I. INTRODUCTION

Education is the primary foundation for developing high-quality, adaptive human resources capable of facing the developments in science and technology in the 21st century. At the senior high school (SMA) level, learning is no longer solely oriented toward achieving cognitive aspects, but is also directed toward developing critical thinking, creativity, communication, collaboration, and problem-solving skills as competencies needed in the Society 5.0 era (OECD, 2023; UNESCO, 2021). Therefore, the implementation of student-centered learning needs to be student-centered so that students gain active, meaningful, and contextual learning experiences. A student-centered learning approach has been proven to increase learning motivation, engagement, independence, and the ability to construct knowledge through authentic learning experiences, thus positively impacting learning outcomes.(Almulla, 2020). Besides that,Hadiyanto, (2024)explains that learning that places students as the main subject contributes to the development of 21st century competencies, especially critical thinking, collaboration, communication, and problem solving.

In biology learning, the application of active learning is becoming increasingly important because the characteristics of biology material require students to conduct observations, investigations, experiments, data analysis, and problem-solving based on phenomena occurring in their environment. Biology learning not only emphasizes mastery of concepts but also develops students' science process skills, scientific thinking skills, and scientific attitudes.(Yudhistian & Cintamulya, 2026)One approach that supports these characteristics is Active, Innovative, Creative, Effective, and Enjoyable Learning (PAIKEM). This approach provides students with opportunities to build knowledge through exploration, discussion, investigation, reflection, and collaboration, making learning more meaningful.

The implementation of active learning also provides space for students to participate directly in the learning process, thereby increasing student engagement, responsibility, and learning outcomes.(Siadari et al., 2024).

One learning model that aligns with the PAIKEM approach is Project-Based Learning (PjBL). This model facilitates students in acquiring knowledge through completing authentic projects related to real-life problems, encouraging them to integrate knowledge, skills, and attitudes. Through project planning, investigation, data collection, product development, and presentation activities, students are encouraged to think critically, creatively, communicate effectively, and take responsibility for their learning outcomes. Project-based learning also provides a more contextual learning experience, enabling students to connect biology concepts with everyday life.

The effectiveness of Project Based Learning in Biology learning has been proven by various studies.Komalasari et al., (2024)reported that the implementation of Problem-Oriented Project-Based Learning was able to significantly increase student creativity because students were actively involved in solving problems through project activities.Hindun et al., (2024)also found that the implementation of Project Based Learning effectively improved students' scientific literacy and collaboration skills, making the learning process more active and meaningful.Fitri et al., (2024)Through a literature review, it was concluded that Project-Based Learning is one of the learning models that most consistently increases student creativity, engagement, and activeness because it places students at the center of learning. The research results indicate that project-based learning can support the achievement of 21st-century competencies while improving the quality of the Biology learning process.

These findings are reinforced by researchAbas et al., (2024)which shows that the integration of Project Based Learning can improve the science process skills and conceptual understanding of Biology students through structured project activities. Furthermore,Sidabariba et al.,(2024)proves that the application of Project Based Learning to the material on Biodiversity has a significant effect on the critical thinking skills of high school students.Situmorang & Sipahutar, (2026)also reported that Project-Based Learning combined with gamification can improve critical thinking skills, collaboration, and student engagement during the learning process. The consistency of the results of these various studies indicates that Project-Based Learning is an effective learning model in improving the quality of biology learning processes and outcomes, making it highly relevant to integrate with the PAIKEM approach.

However, previous research generally focuses on the application of Project Based Learning as a stand-alone learning model. Most studies examine the influence of PjBL on learning outcomes, creativity, critical thinking skills, scientific literacy, or collaboration skills, while research integrating the PAIKEM approach with Project Based Learning in Biology learning is still relatively limited. Furthermore, studies on the effectiveness of integrating the two approaches in Biodiversity material at the high school level have also not been widely reported. This condition indicates a research gap, namely the limited empirical evidence regarding the influence of the integration of the PAIKEM approach with Project Based Learning syntax on improving student learning achievement in Biodiversity material.

Based on the results of initial observations at SMA Negeri 2 Rantau Utara, it was found that the Biology learning process was still dominated by lecture and question-and-answer methods, so that the teacher acted as the center of learning, while students tended to be passive during the learning process. Discussion activities, group work, investigations, and problem-solving were not taking place optimally. This condition caused some students to still have difficulty understanding contextual Biology concepts, which had an impact on low learning outcomes, as indicated by the fact that some students still obtained scores below the Minimum Completion Criteria (KKM). This condition indicated a gap between the demands of the curriculum that emphasized active learning and classroom learning practices that were still teacher-oriented.

Based on the research gap, the novelty of this research lies in the application of the PAIKEM approach integrated with the Project Based Learning model on Biodiversity material at SMA Negeri 2

Rantau Utara. Unlike previous research which generally only applies Project Based Learning as a learning model, this research combines the principles of active learning contained in the PAIKEM approach with the stages of Project Based Learning to create more active, innovative, creative, effective, and enjoyable learning. This research is expected to provide empirical evidence regarding the effectiveness of the integration of the two approaches in improving student learning achievement while also being an alternative Biology learning strategy that is in accordance with the demands of 21st century learning.

II. METHOD

This study uses a quantitative approach with a quasi-experimental research type. The quantitative approach was chosen because the study aims to test the effect of implementing the Active, Innovative, Creative, Effective, and Enjoyable Learning (PAIKEM) approach combined with the Project-Based Learning (PjBL) model on student learning achievement through objective, measurable, and systematic data analysis.(Creswell, 2014; Sugiyono, 2019)The research design used is the Pretest–Posttest Control Group Design, namely an experimental design involving two groups, consisting of an experimental group and a control group.

This research was conducted at SMA Negeri 2 Rantau Utara, Labuhanbatu Regency, North Sumatra Province, in the odd semester of the 2025/2026 academic year, namely from November 2025 to February 2026. The study population was all grade X students of SMA Negeri 2 Rantau Utara who took Biology in the 2025/2026 academic year. The research sample was determined using a purposive sampling technique, namely a sampling technique based on certain considerations tailored to the research objectives. These considerations include equality of student academic abilities, a relatively balanced number of students, and recommendations from Biology subject teachers. Based on the results of the sample determination, class X IPA 2 was determined as the experimental group that received learning using the PAIKEM approach based on Project Based Learning (PjBL), while class X IPA 3 was determined as the control group that received learning using conventional methods. Each class consisted of 35 students, so the total sample size was 70 students. The determination of the two classes was carried out to minimize the influence of external variables so that the differences in learning achievement obtained at the end of the study better reflect the effect of the treatment given.

Data collection was conducted using learning outcome tests administered before treatment (pretest) and after treatment (posttest). The research instrument was an objective multiple-choice test structured based on learning outcomes, learning objectives, and Biology material indicators. Instrument development began with the development of a question grid that referred to the competencies that students must achieve. Next, test items were developed based on the Revised Bloom's Taxonomy, which includes six levels of cognitive ability: remembering (C1), understanding (C2), applying (C3), analyzing (C4), evaluating (C5), and creating (C6). The distribution of test items at each cognitive level was carried out proportionally so that the instrument could measure students' thinking abilities comprehensively, from mastery of basic concepts to higher-order thinking skills (HOTS).

Before being used in the research, the instrument was first validated by material experts and learning evaluation experts to obtain content validity. Next, the instrument was piloted on students who had similar characteristics to the research subjects, but were not included in the research sample. The initial instrument consisted of 40 multiple-choice questions. The results of the empirical validity test using Pearson Product Moment correlation showed that 25 items were declared valid, while 15 items did not meet the validity criteria and were therefore not used in the research. Next, the reliability of the 25 valid items was analyzed using the Cronbach's Alpha coefficient, and an analysis of the level of difficulty and discriminatory power was conducted to ensure the quality of each item. Thus, only 25 items that met the criteria of validity, reliability, having an appropriate level of difficulty, and good discriminatory power were used as research instruments in the pretest and posttest.

The data obtained were analyzed using IBM SPSS Statistics version 25. The analysis began with descriptive statistics to describe the characteristics of the data through minimum, maximum,

average (mean), and standard deviation values. Next, the prerequisite analysis tests were carried out, including the normality test using Shapiro–Wilk, because the number of samples in each group was less than 50 students, and the homogeneity test using Levene's Test to determine the similarity of variance between the experimental group and the control group.

The statistical hypotheses tested are H_0: $\mu_e = \mu_k$ and H_1: $\mu_e \neq \mu_k$, where μ_e represents the average student learning achievement in the experimental group and μ_k represents the average student learning achievement in the control group. The decision-making criteria are based on the Sig. (2-tailed) value, namely if Sig. ≤ 0.05, then H_0 is rejected and H_1 is accepted, so there is a significant influence of the implementation of the PAIKEM approach based on Project Based Learning (PjBL) on student learning achievement. Conversely, if Sig. > 0.05, then H_0 is accepted and H_1 is rejected, which indicates that the implementation of the PAIKEM approach based on Project Based Learning (PjBL) does not have a significant influence on student learning achievement.

III. RESULTS AND DISCUSSION

The research began with a pretest administered to the experimental and control groups to obtain information on students' initial abilities before treatment. The experimental group then participated in a learning process using the Active, Innovative, Creative, Effective, and Enjoyable Learning (PAIKEM) approach based on Project Based Learning (PjBL), while the control group participated in learning using conventional methods. After the entire learning series was completed, both groups were given a posttest with the same instrument to measure student learning achievement after the treatment. The pretest and posttest data were then analyzed using statistical techniques in accordance with the research objectives. The results of the data analysis are described as follows.

1. Normality Test

A normality test was conducted to determine whether the research data came from a normally distributed population as one of the prerequisites for using parametric statistical analysis. The normality test in this study was conducted using IBM SPSS Statistics version 25 with the Shapiro–Wilk method, because the number of samples in each group was less than 50 students. Data are declared normally distributed if the significance value (Sig.) is greater than 0.05, while a significance value less than or equal to 0.05 indicates that the data are not normally distributed. The results of the pretest and posttest data normality test in the experimental and control groups are presented in Table 2.

Table 2. Normality Test

Class	Shapiro-Wilk			Information
	Statistics	Df	Sig.	
*Pre-test*Class A (Control)	0.944	35	0.072	Sig. > 0.05
*Post-test*Class A (Control)	0.957	35	0.187	(Normal)
*Pre-test*Class B (Experimental)	0.968	35	0.159	
*Post-test*Class B (Experimental)	0.955	35	0.403	

Based on the results of the normality test presented in Table 4, it is known that the pretest data in the experimental class obtained a significance value of 0.159, while the posttest data obtained a significance value of 0.403. In the control class, the significance value for the pretest data was 0.072, while the posttest data was 0.187. All significance values obtained in both groups showed a Sig. value > 0.05, so it can be concluded that the pretest and posttest data in the experimental and control classes were normally distributed. By fulfilling the normality assumption, the research data has met one of the prerequisites for parametric statistical analysis using the Independent Samples t-test.

2. Homogeneity Test

A homogeneity test was conducted to determine the similarity of variance between the experimental and control groups as a prerequisite for using parametric statistical tests. The homogeneity test in this study used Levene's Test with the help of IBM SPSS Statistics version 25 at a significance level of 0.05. The results of the homogeneity test for pretest and posttest data are presented in Table 3.

Table 3. Homogeneity Test

	Levene Statistics	df	df2	Sig.

Pre-Test	3,630	1	68	.061
Post-Test	2,474	1	68	.120

Based on the homogeneity test results in Table 3, the Levene Statistic value was 3.630 with a significance value (Sig.) of 0.61. Since the significance value is less than 0.05 (0.61 > 0.05), it can be concluded that the pretest data variance between the experimental and control groups is homogeneous. These results indicate that the initial abilities of students in both groups have different levels of diversity before being given treatment.

Furthermore, the Levene Statistic value is 2.474 with a significance value (Sig.) of 0.120. This significance value is greater than 0.05 (0.120 > 0.05), so it can be concluded that the variance of the posttest data between the experimental group and the control group is homogeneous. Thus, the learning outcome data after treatment has a relatively equal level of diversity in both groups, thus fulfilling one of the assumptions of using parametric statistical analysis.

3. Hypothesis Testing

After the data met the normality assumption and the posttest data met the homogeneity assumption, the analysis was continued with an Independent Samples t-test to determine the effect of the implementation of the Active, Innovative, Creative, Effective, and Enjoyable Learning (PAIKEM) approach based on Project Based Learning (PjBL) on student learning achievement in Biology. The results of the hypothesis testing are presented in Table 4.

Table 4 Hypothesis Testing

Class	Levene's Test for Equality of Variances		t-test for Equality of Means				
	F	Sig	t	df	Sig.(2-tailed)	Mean Difference	Std.Error Difference
Results	2,474	.120	-6,008	68	.000	-19,257	3,205

Based on the results of the Independent Samples t-test in Table 4, the Levene's Test significance value was obtained at 0.120 (> 0.05), which indicates that the data variance between the experimental group and the control group is homogeneous. Therefore, the interpretation of the hypothesis test results refers to the Equal Variances Assumed row. The analysis results show a t value of -6.008 with a degree of freedom (df) of 68 and a significance value of Sig. (2-tailed) of 0.000. Because the significance value is less than 0.05 (0.000 < 0.05), H_0 is rejected and H_1 is accepted. Thus, there is a significant difference between student learning achievement in the experimental group who received learning using the PAIKEM approach based on Project Based Learning (PjBL) and the control group who received learning using conventional methods. These results indicate that the application of the PAIKEM approach based on Project Based Learning (PjBL) has a significant effect on improving student learning achievement in Biology.

The results of the study indicate that the implementation of the Active, Innovative, Creative, Effective, and Enjoyable Learning (PAIKEM) approach based on Project Based Learning (PjBL) has a positive influence on student learning achievement in the Biodiversity material at SMA Negeri 2 Rantau Utara. This is indicated by the increase in the average learning outcomes of students in the experimental class compared to the control class after the learning process took place. This finding indicates that the integration of the PAIKEM approach with the Project Based Learning model is able to create a more active, innovative, collaborative, and student-centered learning process so that students have the opportunity to build their knowledge through direct learning experiences. This condition is in line withFarrow et al., (2024)which states that Project Based Learning is a student-centered learning approach that encourages students to build knowledge through a process of inquiry, collaboration, and project completion, resulting in deeper learning.

The results of this study are in line with various previous studies which reported that the implementation of Project Based Learning is able to improve learning outcomes, student engagement, creativity, and critical thinking skills through learning activities oriented towards project completion and contextual problem solving.(Satria et al., 2025)Other research also explains that project-based learning provides opportunities for students to develop communication, collaboration, and

responsibility skills through investigative activities, group discussions, report writing, and presentations of project results.(Hasanah & Chamdani, 2025). The similarity between the results of this study and the present study lies in the increase in student participation during the learning process, both when identifying problems, conducting investigations, discussing in groups, and presenting project results to classmates.

These results are also supported byIrsyad et al., (2024)which explains that the implementation of Project Based Learning based on a constructivist perspective provides students with the opportunity to construct knowledge through projects related to real situations, so that learning becomes more meaningful and student-centered. However, during the implementation of the study, several students were still found to lack confidence when presenting project results in front of the class and had not participated optimally in discussion activities. This condition differs from several previous studies that reported that the implementation of Project Based Learning was able to increase active student participation at every stage of learning, starting from discussion activities, expressing opinions, to presenting project results.(Irawan & Ahmad, 2025).

These differences are thought to be influenced by students' varying initial abilities, self-confidence levels, previous learning experiences, and communication skills that still need to be developed. These findings are in line withPurnami & Widiadnya, (2024)which explains that fear of making mistakes, low self-confidence, and limited communication experience are factors that can hinder student participation in project-based learning, even though the model is generally able to improve communication and collaboration skills if supported by appropriate teacher facilitation. These findings indicate that the success of implementing PAIKEM based on Project Based Learning is not only determined by the learning model used, but is also influenced by student characteristics, especially the level of self-confidence, as well as a learning environment that is able to support active student involvement during the learning process.(Safitri et al., 2021).

The improvement in student learning achievement in this study can be explained through the learning mechanisms contained in the Project Based Learning model. According to the PjBL steps proposed byNoviati, (2021)The first stage begins with the presentation of essential questions (Start with the Essential Question) related to real-world problems in the surrounding environment. At this stage, the teacher asks questions that can arouse students' curiosity and guide them to identify problems that will be solved through projects. These essential questions encourage students to think critically, connect biology concepts to everyday life, and prepare them for more in-depth investigations. This condition makes students more active from the beginning of the lesson and increases learning motivation, in line with the findings.Nabiella et al., (2025)which shows that Project Based Learning is able to increase student motivation and activeness through direct involvement in every stage of learning.

The next step is to design a project plan (Design a Plan for the Project). The teacher and students develop project objectives, determine work procedures, assign tasks to each group member, and determine the necessary tools and materials. Collaborative planning helps students understand their individual responsibilities and fosters collaborative problem-solving skills. This activity ensures each group member has a clear role, enabling a more focused and effective learning process.(Guo et al., 2020). Next, students and their teachers create a project schedule (Create a Schedule). Creating a schedule allows students to manage their time, determine completion targets for each activity, and cultivate discipline throughout the project. This stage not only helps the project run according to plan but also fosters a sense of responsibility and self-management skills, which are essential components of 21st-century learning.

The core stage of learning is implementing projects and monitoring their progress (Monitor the Students and the Progress of the Project). At this stage, students observe, collect information, analyze data, and develop solutions to predetermined problems. The teacher acts as a facilitator, guiding, providing feedback, and assisting students when they encounter difficulties. Through these investigative activities, students gain hands-on learning experiences, enabling them to understand biology concepts not only theoretically but also apply them in real-world contexts. These activities

contribute to the development of critical thinking, creativity, communication, and collaboration skills among students.

After the project is completed, students compile a report and present the project results (Assess the Outcome) to the teacher and classmates. The presentation provides an opportunity for students to explain the results of their investigation, defend arguments based on the data obtained, and receive input from other groups. This interaction helps students refine their conceptual understanding while also improving their scientific communication skills, self-confidence, and responsibility for the results of their group work. Furthermore, the intergroup discussion process enriches students' knowledge by providing them with diverse perspectives on the material being studied.

The final stage is evaluating the project process and outcomes (Evaluate the Experience). The teacher and students reflect on the entire learning process to identify strengths, challenges, and learning experiences gained during the project. Reflection helps students evaluate the learning strategies they have used and enhances metacognitive skills, enabling them to plan improvements for subsequent learning. Through this evaluation stage, students not only gain a better understanding of concepts but also develop a sense of responsibility for their own learning.

All stages of Project Based Learning align with the characteristics of the PAIKEM approach. The active element is evident when students are involved in every learning process, from identifying problems to reflecting. The innovative element is evident through students' freedom in determining project completion strategies. The creative element develops when students produce products based on the results of investigations. The effective element is reflected in the achievement of learning objectives through systematic learning experiences, while the enjoyable element arises because students learn through challenging, collaborative activities related to real-world problems in their surroundings. Thus, the integration of PAIKEM and Project Based Learning not only improves cognitive learning outcomes but also develops higher-order thinking skills (HRT), communication, collaboration, creativity, and student responsibility for learning.

In the Biodiversity material, the application of the PAIKEM approach based on Project Based Learning provides an opportunity for students to learn concepts through direct observation activities of objects found in the surrounding environment. Students not only learn the theoretical classification of living things, but also identify the level of biodiversity, analyze the factors that influence diversity, and explain the importance of biodiversity conservation efforts. Learning experiences obtained through observation, data collection, discussion, and project preparation make learning more contextual so that the concepts learned are easier to understand, remember, and apply in everyday life.

The success of the PAIKEM approach based on Project Based Learning in this study was seen from the increase in student participation during the learning process. Students were more active in asking questions, discussing, expressing opinions, working together in groups, and were more confident when presenting project results compared to students in the control class. These findings indicate that the integration of the PAIKEM approach with Project Based Learning not only contributes to improved learning achievement, but also has the potential to develop 21st-century competencies, including critical thinking, creativity, communication, collaboration, problem-solving, and learning independence. Overall, the increase in student learning achievement occurred because each stage of learning provided opportunities for students to learn actively through investigations, discussions, collaboration, project preparation, presentations, and reflections so that Biology learning on the Biodiversity material became more meaningful than conventional learning.

IV. CONCLUSION

Based on the results of the research and data analysis that have been carried out, it can be concluded that the implementation of the Active, Innovative, Creative, Effective, and Enjoyable Learning (PAIKEM) approach based on Project Based Learning (PjBL) has a significant influence on student learning achievement in the Biodiversity material at SMA Negeri 2 Rantau Utara. This is proven through the results of the Independent Samples t-test which shows a significance value of 0.000 (Sig. <0.05), so that H_0 is rejected and H_1 is accepted. Thus, there is a significant difference in

learning achievement between students who take part in learning using the PAIKEM approach based on PjBL and students who take part in learning using conventional methods.

The implementation of PAIKEM based on PjBL can increase the active involvement of students in the learning process through problem identification, project planning, investigation, group discussion, report preparation, presentation, and reflection. This learning process provides opportunities for students to build knowledge independently through contextual learning experiences, thus not only improving the understanding of Biology concepts, but also supporting the development of critical thinking skills, creativity, communication, collaboration, and learning responsibility. Thus, the PAIKEM approach based on Project Based Learning can be an alternative effective Biology learning strategy to create student-centered learning and improve the quality of the learning process and outcomes, especially in the Biodiversity material.

V. RECOMMENDATIONS

Based on the research results, the implementation of PAIKEM based on Project Based Learning (PjBL) can be used as an alternative to biology learning to improve student achievement. However, during the implementation of the research, there were still obstacles such as limited learning time and some students who lacked confidence in presenting project results. Therefore, teachers are advised to carry out more thorough project planning and provide guidance so that all students can actively participate. Further research can develop the application of PjBL to other materials by adding variables such as critical thinking skills, creativity, or student learning independence.

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