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THE EFFECTIVENESS OF PROJECT-BASED BIOTECHNOLOGY E-LKPD ON LEARNING OUTCOMES AT SMAN 3 SIAK HULU, KAMPAR REGENCY, RIAU

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ABSTRACT
This research is motivated by the low learning outcomes of students in biotechnology materials caused by the use of teaching materials that have not been able to encourage active involvement of students in the learning process. One of the alternatives that can be used to overcome these problems is the implementation of project-based biotechnology Electronic Worksheets (E-LKPD). This study aims to determine the effectiveness of project-based biotechnology E-LKPD on the learning outcomes of class X students at SMAN 3 Siak Hulu, Kampar Regency, Riau. The research uses a quantitative approach with a quasi experiment method through *a Nonequivalent Control Group Design*. The research sample consisted of two classes, namely the experimental class and the control class which each amounted to 39 students and was selected using *a simple random sampling technique*. The research instrument is in the form of learning outcome tests that have met the validity and reliability tests. Data analysis was carried out descriptively and inferentially through normality tests, homogeneity tests, *Independent Samples t-Test*, and *effect size* analysis (Cohen's d) using IBM SPSS Statistics 26. The results showed that there was a significant difference in learning outcomes between the experimental class and the control class with a value of Sig. (2-tailed) = 0.001 ($p < 0.05$). The *effect size* value (Cohen's d) of 0.813 shows that the use of project-based biotechnology E-LKPD has a great influence on improving student learning outcomes. Thus, it can be concluded that project-based biotechnology E-LKPD is effective in improving student learning outcomes in biotechnology materials at SMAN 3 Siak Hulu, Kampar Regency, Riau.

INTRODUCTION

The development of science and technology in the 21st century has encouraged transformation in the world of education. Learning is no longer only oriented towards the mastery of knowledge, but is also directed towards developing critical thinking skills, creativity, communication, collaboration, and problem-solving as competencies needed in facing global challenges. These changes require the implementation of *student-centered learning*, so that they can build knowledge through active, contextual, and meaningful learning experiences. In this paradigm, teachers play the role of facilitators who create a learning environment that is able to encourage students to think scientifically, collaborate, and solve problems independently (Puriasih & Rati, 2022; Khalisah et al., 2023).

Biology is one of the subjects that has distinctive characteristics because it not only emphasizes the mastery of concepts, but also the scientific process through observation, experiment, investigation, analysis, and drawing conclusions based on empirical facts. Therefore, biology learning requires strategies that are able to actively involve students so that the concepts learned are not only understood theoretically, but can also be applied in daily life. Learning that is still dominated by lecture methods tends to limit students' opportunities to develop high-level thinking skills, resulting in a low understanding of concepts and learning outcomes. On the other hand, learning that provides a hands-on learning experience has been proven to be able to improve learning activities, scientific thinking skills, and academic achievement of students (Fatwa et al., 2023; Nurhasnah et al., 2022). Thus, learning outcomes are an important indicator in evaluating learning success because they reflect the level of competency mastery obtained by students after participating in the learning process (Dakhi & Selatan, 2020). Bayhaqi and Darmawan (2025) emphasized that learning outcomes show the extent to which students are able to understand, process, and apply knowledge in accordance with the learning goals that have been set.

One of the biology materials that requires active learning is biotechnology. This material integrates the concepts of genetics, microbiology, biochemistry, and molecular biology so that it has a fairly high level of complexity. In addition to understanding scientific concepts, students are also required to be able to relate the application of biotechnology in the fields of food, health, agriculture, environment, and industry. This complexity causes many students to have difficulty understanding the material if learning is only done through verbal delivery of concepts. Zulfarina and Mahadi (2019) stated that biotechnology learning will be more effective if students have the opportunity to observe, experiment, analyze, and connect concepts with phenomena encountered in daily life. Therefore, a learning model is needed that is able to provide an authentic learning experience while encouraging students to actively build their knowledge.

One of the learning models that is considered able to meet these needs is *Project Based Learning* (PjBL). This model places learners as the center of learning through the completion of projects related to real problems. During the learning process, students identify problems, prepare plans, carry out investigations, produce products, and reflect on the results obtained. Through this series of activities, students not only gain conceptual understanding, but also develop critical thinking skills, creativity, communication, collaboration, and problem-solving which are important competencies in 21st century learning (Nurhasnah et al., 2022). The effectiveness of Project Based Learning has been proven through various studies. Chiang and Lee (2016) reported that this model was able to increase students' learning motivation and problem-solving skills, while Palopo et al. (2025) and Yohana Sueng et al. (2025) showed that the implementation of Project Based Learning had a positive influence on improving biology learning outcomes.

The success of the implementation of PjBL is not only influenced by the learning model, but also by the learning tools used. One of the tools that plays an important role is the Student Worksheet (LKPD) which functions to guide students in carrying out learning activities systematically. Along with the development of technology, LKPD has developed into an Electronic Student Worksheet (E-LKPD) which is able to integrate various digital media such as images, videos, animations, simulations, and learning links so that the learning process becomes more interactive and flexible (Rahmawati, 2020). The integration of E-LKPD with Project Based Learning syntax provides students with the opportunity to complete each stage of the project in a more targeted manner, while helping them build conceptual understanding through investigation and problem-solving activities. Research by Nurhasnah et al. (2022) shows that the use of project-based LKPD is able to increase learning engagement, critical thinking skills, and student learning outcomes. Therefore, the implementation of E-LKPD based on Project Based Learning has the potential to be one of the effective learning innovations to improve the quality of biology learning, especially in biotechnology materials.

The use of digital teaching materials in biology learning has been proven to be able to improve the quality of the learning process. Research conducted by Robiah et al. (2024) involving Ibnu Hajar shows that the development of electronic biology teaching materials produces valid and effective teaching materials in improving students' cognitive and psychomotor competencies. These findings corroborate that the integration of technology in teaching materials is able to support more interactive and meaningful biology learning.

Based on the results of pre-research in class X at SMAN 3 Siak Hulu, Kampar Regency, it is known that the learning outcomes of students in biotechnology materials are still relatively low. The evaluation data showed that only around 48% of students achieved the Learning Goal Achievement Criteria (KKTP) of 70. The low learning outcomes are influenced by several factors, such as the difficulty of students in understanding abstract biotechnology

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concepts, differences in academic abilities between students, and the use of teaching materials that have not been able to support students to learn actively. During the learning process, teachers still use package books, worksheets, and learning videos as the main learning resources. As a result, learners have not gained learning experiences that encourage them to investigate, discuss, and solve problems independently. This condition shows that more innovative learning tools are needed so that students can be actively involved in the learning process.

One of the innovations that can be applied is the use of Electronic Student Worksheets (E-LKPD)based (PjBL). Various studies show that the integration of E-LKPD with Project Based Learning is able to improve the quality of the process and learning outcomes. Aisya's research (2024) shows that Project-Based Learning-based biotechnology E-LKPD has a very high level of validity so that it is suitable for use in learning. Furthermore, Simamora et al. (2025) reported that the E-LKPD also has a very high level of practicality based on the assessment of teachers and students. Meanwhile, Nomleni et al. (2024), Fatwa et al. (2023), Palopo et al. (2025), and Yohana Sueng et al. (2025) prove that project-based learning can improve learning activities, higher-level thinking skills, and student learning outcomes. These results are in line with the research of Chiang and Lee (2016) which states that Project Based Learning is able to increase learning motivation and problem-solving skills because learners are directly involved in the completion of projects related to real life.

However, the results of the study of previous research show that most of the research still focuses on the development stage of E-LKPD, especially on testing the validity and practicality of the product. Research that tests the effectiveness of the use of E-LKPD on improving student learning outcomes after being applied in real learning is still limited. On the other hand, research on Project Based Learning examines the influence of learning models without utilizing E-LKPD which has been developed specifically for biotechnology materials. This condition shows that there is still a research gap, namely there has not been much research that has tested the effectiveness of the implementation of E-LKPD biotechnology based on Project Based Learning on the learning outcomes of students at the high school level.

In addition, research by Fitriana and Hajar (2021) shows that the development of inquiry-based LKPD makes a positive contribution to the biology learning process. However, the research still focuses on the development of learning tools and has not tested the effectiveness of Project-Based *Learning-based E-LKPD* on student learning outcomes on biotechnology materials. This condition further strengthens the research gap that is the basis for the implementation of this research.

Based on these gaps, the novelty of this research lies in testing the effectiveness of Project-Based Learning-based biotechnology E-LKPD which had previously been declared valid and practical, then implemented directly in biology learning to determine its effect on the learning outcomes of class X students at SMAN 3 Siak Hulu, Kampar Regency. Thus, this study not only continues the product development stage, but also provides empirical evidence regarding the effectiveness of the use of project-based E-LKPD in improving student learning outcomes in biotechnology materials.

Based on this description, this study aims to analyze the effectiveness of the use of Project-Based Learning-based biotechnology E-LKPD on the learning outcomes of class X students at SMAN 3 Siak Hulu, Kampar Regency, Riau. The results of the research are expected to contribute to the development of biology learning, as well as become an alternative for teachers in utilizing innovative digital teaching materials to improve the quality of students' learning processes and outcomes

RESEARCH METHODS

This study uses a quantitative approach with the *quasi experiment* Using the design *Nonequivalent Control Group Design*. This design involves two pre-formed groups, namely the experimental class and the control class. Both groups were given a pretest and posttest, but received different treatments. The experimental class gained learning using *Electronic Student Worksheets* (E-LKPD) Biotechnology is project-based, while the control class follows conventional learning that is commonly applied by teachers.

Table 1. Nonequivalent Control Group Design Research

Groups	Pretest	Treatment	Posttest
Eksperimen	O_1	X	O_2
Controls	O_3	–	O_4

Remarks: X = learning using project-based Biotechnology E-LKPD.

The research was carried out at SMAN 3 Siak Hulu, Kampar Regency, Riau in the even semester of the 2026/2027 Academic Year. The research population was all students of class X. Samples were determined using *the simple random sampling* technique, so that two research classes were obtained, namely class X.3 as an experimental class and class X.4 as a control class.

Table 2. Research Sample

Classes	Treatment	Number of Students
X.3	Project-based Biotechnology E-LKPD	39
X.4	Conventional learning	39
Total		**78**

The research instruments consist of test and non-test instruments. The test instruments are in the form of pretest and posttest questions adapted from *Bukupas:* Complement to the Formative and Summative Biology Textbook for SMA/MA Class X Semesters 1 and 2 (Yrama Widya, 2024), then adjusted to the learning outcomes of biotechnology materials. Non-test instruments include affective and psychomotor observation sheets, interview guidelines, and documentation. All instruments have gone through validity and reliability tests before being used in research.

Table 3. Research Instruments

Instrument Type	Data Obtained	Purpose
Pretest	Students' initial abilities	Knowing the initial condition before treatment
Posttest	Cognitive learning outcomes	Measuring learning outcomes after treatment
Observation sheet	Affective and psychomotor data	Observe learners' activities during learning
Interview Guidelines	Supporting data	Dig up information from Biology teachers
Documentation	Supporting data for the study	Completing evidence of research implementation

The research procedure begins with initial observation and interviews with Biology teachers to identify learning problems. Furthermore, both classes were given a pretest. The experimental class obtained learning using project-based Biotechnology E-LKPD, while the control class used conventional teaching materials. During learning, observations were made on the affective and psychomotor aspects of students. After all treatments were completed, both classes were given a posttest to measure learning outcomes.

Data analysis was conducted using IBM SPSS Statistics version 26. Descriptive analysis is used to describe students' learning outcomes through average scores and standard deviations. Before the hypothesis test was carried out, the data were tested using the Shapiro–Wilk normality test and the Levene homogeneity test. Hypothesis testing using Independent Samples t-Test at a significance level of 5%. The magnitude of the influence of the use of project-based Biotechnology E-LKPD on learning outcomes was analyzed using effect size (Cohen's d).

RESEARCH RESULTS

This section presents the results of data analysis regarding the effectiveness of the use of project-based biotechnology E-LKPD on the learning outcomes of class X students at SMAN 3 Siak Hulu, Kampar Regency, Riau. Data analysis is carried out in stages, starting from descriptive statistical analysis to describe students' learning outcomes before and after learning. Furthermore, an analysis prerequisite test was carried out which included a normality test and a homogeneity test as a basis for determining the analysis technique used. Hypothesis testing was carried out using the Independent Samples t-Test, then followed by N-Gain analysis to determine the level of effectiveness of the use of project-based biotechnology E-LKPD in improving student learning outcomes and effect size analysis (Cohen's d) to determine the magnitude of the influence given. All analysis results are presented systematically in the following subsections.

3.1 Descriptive Statistics of Student Learning Outcomes

Descriptive statistical analysis was carried out to provide an overview of the learning outcomes of students before (pretest) and after (posttest) learning in the control class and experimental class. The statistics analyzed included the number of samples, minimum values, maximums, means, and standard deviations.

Table 3. Descriptive Statistics of Student Learning Outcomes

Variabel	N	Minimum	Maximum	Red	Standard Deviation
Control class pretest	39	7	62	25,38	10,769
Posttest kelas control	39	12	96	52,56	23,176
Experimental class pretest	39	8	75	31,44	16,277
Posttest kelas experiment	39	35	98	69,54	18,334

Based on Table 3, student learning outcomes have increased in both classes after the learning process. In the control class, the average score increased from 25.38 to 52.56, while in the experimental class it increased from 31.44 to 69.54. The average increase in learning outcomes in the experimental class reached 38.10 points, higher than the control class which experienced an increase of 27.18 points.

In addition, the minimum and maximum values in the experimental class after treatment also increased considerably compared to before learning. These results show that students who learn using Project-Based Learning-based biotechnology E-LKPD obtain better learning outcomes than students in the control class. However, the results of descriptive statistics cannot be used as a basis for drawing conclusions, so further statistical testing is necessary.

3.2 Normality Test

The normality test is carried out to find out whether the learning outcome data is distributed normally before the hypothesis test is carried out. The test used Shapiro–Wilk because the sample size was less than 50 students.

Table 4. Normality Test Results

Data	Statistics	df	Say.	Remarks
Control class pretest	0,945	39	0,057	Normal
Posttest kelas control	0,945	39	0,056	Normal
Experimental class pretest	0,955	39	0,119	Normal
Posttest kelas experiment	0,978	39	0,630	Normal

Based on Table 4, all data have a significance value greater than 0.05. The significance value of the control class pretest was 0.057, the control class posttest 0.056, the experimental class pretest 0.119, and the experimental class posttest 0.630. Thus, all learning outcome data is distributed normally so that it meets one of the requirements for a parametric statistical test.

3.3 Homogeneity Test

The homogeneity test was carried out to find out whether the variance of data in the control class and the experimental class had similarities before hypothesis testing was carried out.

Table 5. Homogeneity Test Results

Levene Statistic	df1	df2	Say.	Remarks
2,251	1	76	0,138	Homogeneous

Based on Table 5, a significance value of 0.138 was obtained. The value is greater than 0.05, so it can be concluded that the variance of data in the control class and the experimental class is homogeneous. With the assumption of normality and homogeneity met, the analysis can be continued using the Independent Samples t-Test.

3.4 Uji Hypothesis

Hypothesis testing was carried out using Independent Samples t-Test to determine the effect of the use of Project-Based Learning-based biotechnology E-LKPD on student learning outcomes.

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Table 6. Independent Samples t-Test Results

Classes	N	Mean	Standard Deviation
Posttest Control	39	52,56	23,176
Posttest Experiment	39	69,54	18,334

Table 7. Independent Samples t-Test Results

F	Say.	t	df	Sig. (2-tailed)	Mean Difference
2,251	0,138	-3,587	76	**0,001**	-16,974

Based on Table 7, a Sig. (2-tailed) value of 0.001 was obtained, which is smaller than the significance level of 0.05. These results showed that H_0 was rejected and H_1 was accepted, so there was a significant difference in learning outcomes between the experimental class and the control class.

The average learning outcome of students in the experimental class was 69.54, while the average of the control class was 52.56.The difference in average learning outcomes between the two classes was 16.97 points, which shows that students in the experimental class obtained a higher average learning outcome than the control class.

3.5 Effectiveness Test (N-Gain)

Normalized Gain (N-Gain) analysis was carried out to determine the level of effectiveness of the use of Project-Based Learning-based biotechnology E-LKPD in improving student learning outcomes.

Table 8. N-Gain Results Control Class

Variabel	N	Minimum	Maximum	Mean	Percentage	Category
N-Gain	39	-0,22	0,94	0,3594	35,94%	Ineffective

Table 9. Experimental Class N-Gain Results

Variabel	N	Minimum	Maximum	Mean	Percentage	Category
N-Gain	39	0,18	0,96	0,5715	57,15%	Quite Effective

Based on Table 8 and Table 9, it is known that the average N-Gain in the experimental class was 0.5715 or 57.15%, which is included in the category of quite effective. Meanwhile, the control class obtained an average of 0.3594 or 35.94%, which falls into the ineffective category. These results showed that the improvement in learning outcomes of students in the experimental class was higher than that of the control class after using E-LKPD biotechnology based on Project Based Learning.

3.6 Effect Size

In addition to examining the significance of differences in learning outcomes, this study also calculated effect size to determine the magnitude of the influence of the use of Project-Based Learning-based biotechnology E-LKPD on student learning outcomes. The calculation was performed using Cohen's d based on the mean value and standard deviation of posttest results in the experimental class and the control class.

Table 10. Effect Size Calculation Results

Classes	Mean	Standard Deviation
Eksperimen	69,54	18,334
Control	52,56	23,176

Table 11. Interpretation of Effect Size

Effect Size	Value	Interpretasi
Cohen's d	**0,813**	Large Effect

The calculation results show that Cohen's d value is 0.813. Based on the criteria of Cohen (1988), this value is included in the category of large effect. This means that the use of Project-Based Learning-based biotechnology E-LKPD not only produces statistically significant differences, but also has a strong influence on improving student learning outcomes.

This finding is in line with the results of the Independent Samples t-Test which showed a significance value of 0.001 (<0.05) and was strengthened by the results of the N-Gain analysis, where the experimental class obtained an average score of 57.15% with the category of quite effective, while the control class only obtained 35.94% with the category of ineffective. Overall, the results of the study show that the use of Project-Based Learning-based

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biotechnology E-LKPD is effective and has a great influence on improving the learning outcomes of class X students at SMAN 3 Siak Hulu, Kampar Regency, Riau.

Based on all the results of the analysis that has been carried out, it can be seen that the use of project-based biotechnology E-LKPD provides better results than learning in the control class. This is shown by the increase in the average learning outcomes of students in the experimental class, the fulfillment of the assumption of normality and homogeneity of the data, and the results of the Independent Samples t-Test which show a significant difference between the two classes. In addition, the results of the N-Gain analysis showed that the use of project-based biotechnology E-LKPD was in the category of quite effective, while the effect size of 0.813 showed that the use of E-LKPD had a great influence on improving student learning outcomes. Overall, the findings of this study show that project-based biotechnology E-LKPD is effectively used in biology learning to improve the learning outcomes of class X students at SMAN 3 Siak Hulu, Kampar Regency, Riau. These findings further became the basis for a discussion of the factors that support the effectiveness of the use of project-based biotechnology E-LKPD and its relationship with previous theories and research results.

DISCUSSION

The results of the study show that the use of project-based biotechnology E-LKPD is effective in improving students' learning outcomes in biotechnology materials. This is supported by the results of *the Independent Samples t-Test* which showed a significant difference in learning outcomes between the experimental class and the control class (Sig. = 0.001), as well as *the effect size* value (Cohen's d) of 0.813 which is included in the large effect category. These findings show that the use of digital teaching materials designed based on project activities can create a more meaningful learning process than learning that is only centered on the delivery of material by teachers. Through E-LKPD, students not only learn biotechnology concepts theoretically, but also get the opportunity to explore problems, collect information, discuss, and produce products according to the assigned project tasks. This active involvement helps students build a gradual understanding of concepts so that abstract material becomes easier to understand. These findings are in line with constructivist theory which places learners as the main subjects in building knowledge through learning experiences and interaction with the learning environment. From a constructivist perspective, learning will be more meaningful when students actively connect new knowledge with existing experiences so that the concepts learned become easier to understand and remember in the long run.

The effectiveness of the use of project-based biotechnology E-LKPD also shows that the integration of digital teaching materials with project-based learning is able to improve the quality of the learning process. E-LKPD not only functions as an electronic worksheet, but also as a medium that directs students to learn systematically through the project completion stage. This is in line with research (Hajar et al., 2020) which states that the model *Project-Based Learning* Provide convenience to students in participating in each stage of learning through systematic project completion. The application of project-based learning syntax encourages the active involvement of students in the learning process so that learning becomes more meaningful and easy to understand. In addition, the implementation of the model *Project-Based Learning* It is considered practical and easy to apply in learning because it is able to increase student participation during the learning process. The presentation of material equipped with activity instructions, pictures, illustrations, and project activities helps students understand the concept of biotechnology in a more contextual way. This condition is in accordance with the characteristics of 21st century learning which emphasizes the importance of using digital technology to support an active, collaborative, and student-centered learning process. Research shows that the integration of digital devices in project-based learning can increase student engagement and have a positive impact on learning outcomes and critical thinking skills.

The findings of this study also show that project-based learning provides opportunities for students to have a more authentic learning experience. In biotechnology material, students not only memorize concepts, but also relate the material to phenomena encountered in daily life. This process encourages students to make observations, look for various sources of information, discuss, and formulate solutions to problems provided through the project. These activities help students develop critical thinking skills, problem-solving skills, communication, and collaboration which are important competencies in 21st century learning. Thus, the improvement in learning outcomes obtained by students is not only influenced by the delivery of the material, but also by the learning experience they gain while completing the learning project. This is supported by research results showing that project-based learning in biology consistently improves learning outcomes, high-level thinking skills, and problem-solving abilities.

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The results of this study reinforce previous studies that have reported that project-based learning is one of the most effective approaches in biology learning. Research by Tuaputty et al. (2023) shows that the application of Project-Based Learning in biology learning is able to improve learning outcomes as well as students' critical thinking skills. (UMM Scientific Journal) In line with that, research by Prajoko et al. (2023) also explains that project-based learning combined with digital technology is able to improve students' understanding of concepts because they are actively involved in the learning process. (UNJ Journal) In addition, the results of a meta-analysis conducted by Hizqiyah et al. (2023) show that project-based learning makes a significant contribution to improving life skills and the quality of biology learning because students gain a more contextual and collaborative learning experience.

This research also supports the results of research on the development of project-based E-LKPD on biotechnology materials. Research by Salsabilla and Purnomo (2025) shows that Project-Based Learning-based E-LKPD developed on biotechnology materials meets valid, practical, and effective criteria to train students' learning abilities and outcomes. However, the research focuses more on the product development process, while this study provides empirical evidence regarding the effectiveness of the use of E-LKPD in real learning on student learning outcomes. Thus, this research complements the development research stage through testing the effectiveness of the product after it is implemented in the classroom.

The findings of this study are further strengthened by the results of a meta-analysis that show that project-based learning has a high influence on biology learning outcomes. Research by Inggawati et al. (2025) reported that Project-Based Learning has a combined effect size value of 0.88 which is included in the large category, so that it is effective in improving learning outcomes and high-level thinking skills of students. (University of Wisconsin) These findings are in line with the results of this study which showed a Cohen's d value of 0.813, so it can be concluded that the use of project-based biotechnology E-LKPD has a strong influence on improving learning outcomes. The similarity of these findings shows that the use of projects as a learning strategy has a consistent impact on improving the quality of biology learning.

From a practical perspective, the results of this study show that project-based biotechnology E-LKPD can be an alternative to digital teaching materials that support the implementation of more active and student-centered learning. E-LKPD helps teachers organize learning in a more structured manner through systematic stages of project activities, while making it easier for students to understand complex biotechnology concepts. In addition to improving learning outcomes, the use of E-LKPD also provides opportunities for students to develop critical thinking, communication, collaboration, creativity, and problem-solving skills as competencies needed in 21st century learning. Therefore, the use of project-based E-LKPD has the potential to be applied not only to biotechnology materials, but also to other biological materials that have conceptual and contextual characteristics.

Based on this description, this research contributes to the development of biology learning, especially in the use of project-based digital teaching materials. The novelty of this research lies in testing the effectiveness of project-based biotechnology E-LKPD which has previously been declared valid and practical, then implemented to determine its effect on student learning outcomes. Thus, this study not only strengthens the findings of previous research on the quality of E-LKPD products, but also provides empirical evidence that the use of project-based biotechnology E-LKPD is effective in improving student learning outcomes in biology learning at the high school level.

CONCLUSION

Based on the results of the research, it can be concluded that project-based biotechnology E-LKPD is effective in improving the learning outcomes of class X students at SMAN 3 Siak Hulu, Kampar Regency, Riau. This effectiveness was proven through the results of the Independent Samples t-Test which showed a significant difference in learning outcomes between the experimental class and the control class with a significance value of 0.001 (<0.05). In addition, the results of the N-Gain analysis showed that the experimental class was in the category of quite effective with a percentage of 57.15%, while the control class was in the ineffective category with a percentage of 35.94%. The findings were strengthened by the effect size value (Cohen's d) of 0.813 which is included in the large effect category, thus showing that the use of project-based biotechnology E-LKPD not only provides statistically significant differences, but also has a strong influence on improving student learning outcomes. The results of this study show that the use of project-based biotechnology E-LKPD can be an alternative to digital teaching materials that support more active, contextual, and student-centered biology learning. Therefore, teachers are advised to utilize and develop project-based E-LKPD as one of the learning innovations that can improve the quality of the process and learning outcomes. The next research is expected to test the effectiveness of E-LKPD on other biology materials, involve a wider number of samples, and examine its influence on other variables, such as critical thinking skills, creativity, science literacy, problem-solving skills, and students' learning motivation so that a more comprehensive picture is obtained about the implementation of project-based E-LKPD in biology learning.

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