Practice of the Science of Teaching Journal: Jurnal Praktisi Pendidikan
E-ISSN 2830-568X | https://jurnal.hafecs.id/index.php/hafecspost/index
DOI: https://doi.org/10.58362/hafecspost.v4i2.144
Volume 4 Issue 2, November 2025, pp. 99-115

Development of student worksheets on ecosystem interaction concepts through an integrated environmental approach to critical thinking skills

Nisvie Nur Salsabilla *, M. Arsyad, Amalia Rezeki

Department of Biology education, Faculty of Teacher Training and Education, Universitas Lambung Mangkurat, Banjarmasin, South Kalimantan, Indonesia, 70123

**Corresponding Author Email: nisviens@gmail.com | Received date: 26/06/2025; Accepted date: 14/11/2025*

Abstract

In 21st century education, cultivating critical thinking is recognized as a vital skill that students must acquire. However, according to findings from the PISA survey, Indonesian students still lag behind in this area, scoring only 55.8%, which is below the OECD average of 58.5%. This research focuses on developing student worksheets (LKPD) that incorporate an environmental perspective to enhance the critical thinking abilities of high school students, particularly within the topic of interactions among ecosystem components. The development process adopted the ADDIE framework comprising analysis, design, development, implementation, and evaluation stages. Data were gathered using interviews, student needs assessments, expert reviews of the materials and tools, as well as practicality and effectiveness evaluations through pre- and post-tests. Validation results indicated that the LKPD achieved a very high validity rating, with scores ranging between 88% and 100%. Student feedback from the practicality test was overwhelmingly positive, with an average score of 91%, indicating a high level of usability. Furthermore, the effectiveness test demonstrated a significant improvement in students' critical thinking skills, reflected in a high average N-gain score of 0.74. These findings underscore the pedagogical value of integrating environmental contexts into science instruction, offering an empirically validated framework for strengthening critical thinking and advancing 21st-century competencies in biology education.

Keyword: critical thinking; environmental approach; interaction among ecosystem components; student worksheets

Abstrak. *Pendidikan abad 21 menuntut keterampilan berpikir kritis sebagai bagian dari kompetensi utama yang harus dimiliki peserta didik. Faktanya berdasarkan hasil survei PISA, tingkat berpikir kritis siswa Indonesia masih tergolong rendah dengan nilai 55.8% dari 58.5% rata-rata OECD (Organization for Economic Cooperation and Development). Penelitian ini bermaksud guna mengembangkan lembar kerja peserta didik (LKPD) melalui pendekatan lingkungan terintegrasi keterampilan berpikir kritis siswa SMA pada subkonsep interaksi antar komponen ekosistem. Penelitian ini menerapkan metode research and development (R&D) dengan model ADDIE, melalui tahapan analyze, design, development, implement dan evaluate. Teknik pengumpulan data mencakup wawancara, angket kebutuhan siswa, validasi ahli perangkat, validasi ahli materi, uji kepraktisan siswa serta uji keefektifan melalui pretest dan posttest. Hasil validasi menemukan bahwasanya LKPD yang dikembangkan memperoleh kriteria sangat valid dengan skor rata-rata 88–100%. Uji kepraktisan juga menunjukkan respons sangat positif dari peserta didik dengan skor rata-rata 91% dengan kriteria sangat praktis. Uji keefektifan menunjukkan bahwa penggunaan LKPD mampu meningkatkan keterampilan berpikir kritis siswa secara signifikan dengan nilai rata-rata N-gain sebesar 0,74 dengan kategori tinggi. Temuan ini menyoroti nilai pedagogis integrasi konteks lingkungan ke dalam pengajaran sains, menawarkan kerangka kerja yang tervalidasi secara empiris untuk memperkuat pemikiran kritis dan mengembangkan kompetensi abad ke-21 dalam pendidikan biologi.*

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INTRODUCTION

Twenty-first century education emphasizes the development of higher-order thinking skills, particularly critical thinking, as one of the essential competencies outlined in Indonesia's Merdeka Curriculum. This curriculum promotes the formation of the Pancasila Student Profile, which highlights critical and reflective thinking as key life skills necessary for adaptive learning and problem-solving in a dynamic global society (Rifa'i et al., 2024). Within the context of biology education, critical thinking is especially vital in understanding the interactions among ecosystem components, as students must analyze cause–effect relationships and evaluate the balance between biotic and abiotic factors (Khairunnisa et al., 2022).

Despite this educational mandate, Indonesian students' critical thinking performance remains below international benchmarks. The 2022 Programme for International Student Assessment (PISA) ranked Indonesia 69th out of 81 participating countries, with an average score of 55.8%, still below the OECD mean of 58.5% (OECD, 2024). These findings reveal a substantial gap between the objectives of national education policies and the reality of classroom practice, where students often engage in rote learning and lack opportunities for analytical reasoning.

Previous studies have examined conceptual understanding and misconceptions in ecosystem learning, yet their findings remain largely descriptive and fragmented. Sudianto et al. (2024) found that only 5% of students demonstrated a high level of understanding of ecosystem interactions, while Triana (2023) reported that over 63% of students held misconceptions and 11% had no understanding at all. Similarly, Nurfadilah and Rochintaniawati (2021) discovered that 45% of students misunderstood basic ecological relationships. Although these studies identify learning deficiencies, they seldom offer concrete instructional designs that systematically integrate contextual and critical-thinking frameworks. In particular, prior research has not addressed how student worksheets (LKPD) can be purposefully designed to combine environmental exploration with structured critical thinking indicators. This absence of synthesis represents a critical gap in the literature on effective environmental-based learning tools.

Theoretically, this research is grounded in constructivist learning theory, which posits that students construct knowledge through active engagement and reflection upon real-world experiences (Piaget, 1972; Vygotsky, 1978). In line with this, Contextual Teaching and Learning (CTL) principles emphasize connecting subject matter with authentic environmental contexts to foster meaningful understanding (Johnson, 2002). Furthermore, the critical thinking framework by Facione (2015) identifies six core indicators—interpretation, analysis, evaluation, inference, explanation, and self-regulation—that collectively define the cognitive processes underlying reflective reasoning. Integrating these theoretical models provides a pedagogical foundation for designing LKPDs that simultaneously develop conceptual understanding and critical reasoning skills through experiential, environment-based learning.

The novelty of this research lies in its development of an environment-integrated LKPD explicitly designed around Facione's six indicators of critical thinking. Unlike prior studies that merely embed environmental content as thematic context, this design systematically incorporates observation, reflection, and inference tasks that encourage students to analyze real ecological phenomena. By merging environmental exploration with critical thinking scaffolds, this study introduces an innovative instructional medium that operationalizes CTL principles within the framework of scientific inquiry.

Therefore, this study aims to design, develop, and validate environment-integrated student worksheets that explicitly train critical thinking skills in the topic of ecosystem interactions, contributing to empirical evidence on contextual learning effectiveness. The expected contribution of this research is to provide empirical evidence for the effectiveness of contextual, environment-based instructional media in fostering critical thinking, thereby strengthening the theoretical and practical foundations of 21st-century biology education.

RESEARCH METHODS

This study employed a Research and Development (R&D) design to produce and validate student worksheets (LKPD) that integrate environmental contexts with critical thinking indicators on the subconcept of ecosystem interactions. The R&D approach was chosen because it enables systematic product development, iterative validation, and empirical testing of educational tools (Branch, 2009; Borg & Gall, 2003). Among available

instructional design models such as Borg & Gall's ten-step R&D cycle and Dick & Carey's systems approach, the ADDIE model (Analyze, Design, Develop, Implement, Evaluate) was selected for its flexibility and adaptability to educational product creation (Branch, 2009). Unlike other linear frameworks, ADDIE supports cyclical feedback and iterative refinement, allowing continuous improvement based on expert and user evaluations. This characteristic aligns with the goal of developing valid, practical, and effective instructional materials through repeated validation and implementation cycles.

1) Analyze

This stage is carried out to identify learning needs by interviewing teachers and distributing questionnaires to students. The aim is to determine the actual learning conditions, obstacles faced, and the need for teaching media that is contextual and relevant to the characteristics of the students. This stage forms the basis for developing product specifications (Branch, 2009).

2) Design (Design)

At this point, the development design is organized based on the findings of the previous research, taking into consideration the students' needs and how well they fit into the classroom. The Merdeka Curriculum's learning objectives serve as the foundation for the design, and Pratowo (2011) is cited in the LKPD's framework, the environmental approach refers to Nana Sudjana (in Hartati, 2020), and the critical thinking skill indicators by Facione & Gittens (2016).

3) Development

Using an environmental approach based on critical thinking skill indicators, this stage entails bringing the design concept to life by creating a product in the form of LKPD. It is vetted by subject matter experts and learning tool specialists and undergoes practicality testing.

4) Implementation

At this stage, teacher and student preparation, as well as the teaching and learning process using the developed LKPD, are conducted. The implementation process involves data collection to test the effectiveness of the LKPD, conducted through pre-tests before learning and post-tests after learning.

5) Evaluation

During the evaluation stage, the effectiveness of the LKPD is analyzed before and after its use. Evaluation is conducted both formatively and summatively. Formative evaluation occurs during the development process through feedback from experts, while summative evaluation is conducted through an analysis of the effectiveness of the LKPD based on N-gain scores.

The participants of this study consisted of 37 students of grade XI and 12 students of grade X from SMA Negeri 3 Banjarmasin, along with three expert validators—one subject matter expert (a senior biology teacher) and two media experts (biology education lecturers from Universitas Lambung Mangkurat). The participants were selected using purposive sampling, a method chosen to ensure that respondents possessed the relevant characteristics required for evaluating the LKPD prototype (Creswell & Creswell, 2018). Students were drawn from science-track classes that had completed prerequisite ecology topics, ensuring familiarity with ecosystem concepts. Demographically, the student participants were aged between 16 and 17 years, with a nearly balanced gender ratio (19 male, 30 female). The purposive approach was deemed appropriate given the developmental objective of the study, which required focused feedback from learners and teachers directly engaged with the target curriculum.

Data collection procedures were conducted through several stages, namely: (1) interviews and questionnaires to analyze student needs to support the analysis stage, (2) validation by subject matter and learning tool experts to assess the product's feasibility, (3) practicality testing through student response questionnaires on the use of LKPD, and (4) effectiveness testing with pretest and posttest using critical thinking skill instruments.

The instruments used in this study consisted of: interview guidelines, needs analysis questionnaires, expert validation sheets, student practicality questionnaires, and pretest-posttest questions. The questions were developed based on critical thinking skill indicators developed by Facione & Gittens (2016), including interpretation, analysis, evaluation, inference, explanation, and self-regulation. All instruments were

adapted from established frameworks and reviewed for content validity by two senior biology education experts. Items were refined based on their relevance, clarity, and alignment with critical thinking indicators.

This study adhered to research ethics in educational contexts. Permission to conduct the study was obtained from the principal of SMA Negeri 3 Banjarmasin and the Biology Education Department of Universitas Lambung Mangkurat. Informed consent was obtained from all student and teacher participants, who were assured that their participation was voluntary and that data would be treated confidentially and anonymously. Ethical procedures followed the principles outlined in the American Educational Research Association (AERA, 2011) guidelines to ensure participant welfare and research integrity.

The validity and practicality scores were analyzed using percentage-based formulas (Akbar, 2022) because such descriptive statistics effectively represent expert consensus and user perceptions in product validation studies. The effectiveness of LKPD in improving students' critical thinking skills was analyzed using the N-gain formula, as proposed by Hake (in Azizah & Rosdiana, 2022). N-gain analysis was selected because it provides a normalized measure of improvement by comparing pretest and posttest scores, which is particularly suitable for quasi-experimental educational designs with non-randomized groups (Hake, 1998). The feasibility of implementation was evaluated using mean observation scores and categorized based on Panjaitan et al. (2023).

Data analysis techniques in the form of analysis results, suggestions, and input from validators are analyzed descriptively. Data analysis techniques to obtain the percentage of LKPD validity use the following Formula 1 adapted from Akbar (2022). The percentage scores obtained were then described using criteria as presented in Table 1. The calculation used in the practicality test as the students' response to the LKPD uses Formula 2. The percentage scores obtained were then described using criteria as presented in Table 2.

$$P = \frac{f}{n} \times 100\% \quad \text{..... Formula 1}$$

$$P = \frac{\sum \text{score obtained from the research}}{\sum \text{ideal score for all item}} \times 100\% \quad \text{.....Formula 2}$$

Description:
P = Percentage score
f = Total score obtained
n = Maximum score

Table 1 Validity Criteria

Validity score of student worksheet	Level of validity
80.01% – 100.00%	Highly valid, so it can be used without revision
61.01 % – 80.00%	Valid enough to be used, but needs minor revisions
41.01 % – 60.00%	Less valid, not recommended for use due to the need for major revisions
21.01 %– 40.00%	Invalid, or cannot be used
> 20.00%	Highly invalid, or cannot be used

(Source: Akbar, 2022)

Tabel 2 Practicality Criteria

Practicality score of student worksheet	Level of practicility
80.01% – 100.00%	Very practical
60.01% – 80.00%	Practical
40.01 % – 60.00%	Less practical
21.01 % – 40.00%	Not practical
> 20.00%	Very impractical

(Source: Akbar, 2022)

The practicality of LKPD is also assessed based on its feasibility. The feasibility of LKPD refers to the level of conformity between the LKPD design and its actual implementation in the classroom. Feasibility is measured using an observation sheet filled out by observers during the learning process. The results, which

are known as the average scores, are then described using the feasibility criteria developed by Panjaitan et al. (2023), which are presented in Table 3.

Table 3 Feasibility Criteria

Feasibility score	Feasibility category
$O_k = 4$	Feasible very well
$3 \leq O_k < 4$	Feasible well
$2 \leq O_k < 3$	Poorly feasible
$1 \leq O_k < 2$	Not feasible

(Source: Panjaitan et al., 2023)

The usefulness of this LKPD was examined in order to ascertain how well students' critical thinking abilities in the subconcept of ecosystem component interaction might be developed by its application in conjunction with an environmental approach. Data analysis techniques to obtain LKPD effectiveness data with the N-gain test using Formula 3. The results, which are known percentages, are then described using Hake's effectiveness criteria (in Azizah & Rosdiana, 2022), as presented in Table 4.

$$N_{gain} = \frac{\text{Score posttest-score pretest}}{\text{Maximum score-score pretest}} \quad \text{..... Formula 3}$$

Table 4 N-gain Criteria

N-gain	Criteria
(g) > 0.7	High
0.7 > (g) > 0.3	Medium
(g) > 0.3	Low

(Source: Hake in Azizah & Rosdiana, 2022)

RESULTS AND DISCUSSION

Result

Utilizing an environmental approach, the creation of student worksheets (LKPD) started with a needs analysis conducted utilizing student questionnaires and instructor interviews, which revealed that the limited teaching materials, which relied solely on textbooks and PowerPoint presentations, made it difficult to understand the concept of ecosystem interactions in a contextual manner. Teachers assessed the need for teaching materials that support active learning and critical thinking. This was reinforced by survey findings showing that 80% of students had never used environment-based LKPD, yet 90% expressed interest in such media, indicating a gap between learning needs and the availability of relevant teaching resources, as emphasized by Prastowo (in Amelia & Muzakki, 2021) and Devega et al. (2022) that learning success is determined by the relevance of teaching materials to students' interests and needs.

The initial design of the LKPD was intended to integrate an environmental approach with critical thinking skill indicators. According to Nurmiati et al. (2022), designs with an environmental approach significantly encourage student learning motivation and the development of higher-order thinking skills. The LKPD format refers to Prastowo, with the design results as follows: 1) the title of the LKPD includes the type of biology learning media, the title of the material, an identity column, and the target audience, 2) learning instructions include initial instructions for students covering technical steps before working on the LKPD, such as reading carefully, discussing, preparing the necessary tools, and working collaboratively in groups, 3) the core competencies/key topics relevant to the Biology subject in Phase E of the Merdeka Curriculum, 4) supporting information includes a brief narrative on the interconnections between ecosystem components, along with a QR code to access additional online learning resources, 5) the work steps in the LKPD are structured based on an environmental approach. Students are directed to conduct direct observations in the school garden or pond, then record the various types of interactions found, and 6) assessment.

Expert validation results showed that the developed *Lembar Kerja Peserta Didik* (LKPD) achieved very high validity levels, ranging between 88% and 100% across assessment aspects. These aspects included appearance, font use, structure, environmental contextualization, and alignment with critical thinking

indicators. Improvements from the first to the second validation stage particularly strengthened the structural organization, readability, and visual clarity of the LKPD. Further details of the validation results are presented in Table 5 and Table 6. After validation by device experts, a number of comments and suggestions for improving the LKPD were obtained. Further details of the changes made before and after the revision are presented in Table 7.

Validation tests were also conducted by subject material experts on biology teachers at SMAN 3 Banjarmasin. The purpose of this validation was to assess the accuracy of the content, completeness of the material, and appropriateness of the language used in the LKPD that had been developed. Further details of the validation results are presented in Table 8. Following confirmation by subject-matter specialists, a number of comments and suggestions for improving the LKPD were obtained. The details of the changes made before and after the revision are presented in Table 9.

Table 5 Results of LKPD I Validation by Device Experts

Assessment	Value	Validator 1		Validator 2	
		I	II	I	II
Display aspect	**Score**	68.00%	88.00%	72.00%	88.00%
	Criteria	Valid enough	Highly valid	Valid enough	Highly valid
Font and Spacing Aspect	**Score**	80.00%	80.00%	85.00%	95.00%
	Criteria	Valid enough	Valid enough	Highly valid	Highly valid
Physical criteria aspect	**Score**	100.00%	100.00%	80.00%	80.00%
	Criteria	Highly valid	Highly valid	Valid enough	Valid enough
Worksheet structure aspect	**Score**	70.00%	83.33%	76.67%	90.00%
	Criteria	Valid enough	Highly valid	Valid enough	Highly valid
Environmental approach aspect	**Score**	80.00%	86.67%	93.33%	86.67%
	Criteria	Valid enough	Highly valid	Highly valid	Highly valid
Critical thinking skills indicator aspect	**Score**	83.33%	86.67%	73.33%	80.00%
	Criteria	Highly valid	Highly valid	Valid enough	Valid enough

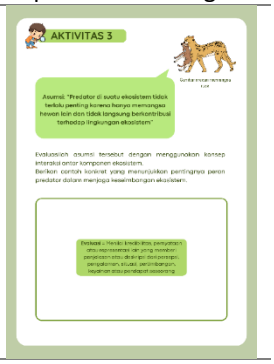
Description: I = Stage 1 validation; and II = Stage 2 validation

Table 6 Results of LKPD II Validation by Device Experts

Assessment	Value	Validator 1		Validator 2	
		I	II	I	II
Display aspect	**Score**	72.00%	84.00%	72.00%	92.00%
	Criteria	Valid enough	Highly valid	Valid enough	Highly valid
Font and Spacing Aspect	**Score**	80.00%	80.00%	100.00%	100.00%
	Criteria	Valid enough	Valid enough	Highly valid	Highly valid
Physical criteria aspect	**Score**	100.00%	100.00%	80.00%	100.00%
	Criteria	Highly valid	Highly valid	Valid enough	Highly valid
Worksheet structure aspect	**Score**	76.67%	83.33%	80.00%	93.33%
	Criteria	Valid enough	Highly valid	Valid enough	Highly valid
Environmental approach aspect	**Score**	80.00%	80.00%	93.33%	86.67%
	Criteria	Valid enough	Valid enough	Highly valid	Highly valid
Critical thinking skills indicator aspect	**Score**	83.33%	86.67%	73.33%	80.00%
	Criteria	Highly valid	Highly valid	Valid enough	Valid enough

Description: I = Stage 1 validation; and II = Stage 2 validation

Table 7 Notes on LKPD Improvements by Device Experts

Assessment	LKPD I		LKPD II	
	Before revision	**After revision**	**Before revision**	**After revision**
Display aspect	No caption provided added to image	Added caption provided to image	No caption provided added to image	Added caption provided to image
				
Font and spacing aspect	The conjunction is still at the beginning of the sentence	Repaired the writing at the beginning of the sentence	Some of the sentences are still not in accordance with PUEBI	Repaired the sentences in accordance with PUEBI
				
Physical criteria aspect	Title is not specific	Revise the title of the LKPD to make it more specific for biology lessons	Title is not specific	Revise the title of the LKPD to make it more specific for biology lessons
				

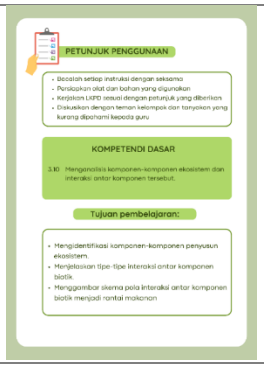
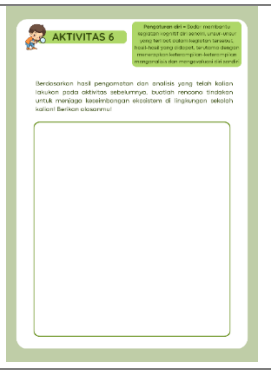
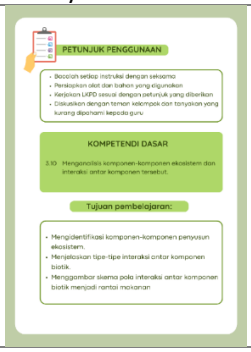
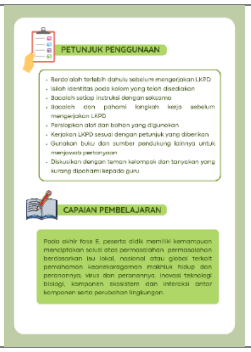
Assessment	LKPD I		LKPD II	
	Before revision	**After revision**	**Before revision**	**After revision**
Worksheet structure aspect	The instructions for use in the LKPD are unclear and lack detail	Added instructions for use	The instructions for use in the LKPD are unclear and lack detail	Added instructions for use
				
Environmental approach aspect	The objects in the LKPD are not specific	Added objects in the form of the school's surroundings that are observed in the work steps	The objects in the LKPD are not specific	Added objects in the form of the school's surroundings that are observed in the work steps
				
Critical thinking skills indicator aspect	Self-regulation indicators not yet included	Added self-regulation indicator	Self-regulation indicators not yet included	Added self-regulation indicator
				

Table 8 Results of LKPD Validation by Material Experts

Assessment	Value	LKPD I Validation		LKPD II Validation	
		I	II	I	II
Accuracy aspect	**Score**	80.00%	100.00%	84.00%	100.00%
	Criteria	Valid enough	Highly valid	Highly valid	Highly valid
Completeness aspect	**Score**	90.00%	100.00%	80.00%	100.00%
	Criteria	Highly valid	Highly valid	Valid enough	Highly valid
Currency and language aspect	**Score**	80.00%	100.00%	72.00%	100.00%
	Criteria	Valid enough	Highly valid	Valid enough	Highly valid

Table 9 Notes on LKPD Improvements by Material Experts

Assessment	LKPD I		LKPD II	
	Before revision	**After revision**	**Before revision**	**After revision**
Accuracy aspect	Self-regulation indicators not yet included	Added self-regulation indicator	Learning objectives are not yet in line with the concepts of audience, behavior, condition, and degree	Adjusted learning objectives in line with the concepts of audience, behavior, condition, and degree
				
Completeness aspect	Learning outcomes not yet contain	Added Learning outcomes	Learning outcomes not yet contain	Added Learning outcomes
				
Currency and language aspect	The language is not appealing to student	Improve the writing style to make it more appealing/less rigid	The language is not appealing to student	Improve the writing style to make it more appealing/less rigid
				

Practicality tests were conducted to identify whether the developed LKPD could be used practically in the learning process. This practicality aspect was assessed based on the ease of use of the LKPD, the clarity of the instructions, the readability of the material, the presentation of the LKPD that encouraged critical thinking, and the suitability of the LKPD with the material. Further details of the practicality test results for LKPD I and LKPD II are presented in Table 10.

Table 10 Practical Results

Assessment	Value	LKPD I	LKPD II
Content feasibility aspect	**Average**	23.08	22.58
	Score	92%	90%
	Criteria	Very practical	Very practical
Instructional material feasibility aspect	**Average**	22.42	22.92
	Score	90%	92%
	Criteria	Very practical	Very practical

The practicality assessment yielded an average score of 91%, indicating that the LKPD was considered very practical by students. This finding suggests that the learning media were both accessible and engaging, fulfilling Mayer's (2014) coherence and signalling principles by minimizing irrelevant information and emphasizing key learning cues. Students reported that task instructions were easy to follow, while the environmental exploration activities made learning more meaningful and enjoyable. Observation data further revealed strong engagement during implementation. Students actively conducted field observations, documented biotic–abiotic relationships, and discussed causal relationships collaboratively. This engagement is consistent with constructivist and experiential learning frameworks, which posit that active participation and peer interaction promote concept internalization (Kolb, 2015). In this study, such engagement translated into higher motivation and persistence during inquiry-based tasks. Figure 1 shows the rise in students' average pretest and posttest scores according to each critical thinking skill indicator.

Table 11 Feasibility Results

Observed aspect	Average score	Category
Feasibility of LKPD I	3.46	Feasible well
Feasibility of LKPD I	3.62	Feasible well

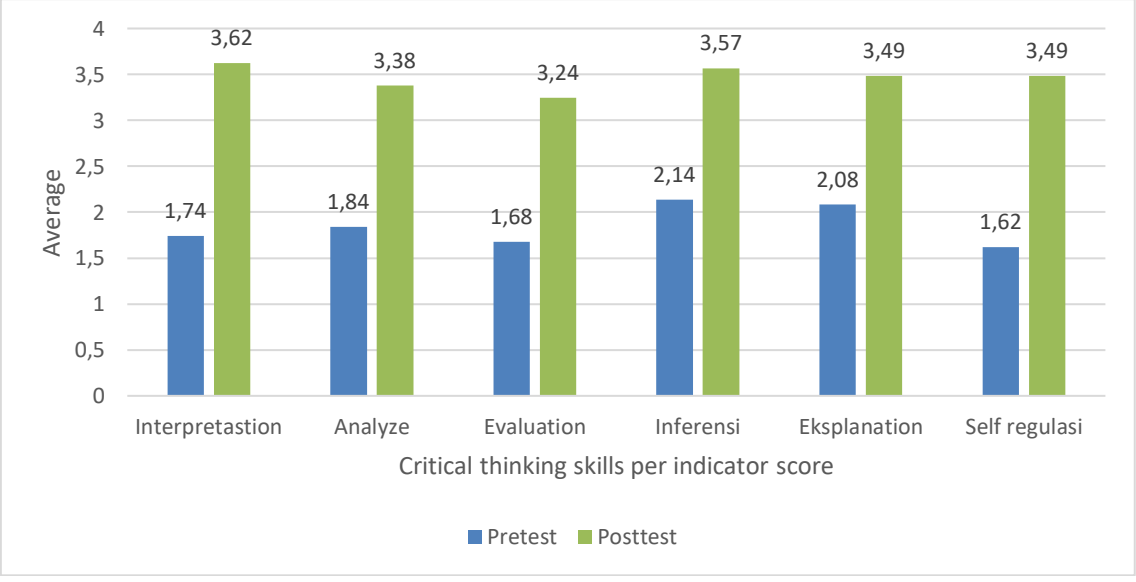


Figure 1 Critical Thinking Skills per indicator score

Figure 1 depicted the improvement across six critical thinking indicators. The analysis showed that interpretation and inference achieved the highest mean gains (ΔM = 0.82 and 0.79, respectively), while self-regulation showed more modest growth (ΔM = 0.65). Standard deviation analysis (SD = ±0.08) indicated relatively consistent improvements across students, suggesting minimal score dispersion and high instructional reliability. Possible confounding factors, such as prior knowledge or varying engagement levels were minimized through uniform instruction and observation protocols. These statistical details affirm that improvements were systematically linked to the instructional intervention rather than external variability.

Evaluation of how well LKPD combined with an environmental approach trains students' critical thinking abilities by calculating the N-gain value and examining the rise in pretest and posttest scores. Table 12 provides specifics of the N-gain findings based on the pretest and posttest scores of the students.

Table 12 N-gain Test Result

Sum of pretest averages	Sum of posttest averages	N-gain	Criteria
47.64	86.60	0.74	High

The pretest–posttest comparison produced an average N-gain of 0.74, categorized as high. This indicates substantial improvement in students' critical thinking skills following the use of the environment-integrated LKPD. The effect size, calculated from the difference between pretest (47.64) and posttest (86.60) means, suggests a large educational impact consistent with Hake's (1998) benchmarks for instructional interventions.

Discussion

The first stage of expert validation of the visual aspects of the LKPD showed results of 68% by validator 1 and 72% by validator 2, indicating the need for visual design improvements. Notes include adjusting the background color, adding illustrations, and providing image captions. Sagita et al. (2024) emphasize the importance of attractive illustrations and good layout in enhancing the appeal of learning media. Hagi & Mawardi (2021) also state that visually appealing designs can increase motivation and engagement in learning. After revisions, the scores significantly improved to 88% and 92%, indicating that visual improvements substantially enhanced the validity of the LKPD.

The use of fonts and spacing initially contained connecting sentences at the beginning of paragraphs and was not optimal in terms of readability. After improvements, validity increased from 80% to 100%. Nurofik et al. (2022) state that readability is crucial in ensuring students' understanding of the content of educational media. These adjustments improved comfort in reading and completing the LKPD. Physical aspects such as the cover also achieved high validity from the start, with scores increasing from 80% to 100%, due to an attractive and relevant cover design, supporting the views of Muslimah (2020) and Wahid (2022) on the importance of appearance and ease of use of LKPD.

In terms of structure, initial validation showed scores of 70% and 76.67% from two validators, with the note that the usage instructions were not detailed enough. Revisions added more detailed and systematic guidelines, increasing validity to 83.33% and 93.33%. (Ranganathan & Rajkumar, 2020) emphasize the importance of clear instructions in guiding self-directed learning. Pratama (in Khalidi et al., 2024) also notes that LKPDs need to present activity stages that support students' mastery of scientific skills, thereby strengthening the pedagogical foundation of LKPDs.

The environmental approach in the LKPD initially scored 80%, then increased to 93.33% after the addition of real-world environmental observation activities, such as observing plants and animals around the school. According to (Harahap et al., 2020), integrating real-world environments into learning not only enhances the relevance of the material but also fosters ecological awareness among students. This revision makes the environmental approach more than just theory, but is implemented through practical activities that enrich contextual learning experiences.

The critical thinking indicator initially did not include the aspect of self-regulation. After the revision that added this aspect, the validity increased from 73.33% to 86.67%. Rifa'i et al. (2024) noted that the ability to regulate and evaluate one's own thinking is key to the development of critical thinking. The addition of

this indicator makes the LKPD more holistic, encouraging students to reflect and compare ideas independently in the learning process.

Expert validation of the material yielded positive results, particularly in terms of content accuracy and completeness. The accuracy score increased from 80% to 100% after adjusting the learning objectives based on the ABCD model, as suggested by Dick, Carey & Carey (in Pitasari & Febriyanti, 2023). The completeness of the material also improved after the addition of basic competencies and learning outcomes, from 90% to 100%. This aligns with the views of Mulyani & Farida (2020) and Septiyani (in Ariana et al., 2022), who emphasize the importance of aligning instructional materials with the curriculum as the foundation for achieving learning objectives.

The language in the initial LKPD was deemed too formal and uninteresting. After being revised to be more communicative and compliant with EYD standards, the score increased from 72% to 100%. Prastowo (2015) and Yolanda (in Maningsih & Fitriani, 2023) noted that effective LKPDs use clear, easy-to-understand, and unambiguous sentences. This language revision not only clarified the content but also increased students' reading interest, as supported by Purnamasari et al. (2020), who stated that good language enhances learning motivation.

A comparative analysis between the first and second validation stages shows that the aspects of environmental approach, physical criteria, and use of letters and spacing are the components with the highest improvement. These three aspects achieved scores above 95% and are classified as “highly valid.” This LKPD not only presents the environmental approach declaratively but also implements it through real activities. Unlike the research by Huda et al. (2023) and Rahayu et al. (2023), which did not optimally address visual aspects and reading comfort, this LKPD stands out in integrating environmental approach, physical design, and readability as part of an effective and contextual learning strategy.

The student worksheets (LKPD) that had undergone validation and revision were then tested for practicality through a small-group trial involving 12 tenth-grade students at SMA Negeri 3 Banjarmasin. The results demonstrated that the LKPD based on an integrated environmental approach to critical thinking skills achieved an average percentage of 91% with the criterion of “very practical”. This finding is consistent with previous research by Sukardi et al. (2019), Bria et al., 2022; Aslam et al., 2021), which stated that LKPDs with an environmental approach generally have a good level of practicality. Balela et al. (2021) and Rahma et al. (2022) also reinforce that LKPD based on critical thinking skills are considered practical in their use.

The aspects that received the highest scores in the practicality test were “ease of understanding the content of the LKPD” and “readability of the language,” indicating that the language used is appropriate for the students' level of understanding. Ilmiah & Fitrihidajati (2024) emphasize the importance of language as a communication tool in learning media that connects students with the content. High comprehensibility indicates that the language and content of the LKPD have successfully facilitated an effective and efficient learning process.

The aspect of learning media suitability also received a high score with an average of 92%, particularly in the statement that the use of an environmental approach aids in understanding the concept of interaction between ecosystem components. This indicates the effectiveness of the contextual approach in bringing students closer to real-world phenomena. Gaba *et al*. (2024) and Safitri et al. (2022) support that environment-based learning experiences make scientific concepts more concrete and increase student engagement. Nugroho et al. (2021) also state that environment-based learning strengthens understanding and problem-solving skills.

In terms of content feasibility, the LKPD received an average of 90% in the “very practical” category, reflecting that the material is appropriate for student needs and encourages critical thinking activities. The LKPD is considered easy to use and supports independent learning. Balela et al. (2021) state that ease of understanding and using the LKPD is a key indicator of practicality. With effective language use and a systematic structure, students find it easier to follow the learning activities comprehensively.

The implementation of the LKPD was obtained from observations by two observers during the learning process. The average implementation score was 3.46 for LKPD I and 3.62 for LKPD II, both of which fell within the “well-implemented” criteria. These results indicate that all components of the LKPD can be effectively applied in the classroom, and students are actively engaged in observation, discussion, and drawing

conclusions. In line with Arfada & Hia (2022), implementation rates above 80% indicate that the learning media can be practically used in real classroom contexts.

The effectiveness of the LKPD in this study was analyzed through on improvements in six critical thinking skill indicators according to Facione & Gittens (2016), namely interpretation, analysis, evaluation, inference, explanation, and self-regulation. Improvements were observed from the results of pretest and posttest comparisons after the use of LKPD based on an environmental approach. The results graph shows that all indicators improved, with interpretation and inference showing the most significant improvement. Students were able to identify the interrelationships between ecosystem components and critically evaluate arguments, the results are in line with those of Wahyuni et al. (2022), which emphasize the importance of interpretation as a foundation for understanding data or information.

Compared to related studies, these findings show stronger learning gains. Huda et al. (2023) reported an N-gain of 0.65 using a scientifically-based e-LKPD, while Nursidin et al. (2022) achieved 0.70 through environment-based instruction. The slightly higher N-gain in this study may be attributed to the explicit integration of environmental exploration with Facione's critical thinking framework, creating a synergistic effect between contextual engagement and cognitive activation. In essence, the environmental contextualization promoted curiosity and observational depth, which served as precursors to analytical reasoning and inferential thinking.

Furthermore, analysis of improvement by indicator revealed that interpretation and inference skills showed the highest gains. This aligns with prior findings by Wahyuni et al. (2022), who argued that interpretation serves as the cognitive foundation for critical reasoning. Students were able to connect field data, such as plant–pollinator interactions or nutrient cycles to abstract ecological principles. The self-regulation indicator, newly introduced in the revised LKPD, showed moderate but notable growth, suggesting the early formation of metacognitive awareness. Variance among indicators (SD = ±0.08) indicates that while analytical and inferential skills improved substantially, reflective thinking may require sustained practice across multiple lessons.

The interpretation indicator improved because students were encouraged to examine the relationships between biotic and abiotic components in ecosystems through direct observation and image analysis. This activity trained students' ability to understand scientific contexts reflectively. Meanwhile, the improvement in the inference indicator was demonstrated through students' ability to conclude the impacts of environmental changes, such as water pollution on the food chain. This reinforces the findings of Andraini et al. (2021) that inference is an important cognitive skill for understanding and concluding information based on observations.

The environmental approach in LKPD provides a relevant learning context, encouraging critical thinking skills through direct observation and data-based discussions. Hastika et al. (2023) state that utilizing the surrounding environment as a learning resource can significantly enhance critical thinking skills. The N-gain test result of 0.74 falls into the high category, indicating that LKPD effectively encourages active student engagement in critical analysis activities related to ecosystem material.

The learning activities implemented, such as school environment observation and group discussions, help students understand the material deeply. This aligns with Wijayanti et al. (2025) research, which shows that environment-based learning activities provide concrete experiences and strengthen understanding of scientific concepts like ecosystems and species interactions. Students not only learn theoretically but also through direct experiences that encourage emotional and intellectual engagement.

The study's findings can be synthesized into a conceptual mechanism linking environmental context, engagement, and reasoning development. The environmental approach provided authentic stimuli that activated observation and inquiry (Harahap et al., 2020; Hastika et al., 2023). This authentic engagement, in turn, encouraged students to interpret and analyze phenomena critically, aligning with the constructivist principle that knowledge emerges through contextualized problem-solving (Vygotsky, 1978). The integration of critical thinking indicators served as cognitive scaffolds guiding students from perception to reflection.

The success of LKPD is also influenced by two main factors, namely the environmental approach and the integration of critical thinking skill indicators. The environmental approach allows students to learn from real-world contexts, encouraging them to evaluate, conclude, and analyze phenomena around them. This result aligns with the research conducted by Mahrus et al. (2022), which showed that environment-based

learning significantly improves critical thinking and problem-solving skills because it requires active engagement in authentic situations.

The integration of critical thinking skill indicators into each stage of the LKPD activities provides systematic and continuous thinking exercises. Students are trained to think reflectively and independently in facing real environmental problems. Nursidin et al. (2022) show that this approach is more effective than conventional learning. Based on an evaluation of 37 students, the average N-gain of 0.74 confirms that LKPD is useful for enhancing critical thinking abilities, while also demonstrating that this medium is valid, practical, and effective as a contextual 21st-century learning tool.

In summary, the results demonstrate that integrating environmental exploration with a structured critical thinking framework can substantially enhance students' analytical and reflective reasoning in biology education. The high validation, practicality, and effectiveness scores collectively indicate that the developed LKPD represents a theoretically grounded, empirically validated innovation in contextual science instruction. The findings of this study contribute to both theoretical and practical dimensions of educational design. Theoretically, they validate the integration of Facione's critical thinking model within the Contextual Teaching and Learning framework as an effective synthesis for designing inquiry-based instructional tools. Practically, the validated LKPD offers educators an adaptable template for developing contextually grounded materials that promote analytical and reflective thinking. The positive student responses also indicate that integrating local environmental contexts can increase relevance and motivation, supporting the Merdeka Curriculum's goal of experiential and competency-based learning.

CONCLUSION

This study developed and validated environment-integrated student worksheets (LKPD) grounded in Facione's critical thinking framework, addressing the lack of contextualized learning media in Indonesian biology education. The LKPD achieved high validity (88–100%), practicality (91%), and effectiveness (N-gain = 0.74, high category), demonstrating its capacity to strengthen students' analytical, evaluative, and reflective reasoning in understanding ecosystem interactions. By embedding authentic environmental exploration and self-regulation tasks into inquiry-based learning, the LKPD bridges conceptual instruction with real-world ecological experience, promoting deeper cognitive engagement and aligning with the Merdeka Curriculum's vision of active, critical learners. Pedagogically, this model provides a replicable design for science educators and curriculum developers to create instructional materials that foster higher-order thinking through contextual learning. Theoretically, it integrates Contextual Teaching and Learning (CTL) principles with Facione's cognitive taxonomy, illustrating how environmental contextualization can activate critical reasoning pathways. However, the study's limited sample and absence of a control group constrain generalization. Future research should test the model across multiple schools, incorporate comparison groups, and explore digital or hybrid versions of LKPD to enhance scalability and accessibility for 21st-century classrooms. Finally, this study contributes to the growing body of research on contextualized learning by providing empirical evidence that integrating environmental observation into LKPD design significantly enhances students' higher-order thinking. Future studies should explore scalability across different ecological topics and student demographics.

ACKNOWLEDGMENT

Appreciation is extended to SMA Negeri 3 Banjarmasin, especially to the principal and biology teachers, for their permission, facilities, and full support during the research process. Gratitude is also addressed to the expert lecturers who served as validators for their valuable input, constructive suggestions, and professional assessments that significantly contributed to the quality of this research. May all forms of assistance provided bring lasting benefits to the field of education and be rewarded as a continuous act of kindness.

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