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The Effectiveness of an Ethno-ESD-Based Science Textbook in Improving Environmental Literacy and Critical Thinking Skills of Junior High School Students on the Topic of Climate Change

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Abstract. Climate change requires educational approaches that enhance students' scientific understanding while developing sustainability competencies and higher-order thinking skills, yet integrating Education for Sustainable Development (ESD) with local wisdom into a single, contextualized resource for junior high school climate change education remains rarely examined. This study investigated the effectiveness of an Ethno-Education for Sustainable Development (Ethno-ESD)-based Science Textbook in improving junior high school students' environmental literacy and critical thinking skills on the topic of climate change. A quantitative, quasi-experimental design with a non-equivalent control group pretest-posttest design was used. Two intact junior high school classes participated: an experimental class taught using the Ethno-ESD-based Science Textbook and a control class taught using the conventional textbook. Data were collected through environmental literacy and critical thinking tests, analyzed using N-Gain analysis, the Independent Samples t-test, and Cohen's d. The experimental class showed greater improvement in environmental literacy (N-Gain = 0.63) and critical thinking skills (N-Gain = 0.62) than the control class (N-Gain = 0.31 for both), with statistically significant differences ($t = 5.873$ and 6.142, $p < 0.05$) and large effect sizes (Cohen's $d = 0.88$ and 0.92, respectively). Integrating ESD principles, climate change education, and local wisdom created meaningful, contextual learning that strengthened students' sustainability competencies and higher-order thinking. The Ethno-ESD-based Science Textbook is therefore an effective, innovative resource for promoting environmental literacy and critical thinking in junior high school science learning, offering a transferable model for other culturally diverse settings.

Keywords: ethno-esd, climate change education, environmental literacy, critical thinking skills, junior high school.

INTRODUCTION

Climate change has become one of the most significant global challenges of the twenty-first century, threatening environmental sustainability, economic stability, and human well-being across the world. The increasing frequency of extreme weather events, prolonged droughts, floods, biodiversity loss, and sea-level rise demonstrates that climate change is no longer a distant threat but an urgent global crisis requiring immediate and collective action. According to the Intergovernmental Panel on Climate Change (Change, 2023), global surface temperatures have increased by approximately 1.1°C above pre-industrial levels, and the world is likely to exceed the 1.5°C warming threshold within the next few decades if greenhouse gas emissions are not substantially reduced. Likewise, the World Meteorological Organization reported that 2023 was the warmest year on record, accompanied by unprecedented concentrations of greenhouse gases and ocean heat content (Organization, 2024). These conditions indicate that climate change is not only an environmental issue but also an educational challenge that requires students to possess adequate knowledge, environmental awareness, and sustainability competencies to address future environmental problems effectively (Change, 2023; Monroe et al., 2022)

Education is increasingly recognized as a strategic instrument for responding to climate change and promoting sustainable development. Climate Change Education (CCE) aims not only to provide scientific understanding regarding environmental changes but also to develop students' environmental awareness, critical thinking skills, problem-solving abilities, and responsible behavior toward the environment. However, recent studies indicate that climate change education remains inadequately implemented in many countries. Teaching practices often emphasize theoretical knowledge and factual understanding while providing limited opportunities for students to critically examine environmental issues and apply scientific concepts to real-world situations. Such conditions may hinder students from developing the competencies required to address sustainability challenges and environmental crises effectively (Cantell et al., 2020; Leal Filho et al., 2023;

Stevenson et al., 2022).

Several strands of prior research are directly relevant to this study. First, studies on climate change education indicate that teaching practices often emphasize theoretical knowledge and factual understanding while providing limited opportunities for students to critically examine environmental issues and apply scientific concepts to real-world situations, which constrains the development of sustainability competencies (Cantell et al., 2020; Leal Filho et al., 2023; Stevenson et al., 2022).

Second, research on environmental literacy shows that students with higher environmental literacy tend to demonstrate stronger environmental awareness, more positive attitudes toward sustainability, and greater engagement in environmentally responsible behavior (Ardoin & Bowers, 2023; Huang & Hsin, 2023; Parmin et al., 2022).

However, recent studies, including those conducted in Indonesia, report that students' environmental literacy remains relatively low, with fragmented knowledge and difficulty connecting scientific concepts to real-life environmental challenges, largely because environmental education is often delivered through conventional, memorization-oriented instruction rather than active exploration and contextual problem-solving sustainability (Cincera et al., 2024; Otto & Pensini, 2017; Su & Yang, 2022).

Third, research on critical thinking indicates that this competency enables students to analyze information objectively, evaluate evidence, formulate arguments logically, and make informed decisions based on scientific reasoning—abilities that are particularly relevant to climate change because the topic involves complex interactions among environmental, social, economic, and cultural dimensions. Nevertheless, many studies report that students' critical thinking skills remain below expectations due to the continued dominance of traditional teaching approaches that emphasize factual knowledge over higher-order thinking and inquiry-based learning (Facione, 2020; Huang & Hsin, 2023; OECD, 2023).

Fourth, Education for Sustainable Development (ESD) has emerged as an influential approach for developing the knowledge, skills, values, and attitudes needed for responsible, sustainability-oriented decision-making, and recent studies show that ESD-based learning contributes positively to students' environmental awareness, sustainability competencies, and higher-order thinking skills (Brundiers et al., 2021; Olsson & Gericke, 2023; Redman & Wiek, 2021)However, the implementation of ESD frequently lacks contextualization with local culture and indigenous knowledge, particularly in culturally diverse countries such as Indonesia.

Fifth, Ethno-Education for Sustainable Development (Ethno-ESD) has emerged as a response to this contextualization gap, integrating ESD with indigenous knowledge, local wisdom, and cultural values, and linking scientific concepts with local environmental practices and traditional ecological knowledge. Previous studies have demonstrated that ethnoscience and local wisdom-based learning positively influence students' environmental awareness, sustainability competencies, and scientific understanding (Aikenhead & Michell, 2023; Kim & Lee, 2024; Nuangchalerm et al., 2023) and that the science textbook, as a central learning resource, plays a key role in operationalizing this integration in the classroom(Huang & Hsin, 2023; Monroe et al., 2022; Parmin et al., 2022)

Despite this body of work, empirical studies examining the effectiveness of Ethno-ESD-based science textbooks remain limited, particularly on the topic of climate change at the junior high school level. Previous studies have predominantly focused either on ESD implementation in science education or on ethnoscience as an independent approach, and relatively few studies have investigated the simultaneous effect of an Ethno-ESD-based learning material on both environmental literacy and critical thinking skills within a single, controlled study. This represents an important research gap, because both competencies are essential for preparing students to address environmental challenges and contribute to sustainable development, yet evidence on whether a single, integrated Ethno-ESD textbook can develop them concurrently—rather than separately—remains scarce.

Building on this gap, this study aims to investigate the effectiveness of an Ethno-ESD-based Science Textbook in improving junior high school students' environmental literacy and critical thinking skills on the topic of climate change. Specifically, the study addresses the following research questions: (1) Is there a significant difference in the improvement of environmental literacy between students taught using the Ethno-ESD-based Science Textbook and those taught using the conventional science textbook? (2) Is there a significant difference in the improvement of critical thinking skills between the two groups? (3) What is the magnitude of the Ethno-ESD-based

Science Textbook's effect on each of these two competencies? The findings of this study are expected to contribute theoretically to the development of sustainability-oriented science education and practically to provide an innovative learning resource that supports climate change education and sustainable development in schools.

METHODS

This study employed a quantitative research approach using a quasi-experimental design with a non-equivalent control group pretest-posttest design to investigate the effectiveness of an Ethno-ESD-based Science Textbook in improving junior high school students' environmental literacy and critical thinking skills on the topic of climate change. This design was selected because it allows researchers to compare learning outcomes between experimental and control groups under natural classroom settings where random assignment is not feasible (Creswell & Creswell, 2018). The experimental group received learning using the Ethno-ESD-based Science Textbook, whereas the control group learned using conventional science textbooks commonly used at school. Both groups were administered pretests before the intervention to determine students' initial competencies and posttests after the intervention to evaluate the effectiveness of the treatment. The research design is presented in Table 1.

Table 1. Non-Equivalent Control Group Pretest-Posttest Design

Group	Pretest	Treatment	Posttest
Experimental Class	O1	X	O2
Control Class	O3	–	O4

Note: O1 and O3 = Pretest; O2 and O4 = Posttest; X = Learning using Ethno-ESD-based Science Textbook.

This study was conducted at a junior high school under Yayasan Perguruan Rakyat (Sekolah Yayasan Perguruan Rakyat). The participants of this study were junior high school students (Grade VII or VIII) at this school who were studying climate change as part of the science curriculum. The sampling technique employed was purposive sampling, based on the following criteria: (1) the school implements the Independent Curriculum (Kurikulum Merdeka); (2) the climate change topic is included in the science syllabus; and (3) the experimental and control classes show relatively similar academic characteristics, as indicated by prior achievement records and teacher input. The study involved two intact classes, each consisting of approximately 30–35 students, resulting in a total sample of 60–70 students. One class was assigned as the experimental group and the other as the control group. This sample size is considered adequate for quasi-experimental research in educational settings to detect meaningful differences between groups (Ary et al., 2020; Gravetter & Wallnau, 2021)

This study involved one independent variable, the Ethno-ESD-based Science Textbook on Climate Change, and two dependent variables: students' environmental literacy and critical thinking skills. The textbook integrates climate science concepts, Education for Sustainable Development (ESD) principles, indigenous knowledge and local wisdom, sustainability values, and student-centered learning activities. Environmental literacy refers to students' capacity to understand environmental issues and demonstrate environmentally responsible behavior, while critical thinking skills refer to students' ability to analyze, evaluate, and solve problems logically and systematically (Huang & Hsin, 2023; UNESCO, 2020).

Two main instruments were employed to measure the dependent variables. First, an environmental literacy test was developed based on the framework proposed by (Ariyatun et al., 2024; Huang & Hsin, 2023; UNESCO, 2020) covering the cognitive, affective, and behavioral dimensions of environmental literacy. Second, a critical thinking skills test was developed based on the framework by (Facione, 2020; OECD, 2023). with indicators consisting of interpretation, analysis, evaluation, inference, explanation, and self-regulation. Both instruments were composed of essay items requiring students to analyze environmental phenomena, evaluate scientific evidence, and formulate arguments related to climate change issues. In addition, an observation sheet was used to document students' engagement, learning activities, and responses during Ethno-ESD learning.

Prior to implementation, all research instruments were validated by experts in science education, educational evaluation, and Education for Sustainable Development (ESD). Content

validity was determined using Aiken's V index, and an instrument was considered valid when the coefficient exceeded 0.75. Subsequently, reliability testing was conducted using Cronbach's Alpha coefficient. The interpretation of reliability followed the criteria proposed by (Hair et al., 2021), where $\alpha > 0.90$ indicates excellent reliability, $\alpha > 0.80$ indicates good reliability, and $\alpha > 0.70$ indicates acceptable reliability (Hair et al., 2021; Tavakol & Dennick, 2011).

Data collection was carried out through three main stages: preparation, implementation, and evaluation. During the preparation stage, a literature review was conducted to identify relevant theories and prior studies on Ethno-ESD, climate change education, environmental literacy, and critical thinking skills. The Ethno-ESD-based Science Textbook and the research instruments were then developed and validated by experts, followed by revisions based on validators' feedback.

During the implementation stage, both the experimental and control classes were administered a pretest to determine students' initial abilities. The experimental class subsequently received instruction using the Ethno-ESD-based Science Textbook, which incorporated local wisdom, sustainability principles, inquiry activities, and climate change projects, while the control class received instruction using the conventional science textbook through teacher-centered instruction. The learning process for both classes was conducted over four to six meetings of equal duration.

During the evaluation stage, posttests were administered to both groups to assess students' environmental literacy and critical thinking skills after the intervention. Observational data were collected throughout the implementation stage to support and triangulate the quantitative findings. The overall research procedure literature review, instrument and textbook development, expert validation, pretest, intervention, posttest, data analysis, and reporting of findings is summarized in Figure 1.

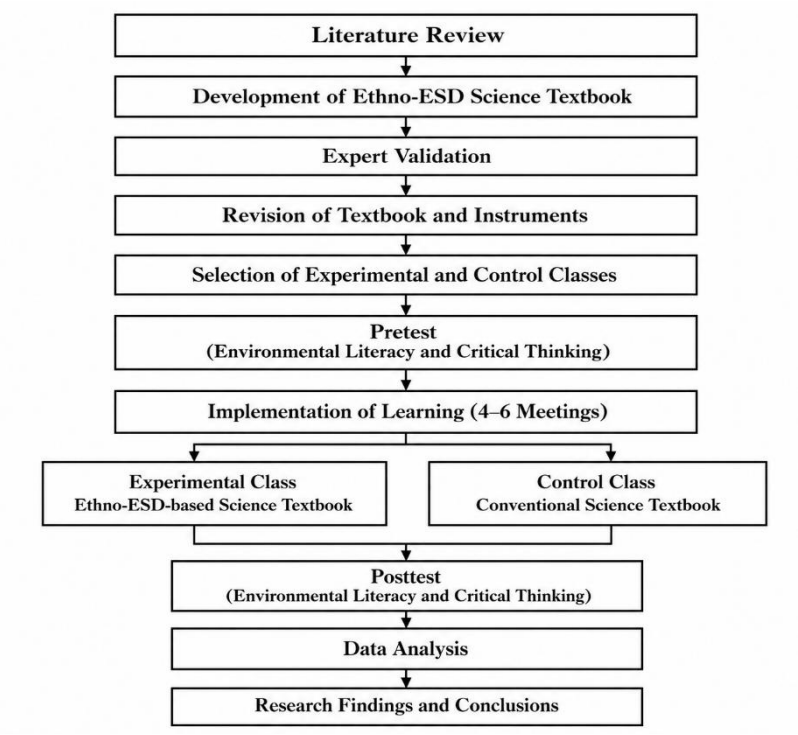

Figure 1. Research Procedure

Data were analyzed using both descriptive and inferential statistics. Descriptive statistics were used to summarize the mean, standard deviation, maximum and minimum scores, and percentage of achievement for each group. Prior to hypothesis testing, the normality of data distribution was examined using the Shapiro-Wilk test, while the homogeneity of variance was tested using Levene's test, to confirm that the assumptions for parametric testing were met. Students' learning improvement was determined by calculating the normalized gain (N-Gain) score, classified into low, moderate, and high categories. The Independent Samples t-test was then conducted to compare posttest scores and N-Gain scores between the experimental and control groups. Finally, Cohen's d effect size was

calculated to determine the magnitude of the Ethno-ESD-based Science Textbook's effect on students' environmental literacy and critical thinking skills (Cohen, 2013; Pallant, 2020). All statistical analyses were performed using IBM SPSS, with a significance level set at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Table 2. Students' Environmental Literacy Scores

Group	Pretest Mean	Posttest Mean	N-Gain	Category
Experimental	58.42	84.67	0.63	Moderate
Control	57.85	71.24	0.31	Moderate

The results of the environmental literacy assessment are presented in Table 2. As shown in Table 2, the experimental class increased from a pretest mean of 58.42 to a posttest mean of 84.67, yielding an N-Gain of 0.63 (moderate category). The control class showed a smaller increase, from 57.85 to 71.24, with an N-Gain of 0.31. This indicates that the gain achieved by the experimental class was approximately twice that of the control class, demonstrating a clearly higher improvement in environmental literacy for students taught using the Ethno-ESD-based Science Textbook.

Table 3. Students' Critical Thinking Skills Score

Group	Pretest Mean	Posttest Mean	N-Gain	Category
Experimental	54.38	82.75	0.62	Moderate
Control	53.94	68.31	0.31	Moderate

The results of students' critical thinking skills are presented in Table 3. As shown in Table 3, the experimental group achieved a posttest mean score of 82.75, compared to 68.31 in the control group, with an N-Gain of 0.62 versus 0.31 a pattern consistent with the gain observed for environmental literacy.

Table 4. Independent Samples t-Test Results

Variable	t-value	Sig. (2-tailed)	Interpretation
Environmental Literacy	5.873	0.000	Significant
Critical Thinking Skills	6.142	0.000	Significant

An Independent Samples t-test was conducted to examine whether the differences between groups were statistically significant. The results are summarized in Table 4. Both significance values were below 0.05, confirming statistically significant differences between the experimental and control groups for both variables.

Table 5. Effect Size of the Ethno-ESD-based Science Textbook

Variable	Cohen's d	Interpretation
Environmental Literacy	0.88	Large
Critical Thinking Skills	0.92	Large

To determine the practical magnitude of the intervention's effect, Cohen's d was calculated. The results are presented in Table 5. Taken together, Tables 2–5 show a consistent pattern: the experimental group outperformed the control group on both dependent variables, the difference was statistically significant, and the magnitude of the effect was large for both environmental literacy and critical thinking skills

The greater improvement in environmental literacy among the experimental class can be explained through constructivist learning theory, which posits that students actively construct knowledge through meaningful interaction with their environment and prior experience. The integration of local wisdom in Ethno-ESD learning enabled students to connect scientific concepts with environmental practices existing in their own

communities, thereby strengthening environmental awareness and sustainability competencies in ways that abstract, decontextualized instruction cannot. This interpretation is consistent with the result, since environmental literacy is not solely a cognitive construct but also involves affective and behavioral dimensions that are best developed through situated, meaningful experience rather than memorization.

The larger gain in critical thinking skills observed in the experimental group is consistent with the view that critical thinking develops through active engagement in interpretation, analysis, evaluation, and problem-solving, rather than through passive reception of factual content (Facione, 2020).The inquiry-based and project-based activities embedded in the Ethno-ESD textbook required students to examine climate-related evidence from scientific, cultural, and social perspectives simultaneously, which plausibly explains why the gain in this multidimensional skill was substantially larger than that of the control group, which relied on conventional, teacher-centered instruction

These findings are consistent with prior research showing that ESD-based learning materials significantly improve environmental literacy, environmental awareness, and pro-environmental behavior (Huang & Hsin, 2023; Monroe et al., 2022; UNESCO, 2020) and that ethnoscience-based instruction similarly enhances students' environmental literacy and sustainability awareness (Parmin et al., 2022; Redman & Wiek, 2021). The pattern observed for critical thinking corroborates (Facione, 2020) and (OECD, 2023), who emphasized that contextual science learning grounded in authentic environmental issues fosters higher-order thinking more effectively than decontextualized instruction. The present study extends this body of work by demonstrating that both competencies can be improved simultaneously within a single, integrated Ethno-ESD textbook, rather than through separate interventions, which is a gap noted in (Bieler & McKenzie, 2024; Kalsoom & Khanam, 2025) and (Wamsler, 2023).

This study contributes to the literature in at least three ways. First, it provides empirical, statistically validated evidence (large effect sizes for both outcomes) for the effectiveness of Ethno-ESD as an integrated educational framework, addressing the previously noted gap between ESD-focused and ethnoscience-focused research strands. Second, it demonstrates that a single textbook-based intervention can simultaneously strengthen a cognitive-affective-behavioral competency (environmental literacy) and a higher-order cognitive skill (critical thinking), suggesting that these two competencies are not independent but may be mutually reinforcing within a contextualized, sustainability-oriented curriculum. Third, by grounding the intervention in Indonesian local wisdom, the study offers a transferable model for contextualizing climate change education with indigenous knowledge in other culturally diverse settings, extending Ethno-ESD theory beyond the cases previously documented by (Aikenhead & Michell, 2023; Kim & Lee, 2024; Nuangchalerm et al., 2023).

Several contextual factors may have influenced the outcomes, including students' motivation, prior environmental experience, classroom interaction, and teachers' pedagogical competence. The quasi-experimental design, while appropriate for classroom-based research, does not fully eliminate the possibility of confounding external influences on student achievement.

CONCLUSION

This study aimed to investigate the effectiveness of an Ethno-ESD-based Science Textbook in improving junior high school students' environmental literacy and critical thinking skills on the topic of climate change. The findings confirm that the textbook is effective: students taught using the Ethno-ESD-based Science Textbook achieved significantly higher gains in both environmental literacy (N-Gain = 0.63 vs. 0.31) and critical thinking skills (N-Gain = 0.62 vs. 0.31) compared to students taught using the conventional textbook, with statistically significant differences ($p < 0.05$) and large effect sizes (Cohen's $d = 0.88$ and 0.92, respectively).

Three major findings can be summarized. First, the Ethno-ESD-based Science Textbook produced a substantially larger improvement in students' environmental literacy than the conventional textbook, reflected in higher posttest scores and N- Gain. Second, the same textbook produced a correspondingly larger improvement in students' critical thinking skills, indicating that the intervention strengthened both competencies concurrently rather than at the expense of one another. Third, both differences were statistically significant and practically meaningful, as confirmed by the Independent Samples t-test and large Cohen's d values, indicating that the observed advantage of the experimental group is unlikely to be due to chance and is educationally meaningful.

This study contributes empirical evidence

that integrating Education for Sustainable Development principles, climate change education, and local wisdom within a single, Ethno-ESD-based Science Textbook can create meaningful and contextual learning experiences that simultaneously enhance students' sustainability competencies and higher-order thinking skills. Theoretically, it strengthens the Ethno-ESD framework by showing its dual impact on affective-behavioral and cognitive outcomes. Practically, it offers teachers, curriculum developers, and policymakers a validated, contextualized instructional resource for climate change education at the junior high school level.

Future studies are encouraged to involve larger and more diverse samples, longer intervention periods, and different educational and cultural contexts to examine the consistency and long-term sustainability of the effects observed in this study. Further research could also explore the differential contribution of specific Ethno-ESD components (e.g., local wisdom content versus inquiry-based activities) to environmental literacy and critical thinking outcomes, as well as potential mediating or moderating variables such as student motivation and teacher pedagogical competence.

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