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The Effect of Project-Based Learning Model on Higher Order Thinking Skills of Senior High School (SMA/MA) Students for Biotechnology Material

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Abstract

The ability to think critically at the levels of analysis (C4), evaluation (C5), and concentration (C6) is known as Higher Order Thinking Skills (HOTS). The ability to discern high school students is really low, according to the researchers. The ability to monitor students at a higher level is weakened because students need a learning style or model that suits their needs in order to achieve their learning goals. With the ability to enhance students' HOTS, Project-Based Learning (PjBL) is a teaching methodology that may be applied to the biological sciences. Because of this, the research in this study used quantitative methods, namely the normality, Levene, and hypothesis tests that used t-tests (independent samples). They were derived from the results of the hypothesis test. The results of this study show that the PjBL learning model significantly affects high-level students understanding of biotechnology material, with a p-value of 0.000 and a p-value of less than 0.05 (refer to equation 2)

Keywords: *Biotechnology; HOTS; PjBL model*

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INTRODUCTION

The 2013 Curriculum continues the Competency-Based Curriculum, which integrates knowledge, attitudes, and skills (Wahyu, 2016). The 2013 curriculum indicates that a scientific approach is the preferred method for conducting student learning activities. The scientific method is a learning approach that entails a sequence of scientific activities, including observation, questioning, experimentation, reasoning, and communication skills. This sequence of activities in the learning process is frequently referred to as 5M

(Hosnan, 2014). A student-driven approach underscores the importance of students' active participation in the learning process in the context of enhancing student performance. In contrast, the scientific approach underscores the teacher's role as a facilitator who assists in developing students' potential through a systematic and discovery-oriented learning process (Wicaksono, 2020).

More and more classrooms are emphasizing the importance of higher-order thinking skills (HOTS) as a core focus of instruction (Hamzah et al., 2022). The cognitive domain in Bloom's taxonomy refers to HOTS as high-level thinking skills, and it is located at the analysis (C4), evaluation (C5), and creation (C6) levels (Jannah, 2021). Saido et al. (2015) also asserted that cognitive development is characterized by three critical components: acquiring knowledge, utilizing knowledge, and contemplating knowledge. Teachers can accomplish this by assisting students in the following activities: observing, forming concepts, producing answers, analyzing, comparing, and making the requisite considerations. This learning process can be facilitated by the teacher's capacity to organize a sequence of activities in a structured and organized manner.

The information obtained from the observations and questions and answers conducted with the biology teacher XII MA at the school where the researcher conducted the study was that only a small number of students were observed to be actively engaged. At the same time, the majority appeared to be unenthusiastic. The conventional teaching and learning process continues, with the teacher exclusively utilizing a blackboard to elucidate the material. Many students need help to respond to the help that the teacher poses during the learning process. Teachers have yet to utilize classroom media like Student Worksheets (LKPD) because they have been accustomed to implementing teacher-centered learning methods for years. Therefore, reform ideas are required in the lesson process to cultivate students who are critical, active, and possess thinking skills at an elevated level.

HOTS is the most critical aspect and is currently garnering attention in the field of education, as per Pratama (2018). Not merely memorizing facts and retelling them precisely as they are in reality, but also thinking at the level of creativity is the highest order of thinking skills. The application of higher-order thinking skills (HOTS) in schools is emphasized by Singh et al., (2020) to facilitate students' skill to think creatively, analyze, evaluate, and apply these skills. Telaumbanua et al., (2024) indicated that educators needed to be more proficient in refining their skills to implement innovative learning strategies, such as the HOTS model, when issues were identified. Based on this assertion, the test questions indicated that students' higher-level thinking skills (HOTS) remain inadequate, at 13.6%. In conclusion, the data indicates that students' high-level thinking skills must improve. The biology teacher asserted that many students still require remediation to meet the minimum completion criteria (KKM) score.

The reason for students' limited skill to think at a higher level is that they require models or learning styles appropriate for their circumstances to achieve their learning objectives. Hamidah and Sinta (2021) contend that educators must be innovative in developing contextual learning that is more pertinent to students' daily lives. Another contributing factor is that biology instructors themselves select learning models and styles that are not suitable or effective, resulting in students feeling fatigued and disinterested during their studies. Asyafah (2019) has expressed the learning model's function as a forum and tool for teachers to transmit their knowledge for learning purposes easily. Learning that emphasizes the teacher's role fails to prioritize the students' role, resulting in a lack of student engagement in the learning process. The PjBL model is employed to enhance students' high-level thinking skills (HOTS). Rahayu et al., (2017) conducted an additional study demonstrating the beneficial effects of a project-based learning (PjBL) approach on students' higher-order thinking skills (HOTS).

The PjBL learning model illustrates a model that may be implemented in biology courses. PjBL is a learning methodology that incorporates a variety of comprehensive educational theories. In PjBL, students actively engage in a collaborative and ongoing inquiry process designed to foster comprehension through direct experience. Students are capable of independently constructing knowledge with profound significance, in addition to acquiring scientific skills and attitudes, as a result of this activity (Wulandari et al., 2019). The implementation of PjBL involves the development of a project that will be executed to generate a product. Zubaidah (2017) posits that project-based teaching and learning is the appropriate model because it incorporates the 4C principles: critical thinking, communication, cooperation, and creativity.

Numerous studies have been conducted on PjBL in the context of learning. Most prior research has incorporated PjBL into the creative thinking skills of students (Putri & Zulyusri, 2022). In addition, this is in line with the research conducted by Fitri et al., (2018), which demonstrated the effects of the PjBL model on students' higher-order thinking skills (HOTS) and self-confidence. Research on the effects of project-based learning models on students ability to think creatively in biology education (Azzahra et al., 2023). Researchers have reviewed existing studies, namely the impact of project-based learning models on students' ability to demonstrate mastery of biotechnology material at the SMA/MA level. It is crucial to do research to confirm the effect of the PjBL model on students' high-level thinking skills (HOTS) in biotechnology subjects, based on the concepts mentioned above and all the problems explained. The question that this study aims to answer is whether or not the Project-Based Learning approach improves students' high-order thinking skills (HOTS). Students need higher-level cognitive abilities (HOTS) to overcome background obstacles and solve real-world contextual problems.

METHOD

The research methodology used in this study is quantitative. Classified as an experiment every day. The research group's control layout is the layout of the pretest/posttest layout. Students in the IPA programme at North Sumatra's Islamic Centre Aliyah Tahfizil Qur'an Madrasah were given the PjBL model to help them improve their high-level reasoning skills (HOTS).

Sample and Participants

The population of this study was all classes. The sampling technique applied was non-probability sampling, namely saturated sampling. *Saturated sampling* was used if all population members were used for the sample (Sugiyono, 2019). This study uses samples from two classes: XII 1 (consisting of 28 students) and XII 2 (consisting of 27 students).

Instrument

The instrument used was a test instrument with 6 essay questions according to the HOTs indicator, namely C4. C5 and C6. The instrument was validated by a validator so that it was suitable for use.

Data Collection

In order to achieve the goal of this research, data extraction techniques were used. Initial, secondary, and tertiary observations, as well as documentation, provide the backbone of data collection techniques. Initial observations and interviews aimed to acquire preliminary data and information regarding the student's condition in their previous learning. The test was conducted to acquire quantitative data, specifically data on students' learning outcomes in relation to biotechnology material. The research subjects' names were included in the documentation, which served as a form of supporting data in the study. Additionally, there were photographs of the ongoing learning process.

Procedure

This study consisted of three stages, namely: (1) the Initial stage (preparation and planning), (2) the Implementation stage, and (3) The final stage of referring (Karomah & Rizal, 2022). The initial stage (preparation and planning) was carried out by observing first, determining the research population, preparing a Learning Implementation Plan (RPP), making Student Worksheets (LKPD), making a grid of assessment instruments (in the form of essay questions that included high-level thinking skills). High level, namely analyzing, evaluating, and creating), carrying out test instruments for experts who had experience in the field of education, especially HOTs problems.

The implementation stage, which is the second stage, involves administering a pre-test to students prior to the commencement of the learning process. This pre-test comprises six essay questions. The learning process for biotechnology material is conducted using the PjBL model, with Student Worksheets (LKPD) that contain learning activities that adhere to the syntax. Mariani et al., (2021) are the source of PjBL, which encompasses the following: the identification of fundamental questions, the development of project plans and schedules, the monitoring and testing of results, and the evaluation of experiences (reflection). Table 1 presents the syntax of PjBL in the context of learning.

Table 1. The syntax of PjBL in the context of learning

Syntax	Learning Activities	Implementation
Determining fundamental questions	1. The teacher presents a video containing problems regarding *nata de coco* in the surrounding environment. 2. The students identify and ask questions about the problem.	Face-to-face meeting

Preparing project planning	1. The teacher outlines the project structure that needs to be prepared. 2. The teacher develops a project structure to create biotechnology products that use food ingredients available in the surrounding environment. 3. The teacher divides the students in class into three groups.	Face-to-face meeting
Arranging a schedule	1. The teacher provides an explanation regarding the provisions related to assignments and the deadline for returning them at the next meeting. 2. The teacher divides tasks between group members.	Face-to-face meeting
Monitoring	The teacher checks the condition of each group.	Face-to-face meeting
Testing results	1. The teacher makes notes regarding the project presented. 2. The teacherprovides responses to each team. 3. The teacherassesses the presentation method of each group.	Face-to-face meeting
Reflection	1. The teacherreviews the activities and results of projects that have been implemented. 2. The teacherconveys the feelings and experiences that have been occurred while completing the project.	Face-to-face meeting

The data collected from the student's answers on the second form will be analysed in the third stage. The data is analyzed using statistical tests after collection. The normality test using the Shapiro-Wilk and the homogeneity test using the Levene tests are both considered to be statistical tests. Using the statistical program SPSS 25, we determined the average of the two samples, and we tested our hypothesis using the t-test (independent samples). The purpose of this hypothesis test is to confirm the validity of the following hypotheses that have already been established:

H_0 : Students high-level understanding of biotechnology is unaffected by project-based learning models (PjBL).

H_a : Students capacity for abstract biotechnological thinking is influenced by the PjBL paradigm of project-based learning.

RESULTS AND DISCUSSION

Description of Research Results

The data was inevitably generated from the control and experimental classes as the study advances. The objective of gathering this data from both courses was to examine the students' capacity for higher-order thinking. The instrument data was derived from the answers students provided on the pre-test and post-tests. Starting with C4 (analyzing), then on to C5 (evaluating), and finally C6 (producing), the questions were structured to zero in on each indication of students' HOTS. Each question had its assessment criteria, and there were six questions. The sum of the scores from each question was used to determine the final score.

Students' Pre-Test Data

The study results data came from the pre-test results of two sample classes using a test instrument of 6 HOTS questions. Figure 1 presents the pre-test average score data. The control class had a standard deviation of 17.03 and an average pre-test score of 26.25 (Figure 1), with a maximum score of 60 (Figure 2) and a minimum score of 2 (Figure 1). The experimental group as a whole had a mean score of 36.78 and a standard deviation of 18.46; the range of possible pre-test scores was from 4 to 65.

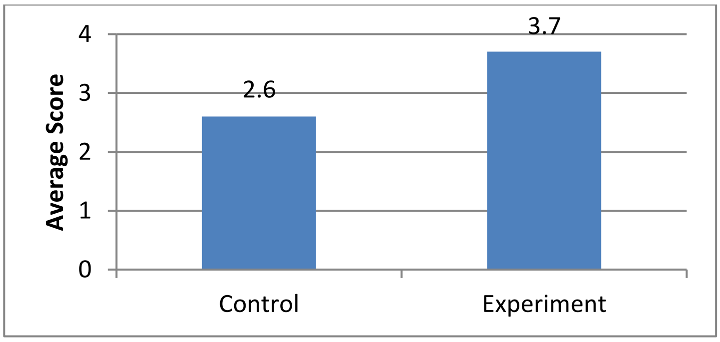

Figure 1. Pre-test average score

Students' Post-Test Data

Learning activities were the means by which this data was collected. With a standard deviation of 24.29, the control class's average post-test score was 52.04. The range of possible scores was 14-92. With a standard deviation of 10.28, the experimental class's average post-test score was 82.33. One hundred is the maximum possible post-test score, while seventy-two is the minimum. The average scores before the exam are shown in Figure 2.

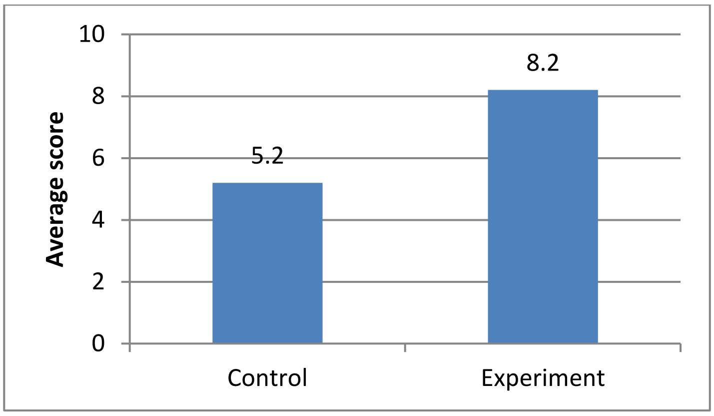

Figure 2. Post-test average score

The image illustrates how each class's results changed after the administration of therapy. Disparities in student achievement were also brought about by the disparities in the way the two groups were educated. Students in the PjBL-using experimental class outperformed their counterparts in the control group, who received more traditional instruction in the form of lectures. There are variations in the learning styles that are used, according to previous research as well. When students in the experimental class are having trouble understanding or keeping up with the material, their teachers are more hands-on than those in the control class who are using the lecture method (65.38% vs. 73.08% (Princess & Desi, 2023).

The indicator for each question is distinct. The *first* question item comprises HOTs questions with domain C4 (analyzing) that pertain to the classification of conventional and modern biotechnology products. This initial question is the foundation for assessing students' initial understanding of conventional and modern biotechnology products by presenting images of each product example. Questions concerning this subject are positioned at the outset to catalyze the subsequent inquiry. Students must respond to three distinctions between conventional and modern biotechnology products. The experimental class achieved the highest pre-test and post-test scores on the first question, with 8 and 10 scores indicating a change in response to the treatment.

The *second* question is in the HOTS C4 domain (analysis). It pertains to collecting data through experimental results and comprehending the *Acetobacter xylinum* bacteria's behavior in relation to its substrate. This second question requires students to evaluate the relationship between the *Acetobacter xylinum* bacteria and their environment and the bacteria's operational mechanisms. The author provides examples of other media that render bacteria incapable of functioning, except liquid media, such as cassava. Students are instructed to compare the methods by which *Acetobacter xylinum* bacteria operate on cassava substrates with liquid media, such as coconut. In the experimental class, students received ten marks for the pre-test and 20 marks for the post-test.

The *third* question examines using raw materials and other mixed ingredients to produce *nata de coco*. Students are required to evaluate the potential consequences of an error in the dosage of an ingredient during the product manufacturing process. Students must, of course, possess a comprehensive understanding of the materials employed in producing products to provide accurate responses to inquiries. The experimental class achieved the highest score on the third question on the pre-test and post-test, which was 10. It indicates that students could answer the question accurately and achieve the maximum score weight.

The *fourth* question in domain C5 (evaluating) pertains to the production of *nata de coco*, *nata de soya*, and *nata de pina*. The fourth question revealed that the control class students could not respond to the question, whereas the experimental class could do so proficiently. It is corroborated by the control class's maximum score of 7, less than the experimental class's maximum score of over seven because the control and experimental classes exhibit distinct behaviors. The control class employed the conventional method (lecture method), while the experimental class implemented the PjBL model. The experimental class achieved the highest pre-test and post-test scores on question 4, with scores of 10 and 20, respectively. Consequently, it was concluded that students were capable of evaluating the process of making data using the model that had been implemented.

The *fifth* question pertains to the potential consequences of employing a different type of sugar in data production, which is still within the C5 domain (evaluation). This type of question is beneficial for developing students' critical thinkingskills, as it requires them to think logically about the consequences of novel ideas that have not been attempted before. In reality, the experimental class students scored ten on the pre-test questions with a low frequency, as they encountered challenges in providing logical and scientific responses. Students achieved a score of 20 with a higher frequency and an increase compared to their pre-test score after implementing the PjBL model.

The *last* question in domain C6 (creating) students are asked to think innovatively about how to make creations or new things from *nata de coco* products if they become *nata de coco* entrepreneurs. The peak in the higher-order thinking (HOTs) category is creativity. Therefore, students must be able to think about what creations to carry out on *nata de coco* products as a selling point that is no less competitive. The pre-test score of the experimental class students on this question could have been higher, with a score of 8, which means the students were less able to think creatively and innovatively. Implementing PjBL in the ongoing learning process increased the experimental class students' post-test scores by 25, which is among the highest score weights.

Based on the questions given, the pre-test score obtained from the control class is 26.25, while the pre-test score for the experimental class is 34.74. Both classes had pre-test scores below the minimum completion criteria (KKM) score for the biology subject, biotechnology material, namely 75. The comparison score shows that the two sample groups have the same skills. In the post-test results, the average score obtained by the experimental class was 82.33, which was higher than the average score of the control class of 52.03. The use of learning models supports this difference in results because learning models are one of the essential needs for students during the learning process. This model helps facilitate understanding of concepts and learning flow.

The PjBL model in this study was implemented using biotechnology material pertinent to daily life. Students are presented with various biotechnology products they already know and use. However, most must know that these products result from scientific processes transforming raw materials into biotechnology products. In addition, the multidisciplinary nature of biotechnology enables its integration with other scientific disciplines, including technology, engineering, and mathematics, to facilitate the acquisition of biotechnology science (Ma'wa et al., 2022).

Prerequisite Test Results

Subsequent analyses of the students' pre - and post-test results demonstrated that the data was homogeneous, normal, and supported the hypothesis.

Normality test

The Shapiro-Wilk test was used to test for normality of the mean scores for both the control and experimental classes, with a significance level of 0.05. Upon completion of data processing within the SPSS program, an output display is displayed. The results of the normalcy test are displayed in Table 2.

Table 2. Normality test

	Experimental Class	**Control Class**
	Pre-test	
Shapiro-wilk Sig.	0,159	0,151
Category	Normally distributed	Normally distributed
	Post-test	
Shapiro-wilk Sig.	0,110	0,142
Category	Normally distributed	Normally distributed

The data for the pre-test scores are comparable to those for the control and experimental classes, according to the Shapiro-Wilk test findings in the table above. The experimental group has a significance level of 0.159, whereas the control group has a value of 0.151. Since both of these numbers are more than 0.05, we can say that the data follows a widely dispersed distribution. The results of the post-test support this conclusion as well; whereas the control group had a significance level of 0.142, the experimental group had a level of 0.110. If the significance value is greater than 0.05, the data is considered to have a regularly distributed distribution, as stated in the normality test requirements, which these results also support. It follows that both the pre - and post-test scores in the two groups followed a normal distribution. Consistent with the findings of Gracia & Indri (2021) and other researchers, the data followed a normal distribution with pre-test and post-test values of 0.172 and 0.88, respectively.

Homogeneity Test

The purpose of this test is to compare the two samples' variances. Using SPSS, we ran a Levene test to see if the control and experimental classes were statistically similar in terms of their two variances. Figure 3 shows the results of the homogeneity test. The pre-test average significance value was 0.178 and the post-test average significance value was 0.172, according to the calculations in the homogeneity test results table. Since the significance level was greater than 0.05, it could be concluded that the population had identical or homogeneous variations.

Tabel 3. Homogeneity Test

		Significance Value	Conclusion
Pre-test	Average	0,178	Homogeneous Data
	Median	0,161	Homogeneous Data
Post-test	Average	0,172	Homogeneous Data
	Median	0,126	Homogeneous Data

Data Analysis Results

Hypothesis Test (Independent Sample t-test)

This study's data was also analyzed using SPSS 25 at a significance level of less than 0.05. The purpose of doing hypothesis testing is to ascertain the veracity of claims that have already been postulated. Both the pre - and post-test findings from the independent sample t-tests are presented in Table 4.

Tabel 4. Data Hypothesis Testing

	Sig. (2-tailed)	Conclusion
Pre-test	0,042	H_a Accepted
Post-test	0,000	

The results from Table 4 indicate that a significant difference in average student scores between the PjBL and traditional learning models may be inferred if the two-tailed tick is less than 0.05. According to the results of the homogeneity (Levene) test, which had a significance level greater than 0.05, and the normal distribution criteria, as determined by Shapiro-Wilk, the data utilised in this independent sample t-test are in agreement. A significance level below 0.05 indicates that the independent sample t-test is legitimate. A null hypothesis (Ho) is rejected and an alternative hypothesis (Ha) is accepted if the significance value is less than 0.05. When comparing the two samples, it is clear that the learning models utilised to gauge students' HOTs had different impacts. We may infer that Ho was rejected since the hypothesis test yielded a significant result of 0.007, which is consistent with the findings of Puspitasari & Siti (2022) in their research. Students ' improved ability to think critically indicates that the PjBL approach was successful.

CONCLUSION

The study results and data analysis conclude that the PjBL learning model influences students' higher-level thinking regarding biotechnology material, which is significant for students. The average post-test score of students on biotechnology material using the PjBL model in the experimental class (worth 82.33) was higher than the learning outcomes of students taught using the conventional model or lecture (52.03) at a significance level of 0.05. The results of the hypothesis test obtained a sig value. (2-tailed) < 0.05, namely 0.000, refers to the hypothesis criteria set, concluding that Ho is rejected and the influence of the PjBL learning model on students' higher-level thinking regarding biotechnology.

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