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Fostering Critical Thinking Through E-Worksheets: A Project-Based Approach to Fish Waste Processing Education

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Abstract

Despite the importance of critical thinking in science education, junior high schools often lack effective instructional models that engage students with real-world environmental issues. One such issue, fish waste management, remains underutilised as a learning context, despite its relevance to local communities. This study investigates the effectiveness of project-based learning (PjBL) assisted by e-worksheets in fostering students' critical thinking skills through the topic of fish waste processing. A quasi-experimental design was employed, involving 30 seventh-grade students in Bandar Lampung, Indonesia. Pre- and post-tests were administered to measure five core indicators of critical thinking: problem identification, information sourcing, hypothesis formulation, clarification, and solution generation. The results, analysed using SPSS 25.0, showed significant improvements across all indicators. For instance, accurate problem identification responses increased from 0% to 47%, and logical hypothesis construction improved from 0% to 37%. Students also reported greater engagement with the digital worksheets, which featured multimedia content, simulations, and open-ended questions. The findings indicate that e-worksheet-assisted PjBL is an effective pedagogical strategy for enhancing students' analytical thinking, environmental literacy, and meaningful learning engagement across science education contexts.

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Keywords: Critical thinking; Project-based learning; E-worksheet; Environmental literacy; Fish waste processing

INTRODUCTION

Environmental issues that directly intersect with students' daily experiences present rich opportunities for contextual learning, particularly within junior high school science education. One such issue is managing fish waste generated at Fish Auction Facilities (FAFs), where large quantities of organic by-products, including fish heads, scales, bones, and entrails, are frequently discarded without proper treatment. When unmanaged, these organic wastes can contaminate water sources and degrade soil quality, emitting strong odours that reduce the quality of life for local communities (Asmal et al., 2016; Simbolon & Kesuma, 2022). Moreover, such conditions pose significant public health risks as the decaying waste becomes a breeding ground for disease vectors and bacteria (Amaral et al., 2024). This phenomenon illustrates an environmental concern and a pressing socio-scientific issue that can be meaningfully integrated into school curricula.

Ironically, the potential of fish waste as a valuable resource remains largely untapped. Several studies highlight that this waste can be processed into organic fertilisers, fish meal, or animal feed, providing sustainable alternatives for community-based (Alfio et al., 2021; Coppola et al., 2021; Mo et al., 2018). However, the lack of community awareness and the absence of related instructional55 integration in science classrooms hinder students' development of practical, environmentally conscious mindsets. In response, Project-Based Learning (PjBL) offers a promising pedagogical model that engages students in solving authentic problems through active investigation and collaboration. Despite its relevance, there remains a paucity of empirical studies exploring PjBL, particularly when assisted by digital tools such as e-worksheets, to address local environmental issues like fish waste management in junior high school settings.

Equally important is cultivating students' critical thinking skills, indispensable in navigating 21st-century challenges, including climate change, environmental degradation, and complex social dynamics. Critical thinking enables students to evaluate information, analyse arguments, and construct evidence-based conclusions (Facione, 2011; Kennedy et al., 2013). This cognitive competence is essential for developing scientific reasoning,

fostering resilience against misinformation, and empowering students to participate in informed civic decision-making (Kuhn, 2019; Walsh & Paul, 1986). However, research indicates that conventional instructional resources such as printed student worksheets derived from textbooks often fail to support the development of higher-order thinking skills due to limitations in content depth, interactivity, and contextual relevance (Abdurrahman et al., 2019; Goodsett, 2020; Satria et al., 2025).

To address this gap, integrating e-worksheets within PjBL frameworks has gained growing attention in recent years. E-worksheets offer various technological affordances, including multimedia integration, open-ended tasks, real-time feedback, and flexible device access. These features have been shown to enhance student engagement, promote differentiated instruction, and streamline formative assessment processes for teachers (Hasnunidah et al., 2023; Osipova & Bagrova, 2023; Nildasari & Nur, 2024). Moreover, interactive digital worksheets can be designed to embed inquiry prompts, simulations, and collaborative activities that encourage students to articulate their thinking and refine their arguments—core practices in scientific learning.

Therefore, this study aims to evaluate the effectiveness of e-worksheet-assisted Project-Based Learning in enhancing junior high school students' critical thinking skills through contextual science instruction on fish waste processing. This study seeks to advance meaningful, student-centred, and sustainable science education by integrating environmental literacy with digital pedagogical strategies. It also offers empirical insights that are aligned with the goals of the Sustainable Development Agenda (SDGs), particularly those related to quality education (Goal 4) and responsible consumption and production (Goal 12).

METHODS

This study employed a quasi-experimental research design to examine the improvement in students' critical thinking skills before and after implementing a project-based learning (PjBL) model supported by e-worksheets, focusing on the contextual theme of fish waste processing. The research was conducted at a junior high school in Bandar Lampung, Indonesia, involving 30 seventh-grade students as participants.

The intervention was carried out over four instructional sessions within two weeks. During this time, students engaged in project-based learning activities guided by e-worksheets incorporating multimedia elements, simulations, and ill-structured tasks to encourage critical engagement with the topic.

The primary research instrument was a critical thinking test consisting of five open-ended questions designed by the researchers. These questions were constructed to measure five core indicators of critical thinking: (1) problem identification, (2) source evaluation, (3) hypothesis formulation, (4) explanation and clarification, and (5) solution generation about environmental issues. The test was administered before (pre-test) and after (post-test) the learning intervention.

To ensure the instrument's validity, a product-moment correlation analysis was conducted. Its reliability was tested using Cronbach's alpha coefficient at a 5% significance level. The resulting pre-test and post-test data were analysed using SPSS version 25.0. Descriptive statistics were used to summarise the data, and a paired sample t-test was employed to determine the significance of differences in students' critical thinking scores before and after the intervention.

RESULT

This section presents the quantitative findings from assessing students' critical thinking skills, conducted before and after implementing the Project-Based Learning (PjBL) model supported by interactive e-worksheets. The assessment focused on five core indicators of critical thinking: (1) problem identification, (2) information evaluation, (3) hypothesis formulation, (4) clarification, and (5) solution formulation. Each indicator was scored on a scale from 1 to 4, with Score 4 representing the highest level of mastery.

Table 1. Comparison of Students' Critical Thinking Performance on Score 4 (Highest Level)

Indicator	Pre-test Score 4 (%)	Post-test Score 4 (%)
Problem Identification	0	47
Information Evaluation	3	43
Hypothesis Formulation	0	37
Clarification	3	30
Solution Formulation	10	13

The results indicate that before the intervention, most students had not yet reached the highest level of critical thinking in any of the five indicators. This is reflected in the low percentage of students achieving a Score of 4 in the pre-test, with an average of only 3.2%. Notably, none of the students scored 4 in problem identification and hypothesis formulation, suggesting they struggled to clearly define problems and construct logical assumptions before the PjBL intervention.

After implementing PjBL supported by e-worksheets, all indicators showed substantial improvement. The most significant increase was observed in problem identification, which rose from 0% to 47%, indicating that students became significantly better at recognizing and articulating environmental issues. The information evaluation indicator also showed a sharp increase, from 3% to 43%, reflecting an enhanced ability to critically assess data and sources after engaging with e-worksheet activities designed to stimulate critical inquiry.

In the hypothesis formulation indicator, the percentage of students achieving the highest score rose from 0% to 37%, showing improvement in the ability to propose testable assumptions based on evidence. The clarification indicator increased from 3% to 30%, suggesting greater student capability in expressing and coherently justifying their opinions or reasoning. The solution formulation indicator showed a more modest improvement, rising from 10% to 13%, which suggests that while students began developing solutions, this area may require further instructional emphasis.

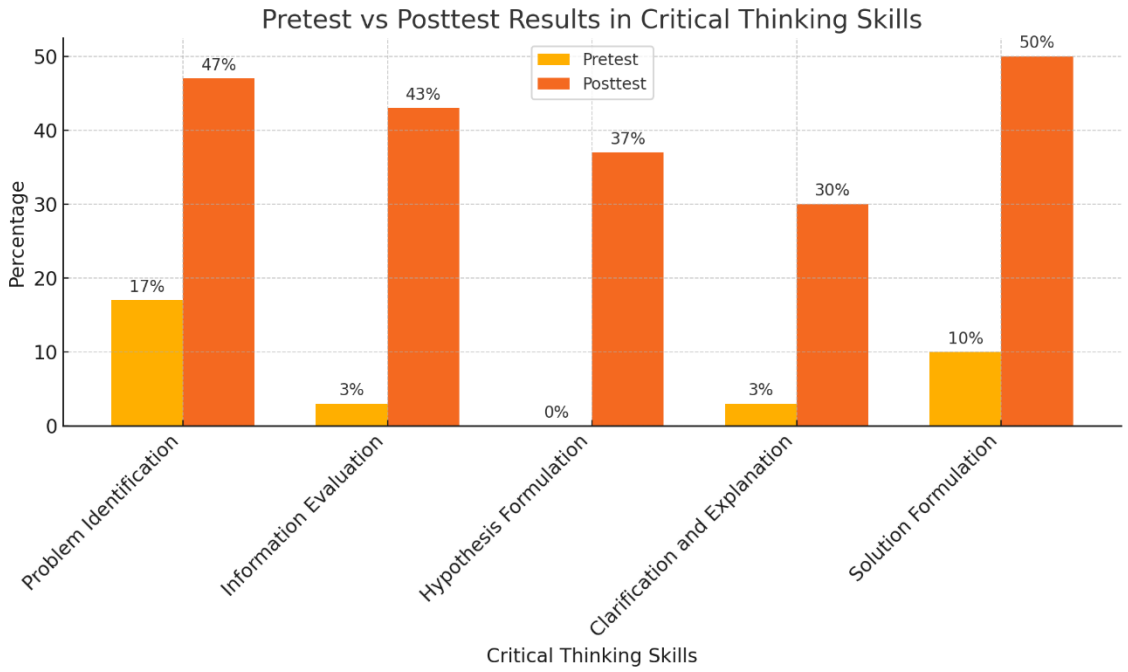


Figure 1. Comparison of Pre-test and Post-test Results by Critical Thinking Indicator

Figure 1 further illustrates the trends in Table 1, clearly visualizing the improvements across all five indicators. The chart highlights the most prominent gains in problem identification and information evaluation, while other indicators also reflect consistent positive changes, albeit at varying degrees. This visual representation reinforces the conclusion that PjBL, when integrated with digital learning tools like e-worksheets, can significantly enhance students' critical thinking performance.

Overall, the average percentage of students achieving a Score 4 increased from 3.2% in the pre-test to 34% in the post-test. This substantial improvement underscores the effectiveness of integrating PjBL with interactive e-worksheets, helping students grasp environmental science concepts and encouraging deeper, evidence-based, and reflective thinking. The student-centered, inquiry-based learning environment provided opportunities for authentic engagement with real-world issues, enabling students to practice higher-order thinking skills in a meaningful and context-rich setting.

These findings support using project-based learning approaches as effective strategies for enhancing critical thinking, particularly in science education at the junior high school level. Integrating interactive digital media, such as e-worksheets, adds value by offering structured, visually engaging, and cognitively stimulating learning experiences. As such, this instructional model aligns well with the demands of 21st-century education,

which emphasizes the development of analytical, collaborative, and problem-solving competencies to address complex global and local challenges.

DISCUSSION

The findings of this study suggest that integrating e-worksheets with Project-Based Learning (PjBL) significantly enhances students' critical thinking skills, particularly in environmental education. The improvements across all five assessed indicators demonstrate that PjBL provides a practical framework for engaging students with authentic, real-world issues. At the same time, e-worksheets serve as valuable scaffolding tools that deepen the learning experience through interactive and multimedia resources.

The increase in students' ability to identify problems underscores the effectiveness of contextual learning. Before the intervention, students struggled to define environmental issues such as fish waste and pollution. Following the PjBL intervention, students demonstrated a clearer understanding of the problem, linking their responses to climate change and environmental sustainability. This aligns with Johnson (2002) assertion that contextual learning improves analytical and evaluative thinking.

These outcomes are also consistent with Vygotsky's scaffolding theory, which posits that guided learning experiences help students construct deeper understanding. Structured e-worksheets functioned as educational scaffolds, enabling students to progress from surface-level knowledge to conceptual insight. By integrating these tools, learners could better define problems, organise information, and build sustainable solutions (Awadelkarim, 2021; Parra et al., 2020).

The improvements in information evaluation reflect students' increased ability to assess source credibility and relevance. E-worksheets provided multimedia resources, such as articles and videos, which guided students through structured evaluations. Furthermore, hypothesis formulation shifted from guesswork to evidence-based reasoning, a cornerstone of scientific literacy. Students began using data and logical justification to support their initial ideas, aligning with principles of inquiry-based learning.

Additionally, the collaborative and hands-on nature of PjBL improved students' ability to articulate their reasoning and engage in meaningful discussions. This development

supports Vygotsky's Zone of Proximal Development concept, in which students learn through social interaction and peer dialogue. Clarification skills, as observed in this study, were strengthened through guided tasks and peer feedback, promoting metacognitive reflection and more profound conceptual mastery (Changwong et al., 2018; Karki & Karki, 2024).

The ability to formulate practical and scientifically sound solutions reflects students' progression into higher-order thinking levels, particularly 'creating' in Bloom's Revised Taxonomy. After participating in PjBL activities, students provided actionable and relevant solutions to environmental problems, signifying their capacity to synthesise information, evaluate alternatives, and generate informed decisions (Hollander, 2014).

Overall, these findings are in line with prior research by (Gani et al., 2025; Julianti et al., 2023; Triwahyudianto et al., 2024), who documented similar enhancements in critical thinking by integrating PjBL and digital tools. This study adds to the growing body of evidence supporting the implementation of student-centred, technology-enhanced pedagogies in science education.

Despite the positive outcomes, this study is not without limitations. It involved a relatively small sample of students from a single school and was conducted over a short period. These factors may limit the generalizability and long-term implications of the findings. Future research should consider expanding the participant pool across multiple schools, incorporating control groups, and employing longitudinal designs to assess the lasting impact of PjBL and e-worksheets on students' critical thinking development.

CONCLUSION

This study concludes that Project-Based Learning (PjBL) supported by e-worksheets effectively enhances students' critical thinking skills in environmental education. Through engaging with real-world issues, specifically the problem of fish waste, students demonstrated measurable improvements across five key indicators of critical thinking: problem identification, information evaluation, hypothesis formulation, clarification, and solution generation.

The integration of e-worksheets in PjBL not only provided structured guidance for students but also increased their motivation and participation in classroom activities. By

contextualising scientific concepts and enabling active inquiry, this approach supports the development of higher-order thinking skills necessary for 21st-century learning.

These findings suggest that PjBL assisted by digital tools can be successfully implemented across various educational domains to foster critical thinking and environmental literacy. Future educational practices should consider leveraging interactive, problem-based learning strategies to cultivate deeper student engagement and cognitive development.

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