



Practicality of Project-Based Learning-Based Electronic Student Worksheets for Teaching Biotechnology to Senior High School Students

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Abstract: This study aims to describe the level of practicality of a Project-Based Learning (PjBL)-based electronic student worksheet (e-LKPD) on biotechnology material for tenth-grade senior high school students. The study employed a Research and Development (R&D) approach adapted from the Plomp model, with a focus on the assessment phase, particularly the practicality evaluation. The research was conducted in two schools, namely SMA Negeri 1 Tambang and SMA Negeri 2 Kampar Kiri Tengah, in Riau Province, Indonesia. Data were collected from 49 students, two biology teachers, and two observers using practicality questionnaires, learning implementation observation sheets, interview guidelines, and documentation. The data were analyzed using both quantitative and qualitative descriptive techniques. The results indicate that the practicality level of the e-LKPD, as assessed by students, reached an average score of 83%, categorized as very practical, while teachers' assessments reached 86%, also categorized as very practical. The implementation of learning using the e-LKPD achieved 100% (very good category) based on student responses and 95% (very good category) based on teacher responses. Observers reported an average implementation score of 94%, categorized as very good. These findings suggest that the PjBL-based e-LKPD is practical for use in biotechnology learning at the senior high school level. Furthermore, it supports the development of 21st-century skills, including critical thinking, creativity, and collaboration, through project-based learning activities.

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Introduction

Along with the rapid development of technology, particularly smartphones, students can now access various digital platforms that support independent, flexible, and creative learning processes. Learning is no longer solely teacher-centered; instead, it requires the active involvement of students in constructing their own knowledge (Afrilianti & Yerimadesi, 2021). Therefore, education must adapt to technological advancements to ensure that learning becomes more meaningful. Students' understanding of subject matter is influenced by the quality of instructional materials used. Instructional materials can be defined as learning resources that assist students in comprehending concepts. In biology, conceptual understanding is particularly crucial, as difficulty in mastering one concept may hinder the understanding of subsequent topics (Dwi Rahmayani et al., 2024). One innovative instructional material is the electronic student worksheet (e-LKPD), a digital version of the student worksheet that can be accessed through electronic devices. It is enriched with text, images, videos, animations, and supporting links, which can enhance students' understanding and engagement (Amelia & Harahap, 2021; Anggraeni & Mahardika, 2026; Sujinah & Yanah, 2024)



The use of instructional materials will be more optimal when supported by an appropriate learning model. A learning model serves as a conceptual framework for achieving learning objectives effectively (Umami et al., 2023). Monotonous learning models that are consistently teacher-centered tend to make students passive and less motivated in the learning process. Therefore, a learning model that promotes active participation and higher-order thinking skills is essential. Project-Based Learning (PjBL) is a relevant model to be integrated with e-LKPD, as it is student-centered and engages learners in project-based activities involving investigation, planning, implementation, and presentation. This approach can enhance critical thinking, creativity, and problem-solving skills. According to theoretical studies, Project-Based Learning aims to foster students' proactive attitudes in solving real-world problems, develop their critical thinking abilities, and increase engagement in complex learning activities that culminate in the production of tangible outcomes. (Kunci et al., 2022; Rahardjanto et al., 2019).

One biology topic that is particularly relevant to this approach is biotechnology, for which the implementation of Project-Based Learning is considered highly appropriate. Biotechnology studies the utilization of living organisms to produce products beneficial to human life, both through conventional and modern biotechnology (Atmojo & Sajidan, 2020). Its instruction requires not only conceptual understanding but also students' ability to apply these concepts through activities or projects, such as producing fermented products. Therefore, the integration of a Project-Based Learning-based e-LKPD is expected to assist students in understanding biotechnology material more deeply and in a more applied manner.

Several studies have demonstrated that the use of Project-Based Learning-based e-LKPD yields positive outcomes, as it exhibits high levels of validity and practicality and can serve as an effective learning resource. In addition, the implementation of the Project-Based Learning model has been proven to enhance students' abilities, particularly higher-order thinking skills (Afrilianti & Yerimadesi, 2021; Kunci et al., 2022; Sujinah & Yanah, 2024). Although previous studies (Sujinah & Yanah, 2024) have developed e-LKPD for other subject areas, studies that specifically integrate project-based learning into biotechnology content with a focus on practicality, particularly in rural contexts, remain limited.

The results of observations and interviews with Biology teachers at SMA Negeri 2 Kampar Kiri Tengah and SMA Negeri 1 Tambang indicate that the learning process still relies on printed student worksheets (LKPD) developed by the MGMP forum and has not yet been integrated with digital approaches or project-based learning. This condition renders the LKPD less effective in facilitating biotechnology learning, as there is a mismatch between the applicative and complex nature of biotechnology content and the still conventional, passive, and non-digital design of the worksheets. This highlights the importance of developing innovative instructional materials that are practical, user-friendly, and aligned with student characteristics as well as the demands of 21st-century learning. Therefore, this study aims to describe the practicality level of an electronic student worksheet (e-LKPD) based on Project-Based Learning (PjBL) in biotechnology material for Grade 10 senior high school students.

Research Method

This study employed the Research and Development (R&D) method to produce and refine a product while simultaneously evaluating its practicality. The development model applied in this research was the Plomp model, which consists of three main phases: preliminary research, prototyping phase, and assessment phase (Plomp & Nieveen, 2013). The Plomp model was selected because it allows for evaluation and revision at each stage of



product development, ensuring that the final product meets practical criteria through systematic and iterative research cycles (Simamora & Hajar, 2025). In previous research, the development process had progressed to the prototyping phase, specifically the validation stage. Based on the study conducted by Aisya (2024), the product was declared valid. Therefore, the present study focuses on the assessment phase, particularly on testing the practicality of implementing the Project-Based Learning-based e-LKPD in biotechnology material for tenth-grade senior high school students.

The type of data collected in this study was quantitative data. The data sources consisted of both internal and external sources. Internal data were obtained from tenth-grade students of SMA Negeri 1 Tambang and SMA Negeri 2 Kampar Kiri Tengah, Biology subject teachers from both schools, and two observers. External data included supporting references and relevant documentation. The population of this study comprised all tenth-grade students of SMA Negeri 1 Tambang and SMA Negeri 2 Kampar Kiri Tengah. The sampling technique employed was Cluster Random Sampling using a lottery method. This technique was chosen for its practicality, as it provides equal opportunities for all classes within the population to be selected as research samples and helps minimize potential bias. One tenth-grade class from each school was selected as the sample. Thus, the research sample consisted of Class X.3 from each school, with 22 students from one school and 27 students from the other, totaling 49 students. In addition to student participants, the researchers also included Biology teachers and two observers as part of the research sample.

Data were collected using research instruments in the form of a practicality questionnaire that had been validated by experts with a percentage value of 96.6% in the very valid category, an implementation observation sheet, interview guidelines, and documentation. The data obtained were analyzed using both quantitative and qualitative descriptive approaches. The results from the practicality questionnaire, implementation questionnaire, and observation sheets were analyzed quantitatively and presented in the form of percentage scores to determine the level of practicality of the e-LKPD used. Meanwhile, the interview data were analyzed qualitatively to support and strengthen the research findings.

The practicality of the e-LKPD from the students' perspective was assessed using a student questionnaire covering aspects of usability, presentation, time efficiency, and benefits. Meanwhile, the practicality of the e-LKPD from the teachers' perspective was evaluated based on aspects of usability, time allocation, students' responses, and the achievement of learning objectives. The level of learning implementation using the e-LKPD was assessed by students, subject teachers, and observers. To examine the implementation process, the Percentage of Agreement was used to determine the level of consistency and stability between observers, based on "Yes" and "No" responses. Students, subject teachers, and observers provided evaluations based on the stages of learning activities, which included the introduction, core activities, and closing stages. The quantitative data analysis technique was carried out using the following formula:

$$PRS = \frac{\sum A}{\sum B} \times 100\%$$

Description :

PRS = the percentage of students who provided positive responses

$\sum A$ = the total score obtained

$\sum B$ = the maximum possible score for positive responses

Based on the practicality assessment of the e-LKPD, the calculation was based on a Likert scale with the following criteria: 0–20% (not practical), 21–40% (less practical), 41–60% (moderately practical), 61–80% (practical), and 81–100% (very practical) (Aldi et al., 2022).

$$\text{The implementation level}(\rho) = \frac{\text{Average number of implemented aspects}}{\text{Total number of observed aspects}} \times 100\%$$

Based on the assessment results of the e-LKPD implementation, the calculation was based on a Likert scale with the following criteria; $\rho \leq 20\%$ Very Poor, $20\% < \rho \leq 40\%$ Poor, $40\% < \rho \leq 60\%$ Fair, $60\% < \rho \leq 80\%$ Good, $\rho > 80$ Very Good (Afrilianti & Yerimadesi, 2021).

Result and Discussion

This study examines the level of practicality of the previously developed e-LKPD by analyzing the practicality questionnaires and the learning implementation observation sheets assessed by students, subject teachers, and observers. The results of the students' practicality questionnaire analysis are presented in Table 1.

Table 1. The Results of Practicality Assesment by Students

No	Statement	SMA N 2 KTT	SMA N 1 TBG	Average %	Category
1	Usability Aspect	93 %	75 %	84 %	Very Practical
2	Presentation Aspect	92 %	69 %	81 %	Very Practical
3	Time Aspect	96 %	68 %	82 %	Very Practical
4	Benefit Aspect	94 %	71 %	83 %	Very Practical
	Average %	94 %	71 %	83 %	Very Practical
	Category	Very Practical	Practical		

The usability aspect obtained a percentage of 84%, categorized as very practical, because the e-LKPD is easy to operate and systematically organized. The results of student interviews support this finding, as they stated that the project steps were explained sequentially, easy to understand, and encouraged them to be more active and challenged in completing the practicum. This indicates that the e-LKPD facilitates students' direct engagement in the learning process. This finding is consistent with previous studies suggesting that e-LKPD should support students in becoming more active during learning (Huda et al., 2023; Wahyu Mulyasari, 2022). The presentation aspect obtained a percentage of 81%, categorized as very practical, because the material is presented in a structured manner and supported by illustrations (Figure 1), which help students understand biotechnology concepts more deeply. This is also supported by previous research stating that digital instructional materials enriched with multimedia elements can increase students' interest in learning (Amelia & Harahap, 2021; Gilakjani, 2012).



Figure 1. The e-LKPD Equipped with Illustrations

In terms of the time aspect, the PjBL-based e-LKPD also demonstrated a very high level of practicality. The e-LKPD helps students manage their learning time more effectively through clear instructions, structured learning activities, and flexible learning processes. This finding is consistent with previous studies stating that instructional materials can improve time efficiency in learning (Barakat et al., 2024; Wang et al., 2025). However, interview results revealed that in certain practicum components, such as determining fermentation time and implementing work procedures, teacher guidance was still required (Figure 2). This indicates that although the e-LKPD is practical, the teacher’s role remains essential as a facilitator in the implementation of project activities.



Figure 2. Teacher Assistance During the Learning Process.

In terms of the benefit aspect, the PjBL-based e-LKPD has a positive impact on the learning process. The e-LKPD not only helps students understand biotechnology concepts but also develops 21st-century skills, such as critical thinking, creativity, collaboration, and communication. The PjBL model enables students to learn through direct experience in completing projects, making the learning process more meaningful. In light of previous studies, these findings are consistent with research indicating that project-based learning can enhance students’ higher-order thinking skills and problem-solving abilities. (Bonoff et al., 2024; Keleman, 2021; Putri et al., 2023).

The quantitative findings obtained are consistent with the results of student interviews, which indicate that the Project-Based Learning-based e-LKPD is considered easy to use and engaging. Students stated that the learning process became more enjoyable because they not only studied theoretical concepts but also carried out hands-on practice through project activities. One student expressed that *“The project-based e-LKPD is good and interesting. The learning process is not boring because we do not only study theory, but also engage in direct practice.”* This finding suggests that the e-LKPD is able to enhance students’ interest and comfort in the biotechnology learning process.

The developed e-LKPD was analyzed based on the results of questionnaires completed by Biology subject teachers. The assessment was conducted across several aspects, namely usability, presentation, time efficiency, and benefits, to determine the practicality of the e-LKPD. The results of the practicality analysis by teachers are presented in Table 2.

Table 2. The Results of Practicality Assessment by Teachers

No	Statement	FR	NF	Average %	Category
1	Usability Aspect	92 %	88 %	90 %	Very Practical
2	Presentation Aspect	83 %	83 %	83 %	Very Practical
3	Time Aspect	100 %	75 %	88 %	Very Practical
4	Benefit Aspect	75 %	88 %	82 %	Very Practical
	Average %	88 %	84 %		
	Category	Very Practical	Very Practical	86 %	Very Practical

Based on the results of the practicality analysis conducted by Biology subject teachers, the findings indicate that the e-LKPD demonstrates a very high level of practicality across various aspects. The usability aspect obtained a score of 90%, the presentation aspect 83%, the time aspect 88%, and the benefit aspect 82%, as reflected in the questionnaire data collected during the research. Overall, the results of the teachers' practicality questionnaire show that the e-LKPD achieved an average score of 86%, which falls into the very practical category.

The usability aspect of the PjBL-based e-LKPD was rated as very practical because it is easy to operate and clearly outlines the learning objectives (Figure 3). Its simple design and clear instructions indicate that the e-LKPD has taken teachers' needs into consideration. This finding is consistent with previous studies stating that PjBL-based e-LKPD assists teachers in classroom management and instructional processes (Achmad et al., 2024; Anggraeni & Mahardika, 2026). In terms of the presentation aspect, the PjBL-based e-LKPD was also categorized as very practical because the material is delivered in a structured manner and includes contextual activities (Hajar & Ferawati, 2024). The integration of text, visuals, and project-based activities within the e-LKPD supports multimodal learning, thereby enhancing conceptual understanding and increasing the attractiveness of the learning process. These findings offer a different perspective from studies conducted by (Afidah, 2015; Nasution & Fadilah, 2024), which suggest that excessive cognitive information and an abundance of project-based activities may overwhelm students and potentially hinder the learning process.

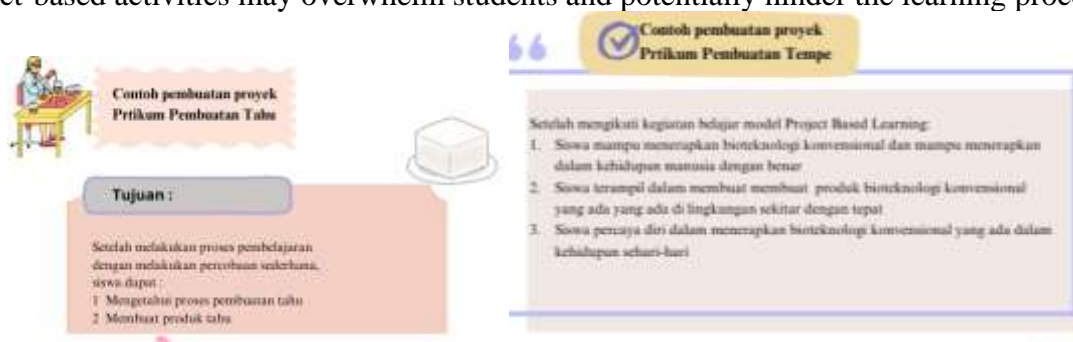


Figure 3. Learning Objectives

In terms of the time aspect, the e-LKPD assists teachers in managing learning more efficiently through clear instructions (Figure 4), a structured workflow, and flexible access. Project-based learning, which generally requires extended time allocation, can be optimized through the use of the e-LKPD as a guiding framework. This finding is supported by previous research indicating that the use of digital instructional materials can enhance learning efficiency and expand students' learning space (Pates & Sumner, 2016; Yadav, 2024). Regarding the benefit aspect, the PjBL-based e-LKPD has a positive impact by helping students understand biotechnology concepts while simultaneously developing 21st-century skills such as critical thinking, creativity, collaboration, and communication. The PjBL model promotes meaningful learning through the completion of authentic projects. In line with previous studies, these findings support research demonstrating that project-based learning can improve students' higher-order thinking skills and problem-solving abilities (Keleman, 2021; Putri et al., 2023; Umami et al., 2023).



Figure 4. Work Procedure with Clear Instructions.

The research results indicate that the Project-Based Learning (PjBL)–based e-LKPD demonstrates a very high level of practicality according to both students and teachers. This suggests that the e-LKPD is easy to use, efficient, and beneficial in biotechnology learning, as it supports structured, interactive, and project-oriented learning activities. The high level of practicality indicates that the e-LKPD is not only technically feasible but also pedagogically relevant in enhancing students’ engagement, critical thinking, and collaboration (Keleman, 2021; Simamora & Hajar, 2025). The results of teacher interviews further reinforce these findings, as teachers stated that the e-LKPD is systematically organized, with clear and well-integrated project steps. Consequently, it supports directed, effective, and meaningful learning while facilitating the optimal achievement of learning objectives (Dwi Rahmayani et al., 2024; Sujinah & Yanah, 2024).

The implementation of learning using the e-LKPD was analyzed through observation sheets completed by students during the first and second meetings. The observed aspects included the introduction, core activities, and closing stages to determine the extent to which the learning steps were carried out according to the lesson plan. The results of the implementation observation by students are presented in Table 3.

Table 3. The Results of the Learning Implementation Observation Sheet by Students

No	Statement	First Meeting		Second Meeting		Average %	Category
		SMA N 2 KKT	SMA N 1 TBG	SMA N 2 KKT	SMA N 1 TBG		
1	Introduction	100 %	100 %	100 %	100 %	100 %	Very Good
2	Core Activities	100 %	100 %	100 %	100 %	100 %	Very Good
3	Closing	100 %	100 %	100 %	100 %	100 %	Very Good
Rata-Rata %		100 %		100 %		100%	Very Good
Category		Very Good		Very Good			

The results of the implementation analysis obtained from the students’ observation sheets indicate that each learning session was carried out effectively, as reflected by an average percentage of 100% in the very good category. This means that every stage of the learning process was implemented optimally. These findings are reinforced by the results of student interviews, which revealed that all stages of learning could be properly conducted through the use of the PjBL-based e-LKPD. Students reported feeling more active and engaged in the learning process because they were directly involved in project activities, starting from preparation, conducting the practicum, to discussing the results. Furthermore, students stated that the e-LKPD encouraged group collaboration, such as dividing tasks in preparing tools and materials, conducting observations, and recording practicum results. This demonstrates that the e-LKPD supports the comprehensive implementation of learning in

accordance with the Project-Based Learning synta (Anggraeni & Mahardika, 2026; Simamora & Hajar, 2025).

The implementation of learning using the e-LKPD was also evaluated by the Biology teachers during the first and second meetings. The observed aspects included the introduction, core activities, and closing stages to assess the alignment between the implemented learning process and the planned instructional steps. The results of the implementation observation by teachers are presented in Table 4.

Table 4. The Results of the Learning Implementation Observation Sheet by Teachers

No	Statement	First Meeting		Second Meeting		Average %	Category
		FR	NF	FR	NF		
1	Introduction	100 %	100 %	100 %	100 %	100 %	Very Good
2	Core Activities	92 %	92 %	92 %	92 %	92 %	Very Good
3	Closing	100 %	67 %	100 %	100 %	92 %	Very Good
Average %		97 %	86 %	97 %	97 %	95 %	Very Good
Category		Very Good		Very Good			Good

The analysis results indicate that, based on the implementation observation sheets, each stage of the learning process was carried out very well, with a percentage score of 95% categorized as very good. This finding is supported by the results of interviews conducted with the subject teacher. From the interview with the Biology teacher, it was revealed that the Project-Based Learning (PjBL)–based e-LKPD has a systematic and well-structured design. The teacher stated that the components—learning objectives, project steps, materials, and evaluation—are well integrated, making it easier for both teachers and students to understand the learning flow. Furthermore, the interview results indicate that the e-LKPD encourages students to think critically through problem analysis within project activities (Figure 5), to think creatively in designing solutions, and to collaborate effectively in group work (Anggraeni & Mahardika, 2026; Kunci et al., 2022).

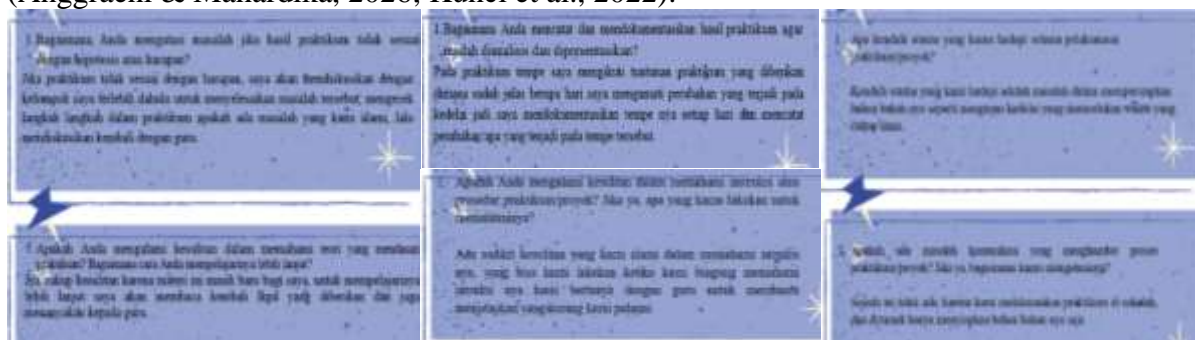


Figure 5. Analysis of Group Problems Encountered by Students.

the teacher revealed several challenges in implementing the e-LKPD, such as limited instructional time and differences in students' abilities to understand project instructions. The school facilities were considered relatively adequate; however, adjustments were still required in certain activities to align them with the school's conditions. he teacher also suggested that the e-LKPD be further developed by providing more detailed instructions, incorporating a wider variety of projects, offering clearer assessment rubrics, and adding interactive and multimedia features to enhance the overall effectiveness of the learning process.

The implementation of learning using the e-LKPD was also examined through observation sheets completed by observers during two meetings. The observations focused on

the introduction, core activities, and closing stages of the lesson to ensure that all phases were conducted according to the planned procedures. The results of the observers' evaluations are presented in Table 5.

Table 5. The Results of the Learning Implementation Observation Sheet by Observers

No	Statement	SMA N 2 KTT		SMA N 1 TBG		Average %	Category
		SP	MM	SP	MM		
1	Introduction	100 %	100 %	96 %	96 %	98 %	Very Good
2	Core Activities	96 %	96 %	96 %	96 %	96 %	Very Good
3	Closing	85 %	85 %	90 %	90 %	88 %	Very Good
Average %		94 %	84 %	94 %	94 %	94 %	Very Good
Category		Very Good		Very Good			

The implementation results obtained from the observers (Figure 6) indicate a very good category, with an average percentage reaching 94%. This shows that each stage of the learning process was carried out in accordance with the steps of Project-Based Learning. It also demonstrates that the e-LKPD was effectively implemented throughout all phases of the lesson, from the introduction to the core activities and the closing.



Figure 6. Completion of the Observer Questionnaire

The results of the learning implementation analysis, which fall into the very good category according to students, teachers, and observers, further strengthen the finding that the PjBL-based e-LKPD can be optimally implemented in biology learning. The high level of implementation indicates that the e-LKPD is not only practical but also compatible with the instructional strategies applied in the classroom. This demonstrates that integrating digital instructional materials with the Project-Based Learning model is an effective strategy for improving the quality of biology education, particularly in teaching biotechnology topics (Atmojo et al., 2022; Atmojo & Sajidan, 2020).

Overall, the findings of this study indicate that the PjBL-based e-LKPD demonstrates a very high level of practicality across all assessed aspects, namely usability, presentation, time efficiency, and benefits. The consistently high scores in each aspect suggest that the developed e-LKPD is not only user-friendly but also effective in supporting the learning process. These findings reinforce that the PjBL-based e-LKPD can be recommended as an innovative instructional material aligned with the demands of 21st-century learning and is appropriate for use in senior high school biology classes (Rahardjanto et al., 2019; Rahmania, 2021).



Conclusion

Based on the research findings, it can be concluded that the Project-Based Learning (PjBL)-based e-LKPD on biotechnology material demonstrates a very high level of practicality. The practicality assessment provided by teachers yielded an average percentage of 86%, categorized as very practical, while the assessment given by students resulted in an average percentage of 83%, also categorized as very practical. These results indicate that the developed e-LKPD is easy to use, systematically presented, time-efficient, and provides tangible benefits in supporting the learning process.

The implementation of learning using the PjBL-based e-LKPD was categorized as very good based on assessments from teachers, students, and observers. Teachers rated the implementation at 95%, students at 100%, and observers at 94%. The high level of implementation indicates that learning using the e-LKPD was carried out optimally in accordance with the PjBL syntax, covering the introduction, core activities, and closing stages. Thus, the e-LKPD is not only technically practical but also pedagogically relevant to be applied as an instructional strategy in the classroom. Overall, the developed Project-Based Learning (PjBL)-based e-LKPD can be considered suitable for use as an instructional resource in biotechnology learning at the senior high school level. The use of this e-LKPD enhances students' active engagement, supports student-centered learning, and promotes the development of 21st-century skills such as critical thinking, creativity, collaboration, and communication. Therefore, the PjBL-based e-LKPD can be recommended as an innovative instructional material to support more meaningful and contextual biology learning.

Recommendation

Based on the findings of this study, teachers are recommended to integrate Project-Based Learning (PjBL)-based e-LKPD into biotechnology instruction to enhance student engagement and learning autonomy. Biology curriculum developers are encouraged to design digital instructional materials that are adaptive, contextual, and aligned with the demands of 21st-century learning. Meanwhile, future researchers are advised to examine the effectiveness of e-LKPD using quasi-experimental designs and to investigate its impact on critical thinking skills and digital literacy. As a precaution, technical constraints such as limited internet access and device variability should be considered; therefore, the development of e-LKPD with offline features and lightweight interfaces is highly recommended to minimize research bias.

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