**Jurnal Pembelajaran Dan Biologi Nukleus** p-ISSN: 2442-9481
Vol 11 (4): 1184 - 1196, December 2025 e-ISSN: 2685-7332

# An Environment-Oriented PBL Digital Worksheet to Support Critical Thinking Development in Ecosystem Learning

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*Submitted September 29 Th 2025, and Accepted December 02 Th 2025*

## Abstract

**Background:** *The development of students' critical thinking skills requires learning media that actively engage students in problem analysis, reasoning, and decision-making processes. However, the use of electronic student worksheets (E-LKPD) in schools is still limited and often does not fully integrate problem-based learning principles or contextual environmental issues. Many available LKPDs remain procedural and teacher-centered, reducing opportunities for students to practice higher-order thinking skills independently. This condition indicates the need for innovative E-LKPD that are systematically designed to support critical thinking development through problem-based learning approaches. This study aims to develop and evaluate the effectiveness of an environment-based Problem-Based Learning (PBL) electronic student worksheet (E-LKPD) on ecosystem content to enhance senior high school students' critical thinking skills.* **Methodology:** *This research employed a Research and Development (R&D) method using ADDIE model, which consists of analysis, design, development, implementation, and evaluation stages. The product was validated by two experts using a Likert-scale-based expert validation questionnaire covering content, media, and language aspects. Practicality testing involved one biology teacher and nineteen students, while effectiveness was analyzed using a pretest–posttest design with the Shapiro–Wilk test and paired t-test.* **Findings:** *The validation results obtained an average percentage of 91%, categorized as very valid. Practicality testing involving 1 teacher and 19 students SMAN 1 Toari showed positive responses with a percentage of 84%, classified as very practical. The effectiveness of the E-LKPD was evidenced by an increase in the average score from 82.68 to 89.46 among students of class X.4 at MAN 1 Kolaka, along with a significance value of 0.000, indicating a significant difference after the implementation of the E-LKPD.* **Contribution:** *These findings indicate that the environmental-based PBL E-LKPD contributes to the design of biology learning by providing a structured and interactive digital worksheet that facilitates problem-oriented learning and critical thinking development. The integration of contextual environmental issues within the E-LKPD supports meaningful ecosystem learning and reinforces the role of digital learning media in promoting active, analytical, and student-centered biology instruction.*

**Keywords:** *Critical Thinking; Ecosystem; E-LKPD; Environmental-Based Learning; Problem-Based Learning*


https://doi.org/10.36987/jpbn.v11i4.8335

## INTRODUCTION

In the twenty-first century, senior high school students are required to master the 4C skills (Critical Thinking, Communication, Creative Thinking, and Collaboration) to effectively overcome the complex challenges posed by the Industrial Revolution 4.0. Numerous studies emphasize the importance of these competencies. Arnyana (2019) demonstrates that 4C skills can be trained through problem-based learning, cooperative strategies, and interactive approaches. Mardhiyah et al., (2021) emphasize that knowledge alone is not sufficient; skills are essential to developing high-quality human resources. Fadilah & Aloysius (2024); Nurhayati et al., (2024); Putri & Ulfa (2025) also warn that the abundance of information in the digital era brings both opportunities and risks, especially when students lack analytical evaluation skills. Evidence consistently shows that 4C competencies are not optional but essential for students to adapt, innovate, and succeed in a world that is increasingly complex and technology-driven.

Student-centered learning models, such as Problem-Based Learning (PBL), are highly suitable for fostering 4C skills. PBL encourages students to engage with contextual problems, analyze them, formulate solutions, and collaborate in groups (Arnyana, 2019). Critical thinking is particularly central to these processes—including interpretation, analysis, inference, evaluation, and reflection (Mardhiyah et al., 2021). (Darwati & Purana 2021) note that PBL requires mental activity to understand concepts through presented problems, enabling students to develop critical, innovative, and creative abilities. Masrinah et al., (2019) further explain that PBL provides experience in dealing with real-life problems, emphasizing communication, cooperation, and reasoning skills.

Although various studies have investigated the development of electronic student worksheets (E-LKPD) based on Problem-Based Learning to improve critical thinking skills in biology contexts, most have primarily focused on demonstrating validity, practicality, and effectiveness through quantitative outcomes such as n-gain scores or mastery statistics (Karomah & Purnomo 2025; Maha & Manalu 2025). For example, research on PBL-based E-LKPDs in ecosystem and circulatory system materials has shown high validity, practicality, and increased critical thinking scores, but these studies tend to emphasize final achievement outcomes rather than systematic design features that explicitly integrate environmental contextual problems and cognitive engagement strategies during learning (Maha & Manalu, 2025). Similarly, other developments such as E-LKPDs for excretory systems and immunology have documented feasibility metrics but do not explore how the instructional design enhances deeper analytical reasoning or student engagement with contextual environmental scenarios (Gultom & Syafi'i 2025; Nayla & Ulfa 2025). Moreover, while PBL worksheets have been explored in environmental change topics, studies often stop at evaluating effectiveness without concurrently examining how design elements and contextual integration influence the process of critical thinking development in biology classrooms (Fadilah & Aloysius, 2024). These limitations highlight a gap in the literature regarding comprehensive instructional design and empirical evaluation of environment-based PBL E-LKPDs that support meaningful critical thinking and real-world problem analysis in biology learning.

The concept of ecosystems is a highly relevant topic for environmentally oriented learning (Mursita et al., 2022). Ecosystem material is not only rich scientifically but also involves contemporary issues such as biodiversity conservation, environmental changes, and anthropogenic impacts—issues that require students to think critically and systemically (Fitriani et al., 2021). By integrating PBL and electronic worksheets, learning can be designed to enable students to actively investigate environmental problems, propose solutions, and reflect on their implications (Hanida et al., 2023; Utami, 2019).

However, classroom practices in many high schools still reveal that students tend to be passive, express logical arguments inadequately, and often fail to work collaboratively in an effective manner (Nisa & Liestyasari, 2025). Initial observations at SMAN 1 Toari show low participation, limited depth of analysis, and unequal distribution of workload within groups. This condition indicates that conventional learning has not fully optimized the potential of PBL to develop critical and collaborative thinking skills (Virliana & Fauziah, 2025).

Moreover, challenges in micro-educational contexts such as monotonous teaching methods and limited facilities continue to hinder effective learning (Elitasari, 2022). Therefore, an innovation such as an environmental-based PBL E-LKPD is highly needed (Hidayah & Kuntjoro, 2022). This innovation is expected not only to improve students' critical thinking skills but also to provide contextual and meaningful learning experiences while fostering ecological awareness (Suryaningsih & Nurlita, 2021).

Given this background, this study was conducted to address the gap in previous research by developing and evaluating an environmental-based Problem-Based Learning (PBL) Electronic Student Worksheet (E-LKPD) that is systematically designed to support critical thinking development in ecosystem learning. Unlike prior studies that primarily emphasize learning outcomes, this research integrates contextual environmental problem scenarios into the instructional design of the E-LKPD and evaluates its validity, practicality, and effectiveness in a comprehensive manner. The findings of this study are expected to contribute to the design of biology learning media by providing empirical evidence on how environment-based PBL E-LKPD can facilitate active learning, analytical thinking, and meaningful engagement in ecosystem concepts for senior high school students.

## METHOD

This study employed a Research and Development (R&D) design using the ADDIE model—analysis, design, development, implementation, and evaluation—as recommended for digital learning media development (Nasution & Taufik, 2025; Rustandi, 2021). The ADDIE model was chosen because it provides a systematic framework to produce learning tools that support 21st-century skills, especially critical thinking enhancement (Fadilah & Aloysius, 2024).

### Population And Sample

The population of this study consisted of senior high school students enrolled in Grade X at SMA Negeri 1 Toari and MAN 1 Kolaka. The sampling technique used was *purposive sampling* method, in which participants were intentionally selected based on their relevance to the research objectives and their readiness to implement the developed learning media, as commonly applied in educational development research (Creswell & Creswell, 2017; Sugiyono, 2020).

The practicality trial involved one biology teacher and 19 students of class X-B at SMA Negeri 1 Toari to evaluate the usability, clarity, and acceptability of the PBL-based E-LKPD. Meanwhile, the effectiveness test employed a one-group pretest–posttest design involving 28 students of class X.4 at MAN 1 Kolaka to examine improvements in students' critical thinking skills after the implementation of the environmental-based PBL E-LKPD. The use of different trial groups enabled comprehensive evaluation of both practicality and effectiveness in authentic classroom settings.

### Instrument

The research instrument used to measure the effectiveness of the learning media consisted of pretest and posttest essay tests developed based on critical thinking indicators, namely elementary clarification, basic support, inference, advanced clarification, and strategies and tactics. These indicators are derived from Ennis' critical thinking framework and have been widely adopted in educational research, including recent studies on the development of critical thinking assessment instruments (Sa'idah et al., 2025). The test instrument comprised five essay items, with each item representing one critical thinking indicator. In the pretest, each item was scored within a range of 5–20, resulting in a total score range of 25–100. Meanwhile, in the posttest, each item was assigned a score range of 35–70, yielding a total score range of 50–100. Scoring was conducted using a critical thinking rubric to systematically assess students' achievement for each indicator.

### Procedure

The research procedure followed the ADDIE model:

***Analysis Stage***

This stage was conducted through unstructured interviews with a biology teacher to identify the need for learning media. The findings showed that interactive learning media were still limited, and teachers generally relied only on printed textbooks. Students expressed the need for more interactive learning tools to help them understand the material more effectively.

***Design Stage***

This stage, research instruments such as expert validation questionnaires and student response questionnaires were prepared. The E-LKPD design was created using the Canva application, incorporating PBL-based activities and ecosystem content. The E-LKPD was developed with attractive visual designs and included two contextual problem scenarios: forest conversion and nickel mining.

***Development Stage***

The development stage included product creation, expert validation, and revisions based on feedback. All components of the E-LKPD were created using Canva, featuring a blue-white color scheme and visual elements representing ecosystems. Validation was carried out by two experts assessing materials, media, and language aspects.

***Implementation Stage***

Field testing was conducted involving one biology teacher and nineteen students from First grade-X.B class of SMAN 1 Toari high school. The implementation stage involved limited classroom testing with one biology teacher and students to evaluate the practicality and classroom applicability of the developed E-LKPD. The implementation was conducted over two learning meetings (2 × 45 minutes each), during which the E-LKPD was used as the main learning media for ecosystem instruction. The learning activities followed the Problem-Based Learning (PBL) scenario, including problem orientation, investigation, and reflection, to engage students in contextual problem solving. Practicality was assessed using teacher and student response questionnaires. The practicality criteria were determined based on percentage scores following Nazah et al., (2020), where 76–100% is categorized as very practical, 51–75% practical, 26–50% less practical, and 20–25% not practical.

***Evaluation Stage***

Assessing overall effectiveness, usability, and learning outcomes to refine the final product. At the evaluation stage, the researcher assessed the effectiveness of the PBL-based E-LKPD by comparing students' abilities before and after using the media through pre-test and post-test essay assessments involving 28 students of First grade-X.4 class at MAN 1 Kolaka high school. The test data were analyzed using SPSS, beginning with a Shapiro–Wilk normality test to ensure that the data met statistical assumptions, followed by a paired t-test to determine whether there was a significant improvement in students' critical thinking skills after using the developed learning media. Prior to conducting the effectiveness test, descriptive analysis of the pre-test and post-test scores was performed to examine the initial characteristics of the data.

**Data Analysis**

Data were analyzed using descriptive and inferential methods. Expert validation scores were used to determine product validity, while teacher and student questionnaires were used to assess practicality. Effectiveness was analyzed using the Shapiro–Wilk test at a significance level of $\alpha = 0.05$ to examine data normality, followed by a paired sample t-test at the same significance level to evaluate significant differences between pretest and posttest scores.

## RESULT AND DISCUSSION

### Result

### Data Analysis Techniques

The data obtained from expert validation, field trials, and students' critical thinking tests were analyzed to assess the validity, practicality, and effectiveness of the environmental-based PBL E-LKPD. This analysis aims to determine the feasibility of the media, its ease of use, and its impact on improving students' critical thinking skills.

#### *Validity Analysis*

Validation was conducted by two experts who assessed the aspects of content, media, and language.

**Table 1.** Results of Expert Validation of the E-LKPD

| Expert Validator | Percentage | Category |
|---|---|---|
| Validator 1 | 91% | Very Valid |
| Validator 2 | 91% | Very Valid |
| Average | 91% | Very Valid |

The validation results show that the E-LKPD obtained an average percentage score of 91% from the two expert validators, indicating that it falls into the very valid category and is feasible to use without major revisions. Suggestions from the validators included adding more student activities, adjusting the background design, and using more realistic images for the problem scenarios. All revisions were carried out according to these recommendations.

#### *Practicality Analysis*

A field trial was conducted with 1 teacher and 19 students of Class X-B at SMA Negeri 1 Toari. The questionnaire results are as follows:

**Table 2**. Analysis of Teacher and Student Response to the E-LKPD

| Respondent | Percentage (%) | Category |
|---|---|---|
| Teacher | 94 | Very Practical |
| Students | 79 | Very Practical |
| Average | 86 | Very Practical |

The field trial results showed that the E-LKPD obtained an average response score of 86%, categorized as very practical, indicating that the media is easy to use for both teachers and students. The teacher and student response questionnaires used a 4-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree) with a total of 10 items. Based on the scoring interpretation is 76–100% is categorized as very practical, 51–75% practical, 26–50% less practical, and 20–25% not practical.

#### *Effectiveness Analysis*

Effectiveness analysis was conducted specifically for the trial implemented at MAN 1 Kolaka. The techniques included:

**Descriptive Analysis**

Pretest and posttest data were analyzed to obtain the mean, minimum, maximum, and standard deviation. The descriptive analysis results showed that the pre-test scores had an average of 82.68, while the post-test scores increased to 89.46. This increase indicates a positive effect of the treatment on students' learning outcomes.

**Table 3.** Descriptive Statistical Data of Pre-test and Post-test

| | N | Minimum | Maximum | Mean | Std. deviation |
|---|---|---|---|---|---|
| Pretest | 28 | 70 | 95 | 82.68 | 6.733 |
| Postest | 28 | 81 | 100 | 89.46 | 5.953 |

**Normality Test**

Based on the results of the normality test using the Shapiro–Wilk method, the significance value for the pre-test was 0.84 and for the post-test was 0.10. Since both significance values are greater than 0.05, it can be concluded that the pre-test and post-test data are normally distributed, and therefore the analysis can be continued using parametric statistical tests in accordance with educational statistics guidelines.

**Table 4**. Normality Test Results

| | Kolmogorov-Smirnov | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | **Sig.** |
| Pretest | .149 | 28 | .116 | .935 | 28 | **0.84** |
| Postest | .202 | 28 | .005 | .898 | 28 | **0.10** |

**Paired t-Test**

Since the data were normally distributed, the analysis was conducted using a paired t-test. The results showed a significance value of 0.000, indicating a significant difference because the value is smaller than 0.05. Thus, there was a substantial improvement in students' learning outcomes between the pre-test and post-test after the treatment was given.

**Table 5**. Paired t-Test Results

| | Paired differences | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Mean** | **Std. deviation** | **Std. error mean** | **lower** | **upper** | **1** | **df** | **Sig. (2-taled)** |
| **Pair 1** | | | | | | | | |
| **Pretest-Postest** | -6.786 | 5.513 | 1.042 | -8.924 | -4.648 | -6.518 | 27 | .000 |

Note: 95% confidence interval of the difference

**Discussion**

The development of the environmental-based Problem-Based Learning (PBL) E-LKPD on ecosystem material was carried out to provide more interactive and engaging learning media that align with the needs of both teachers and students. Based

on the analysis stage, it was found that the instructional media used in the classroom were still limited to printed textbooks, leading students to require more innovative learning materials to better understand ecosystem concepts. The developed E-LKPD addressed this need by offering PBL-based activities through contextual problem scenarios, such as forest conversion and nickel mining, designed to stimulate students' critical thinking skills.

The validation results from two expert validators showed that the E-LKPD achieved an average score of 91%**,** categorized as *very valid*. This high validation score indicates that the material, media, and language components met the required feasibility standards and aligned with the learning objectives. Revisions based on validator feedback—such as adding more student activities, improving visual design, and using more realistic illustrations—further strengthened the product's quality, making it suitable for use without major modifications.

These findings are consistent with the study by Rizaldibet al., (2023), which stated that PBL-based learning products can be categorized as highly valid when they receive high expert validation ratings, as expert judgment reflects the suitability of content and the effectiveness of media design in achieving learning goals. High validity is also supported by research from Khasanah & Indah (2024); Novita & Bare (2022), which found that PBL-based modules are considered highly feasible when they meet the aspects of substance, psresentation, and visual design. These consistent findings reinforce that the developed PBL-based E-LKPD meets quality standards and is valid for implementation in learning.

In terms of practicality, the limited field trial involving 1 teacher and 19 students SMAN 1 Toari showed excellent results. The practicality response reached an average of 86%, categorized as *very practical*. Teachers found that the E-LKPD supported classroom management and facilitated the structured implementation of the PBL model. Meanwhile, students responded positively as the E-LKPD was easy to understand, visually appealing, and helped them actively engage in problem-solving. These findings align with previous studies showing that E-LKPD can enhance motivation, engagement, and conceptual understanding due to its attractive and systematic visual presentation (Masrinah et al., 2019; Novianti et al., 2023).

The effectiveness of the E-LKPD tested on 28 students of class X.4 at MAN 1 Kolaka is also evident from the improvement in students' learning outcomes. The average pre-test score of 82.68 increased to 89.46 in the post-test, indicating a meaningful gain. The paired t-test result with a significance value of 0.000 confirmed that there was a significant difference after using the E-LKPD. These results illustrate that problem-based learning can enhance students' cognitive abilities and critical thinking skills because they are directly involved in exploration, analysis, and reflection processes. This is supported by studies from (Efendi et al., 2025; Sahadah & Yuliani, 2024), which demonstrated that PBL-based E-LKPD can improve critical thinking indicators, and by research from Hanifa & Budiman (2023); Putri & Ulfa (2025), which reported increases in learning outcomes and analytical skills after using similar media.

The effectiveness of this approach is further supported by findings from Masrinah et al., (2019); Sukmawati & Ghofur (2023), which concluded that PBL-based E-LKPD enhances several critical thinking indicators such as interpretation, inference,

and evaluation. Furthermore, international evidence from meta-analysis studies by Arnyana, (2019); Su et al., (2025) showed that PBL has a significant impact on improving critical thinking across educational levels. Research by Achoita et al., (2025); Artini et al., (2023) also found that E-LKPD development is valid, practical, and effective for thematic learning in elementary schools, as reflected in improved student post-test results. The effectiveness is attributed to the interactive features of E-LKPD, which facilitate independent learning, provide step-by-step guidance, and present content in an engaging manner, enabling students to be more involved in the learning process. Moreover, studies by Hafizah et al., (2024); Mardhiyah et al., (2021) confirmed that PBL significantly enhances students' critical thinking skills, influenced by the quality of problem scenarios and the teacher's role as a facilitator. These findings collectively reinforce that PBL-based E-LKPD with contextual scenarios can effectively stimulate students' analytical activities and improve critical thinking skills, as demonstrated in numerous supporting studies.

## CONCLUSION

Based on the research results, the environmental-based Problem-Based Learning (PBL) E-LKPD on ecosystem material provides a significant pedagogical contribution to enhancing high school students' critical thinking skills, particularly through contextual environmental problem scenarios that strengthen analysis, inference, and evaluation indicators, as evidenced by a significant difference in pre-test (82.68) to post-test (89.46) scores ($p=0.000$), expert validity of 91%, and average teacher-student practicality of 86%. The pedagogical implications recommend that biology teachers integrate this media for active learning aligned with the Merdeka Curriculum, although limited by effectiveness testing only at MAN 1 Kolaka ($n=28$) since practicality testing at SMAN 1 Toari involved only 19 Class X-B students with some absences, making it less representative for further effectiveness evaluation; future research requires larger samples, control groups, and diverse school contexts.

## ACKNOWLEDGEMENTS

This research would not have been possible without the support of various parties. The author expresses utmost gratitude to the supervising lecturers for their valuable guidance and input. Special thanks also to the biology teachers and students at SMAN 1 Toari and MAN 1 Kolaka who welcomed and supported the research implementation at their schools. Additionally, to family, partner, and friends who continuously provided moral support, encouragement, and endless inspiration throughout the writing and article development process. May the results of this research contribute to the advancement of biology education in Indonesia.

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**How To Cite This Article, with *APA style* :**

Salsabila, S., Astuti, W., Ernawati, E., Maretik, M., & Tendrita, M. (2025). An Environment-Oriented PBL Digital Worksheet to Support Critical Thinking Development in Ecosystem Learning. *Jurnal Pembelajaran dan Biologi Nukleus*, *11*(4), 1184-1196. https://doi.org/10.36987/jpbn.v11i4.8335

**Conflict of interest** : The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**Author contributions** : All authors contributed to the study's conception and design. Material preparation, data collection and analysis were performed by all authors. The first draft of the manuscript was submited by [**Syifa Salsabila**]. All authors contributed on previous version and revisions process of the manuscript. All authors read and approved the final manuscript.