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Application of Project-Based Learning (PjBL) Model on Biodiversity Material to Foster Knowledge of Students at Takengon State Senior High School 6

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Abstract: Project-Based Learning (PjBL) is an active and innovative learning model that can improve students' understanding of complex concepts in biology. This study aims to analyze the application of the PjBL model in biodiversity material and its impact on the knowledge of 10th grade high school students. The research method used a quasi-experimental design with a pretest-posttest control group design. The research sample consisted of 55 students divided into two groups: an experimental group (28 students) using the PjBL model and a control group (27 students) using a conventional learning model. The results showed a significant difference between the learning outcomes of the experimental and control groups ($p < 0.05$). The average posttest score of the experimental group (85.2) was higher than that of the control group (74.6). The PjBL model proved to be effective in fostering students' knowledge of biodiversity through authentic and contextual learning experiences.

Keywords: Biodiversity; Biology; Project-based learning; Student knowledge

Introduction

Biodiversity is one of the fundamental subjects in biology learning that requires a deep understanding of the concepts of ecology, taxonomy, and conservation. This material is not only theoretical but also has broad practical applications in everyday life and contemporary environmental issues. However, biodiversity learning in high schools still faces various challenges in terms of effective delivery methods.

Initial observations at Takengon State High School 6 show that learning about biodiversity is still dominated by a teacher-centered approach using lectures and memorization. This condition makes it difficult for students to understand abstract and complex concepts, and they are unable to relate what they learn to real phenomena in their surroundings. Learning outcome data shows that the average student score on biodiversity material is still below the Minimum Passing Grade (KKM), which is around 65-70, even though the KKM is set at 75.

The problems with conventional learning require innovative approaches that can increase student engagement and provide meaningful learning experiences (Susilawati et al., 2023; Wurdinger et al., 2010). Project-Based Learning (PjBL) is one alternative learning model that can address these challenges (Helle et al., 2006; Thomas, 2000). The PjBL model allows students to learn through in-depth investigation of authentic and complex problems, produce tangible products, and develop 21st-century skills.

Project-Based Learning (PjBL) is a student-centered learning model that provides meaningful learning experiences and problem-solving through the implementation of projects that produce a product (Surya et al., 2018). According to Bell (2010), PjBL is a learning approach that gives students the freedom to plan learning activities, carry out projects

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collaboratively, and ultimately produce work products that can be presented to others (Partnership for 21st Century Skills, 2019).

The Buck Institute for Education (2015) defines PjBL as a systematic teaching method that involves students in learning complex knowledge and skills through a structured inquiry process, authentic and challenging questions, and carefully designed tasks and products (Ministry of Education and Culture, 2018; Polman, 2000). The main characteristics of PjBL include: (1) focusing on questions or problems that encourage students to experience and grapple with the central concepts and principles of a discipline; (2) involving students in constructive investigation; (3) being driven by student voice and choice; and (4) producing authentic products.

The PjBL learning syntax according to Rivet et al. (2008) consists of six stages: (1) Start with the essential question, (2) Design a plan for the project, (3) Create a schedule, (4) Monitor the students and the progress of the project, (5) Assess the outcome, and (6) Evaluate the experience. Each stage plays an important role in ensuring the successful implementation of PjBL.

The theoretical basis of PjBL stems from constructivism theory, which emphasizes that learning is an active process in which students construct their own knowledge through interaction with their environment (Diniaty et al., 2015; Merdekawati et al., 2011). This theory was developed by figures such as Piaget, Vygotsky, and Dewey. Then Vygotsky's social constructivism theory emphasizes the importance of social interaction in learning. In PjBL, students work in collaborative groups that enable the zone of proximal development, where students can achieve a higher level of understanding with the help of peers or teachers (Sufi et al., 2025; Vygotsky, 1978).

Dewey's experiential learning theory also forms the basis of PjBL, which emphasizes the importance of direct experience in learning. Through projects, students not only learn about concepts but also experience the process of applying concepts in real-life situations.

In the context of biodiversity learning, the PjBL model can be implemented through projects such as local flora and fauna inventory, herbarium creation, mini-research on endemism, or conservation campaigns. These projects not only improve students' conceptual understanding but also develop research, collaboration, and communication skills (Ibrahim et al., 2025; OECD, 2019).

Biodiversity is the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part (Convention on Biological Diversity, 1992). Biodiversity encompasses three levels: genetic diversity, species diversity, and ecosystem diversity.

In the context of secondary education, biodiversity material is highly complex because it involves concepts from various branches of biology such as taxonomy, ecology, genetics, and evolution. Students are required to understand not only definitions and classifications, but also the ecological processes underlying the formation of biodiversity and the threats it faces.

Research by Novak et al. (2018) shows that effective biodiversity learning requires an approach that can concretize abstract concepts through direct experience with nature. Students need to be encouraged to observe, identify, and analyze biodiversity in their surrounding environment.

Various studies have proven the effectiveness of PjBL in science learning. Research by Capraro et al. (2013) shows that students who learn using the PjBL model have a deeper understanding of concepts and better knowledge transfer abilities compared to traditional learning (Okatama, 2017; Trianto, 2014).

In the context of biology learning, research by Ergül et al. (2014) found that PjBL can increase student motivation and critical thinking skills (Fitriah, 2017; Nissa et al., 2017). Students involved in biology projects showed significant improvements in conceptual understanding and scientific process skills (Damayanti et al., 2023; Sari et al., 2016).

Specifically for biodiversity material, research by Vatau et al. (2015) shows that project-based learning can increase students' environmental awareness and their understanding of the importance of biodiversity conservation (Samedi, 2021).

This study aims to analyze the application of the Project-Based Learning model in biodiversity material and measure its impact on student knowledge (Larmer et al., 2015; Riduwan, 2012). Specifically, this study will answer the question: "How does the application of the PjBL model affect the improvement of student knowledge in biodiversity material compared to conventional learning?"

Method

Type and Design of Research

This research uses a quantitative approach with a quasi-experimental design method. The design chosen is a pretest-posttest control group design (Rahman et al., 2013). This design was chosen because it allows researchers to compare learning outcomes between groups using the PjBL model (experimental group) and groups using conventional learning (control group). The research design scheme is as follows:

Experimental Group: $O_1 \quad X_1 \quad O_2$

Control Group: $O_1 \quad X_1 \quad O_2$

Explanation:
O_1 = Pretest (initial test)
O_2 = Posttest (final test)
X_1 = Treatment with the PjBL model
X_2 = Treatment with conventional learning model

Population and Sample

The population in this study was all 10th grade students at SMA Negeri 6 Takengon in the 2025/2026 academic year, totaling 240 students. The sampling technique used cluster random sampling, where two classes were randomly selected to be the experimental and control groups.

The research sample consisted of 55 students divided into an experimental group of 28 students (class X-1) and a control group: 27 students (class X-2). The criteria for sample selection were classes with relatively homogeneous academic abilities based on the average scores in biology in the previous semester (Mustamin, 2015).

Research Instruments

Learning Achievement Test

The main instrument was an objective test (multiple choice) consisting of 25 questions with 4 answer choices. This test measured students' knowledge of biodiversity material, which included: (1) Basic concepts of biodiversity (gene, species, ecosystem levels). Indonesian biodiversity; (2) Classification of living things; (3) Threats to biodiversity; (4) Efforts to preserve biodiversity.

Observation Sheet

The observation sheet is used to observe the implementation of learning with the PjBL model and conventional learning.

Research Procedure

Preparation Stage

Development of learning tools (lesson plans, teaching materials, instruments) (Fadilah et al., 2017).

Implementation Stage

Experimental Group (PjBL Model): Learning was carried out in 6 meetings (12 lessons) with the following syntax: (1) Meetings 1-2: Start with Essential Question & Design Project: The teacher presents the essential question: "How is biodiversity around our school and what can we do to preserve it?" Students are divided into groups (4-5 people). Each group chooses a project focus: flora/fauna inventory, herbarium creation, conservation campaign, or mini research. (2) Meetings 3-4: Create Schedule & Monitor Progress: Groups create a timeline and division of tasks. Conduct field observations and data collection. Teachers monitor and provide guidance. (3) Meeting 5: Assess the Outcome: Groups complete project products. Presentation preparation. (4) Meeting 6: Evaluate the Experience: Presentation of project results, learning reflection, project evaluation (Yusud, 2015).

Control Group (Conventional Learning): Learning through lectures, discussions, and question-and-answer sessions. Use of learning media in the form of presentation slides and individual assignments and exercises.

Data Analysis Techniques

Descriptive Analysis

Includes calculation of mean, median, mode, standard deviation, minimum and maximum values for pretest and posttest data for both groups.

Prerequisite Tests

Normality test using the Shapiro-Wilk test and Homogeneity test using Levene's test.

Hypothesis Testing

Independent t-test to compare posttest results between the experimental and control groups. Paired t-test to compare pretest and posttest results within each group. N-Gain analysis to measure students' knowledge gain.

N-Gain Formula:
N-Gain = (Posttest score - Pretest score) / (Maximum score - Pretest score)

N-Gain Interpretation:
N-Gain > 0.7: High improvement
0.3 ≤ N-Gain ≤ 0.7: Moderate improvement
N-Gain < 0.3: Low increase

All statistical analyses were performed using SPSS software version 25 with a significance level of $\alpha = 0.05$.

Result and Discussion

Effectiveness of the PjBL Model in Improving Student Knowledge The results showed that the application of the Project-Based Learning (PjBL) model to biodiversity material was effective in increasing student knowledge. This was evident from the significant difference between the posttest results of the experimental group (85.2) and the control group (74.6) with a p value of $0.000 < 0.05$.

The advantage of the PjBL model lies in its student-centered learning approach, where students are actively involved in the process of knowledge construction through direct experience. In the context of biodiversity material, students not only memorize definitions and classifications, but also experience the process of observation, identification, and analysis of biodiversity in their surrounding environment (Savery, 2015).

Projects carried out by students, such as inventorying the flora and fauna around the school, creating herbariums, and conducting conservation campaigns, provide authentic and meaningful learning experiences. Students can directly see abstract concepts such as genetic diversity in leaf morphology variation, species diversity through the identification of various types of plants, and ecosystem diversity through the observation of different habitats.

Improvement in Conceptual Understanding

N-Gain analysis shows that the experimental group had a higher increase in knowledge (0.68) compared to the control group (0.41). Although both groups were in the moderate improvement category, this difference was statistically significant (p = 0.000).

The increase in conceptual understanding in the experimental group can be explained by several factors: (1) Contextual Learning: Students learned the concept of biodiversity in a real context through direct observation in the school environment (Barlenti et al., 2017; Desmiwati et al., 2017; Falaq, 2017; Rivet et al., 2008; Sudrajat, 2017). This helped students understand that biodiversity is not just a theoretical concept, but a real phenomenon that can be observed and studied. (1) Active Knowledge Construction: Through projects, students actively construct their own knowledge by collecting data, analyzing information, and concluding from their observations. This process is in line with the principles of constructivism, which emphasizes the active role of students in learning. (2) Collaborative Learning: Group work in projects allows for discussion and exchange of ideas among students. Students with a better understanding can help their peers (peer tutoring), while group discussions help deepen their understanding of concepts.

Student Motivation and Engagement

Observations during learning showed that students in the experimental group had higher motivation and engagement. This was reflected in the students' enthusiasm in conducting field observations, their activeness in group discussions, and the quality of the products they produced. This increase in motivation can be explained by several factors: Autonomy: Students have the freedom to choose the focus of the project according to their interests, so they feel a sense of ownership over their learning. Relevance: Projects related to the surrounding environment make learning relevant to students' lives. Achievement: Producing tangible products provides a sense of accomplishment that increases motivation to learn.

Conclusion

Based on the research results and discussion, it can be concluded that: The application of the Project Based Learning (PjBL) model is proven to be effective in developing students' knowledge of biodiversity. This is indicated by a significant difference between the posttest results of the experimental group (85.2) and the control group (74.6) with a p-value of 0.000 < 0.05; The group of students who learned with the PjBL model experienced a higher increase in knowledge compared to the group who learned with the conventional model. The N-Gain analysis showed that the increase in the experimental group (0.68) was higher than that in the control group (0.41) with a significant difference (p = 0.000); and Student motivation and engagement in PjBL learning were higher than in conventional learning, as reflected in their enthusiasm in carrying out projects and the quality of the products produced.

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All author declare no conflict of interest.

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