iejee

International Electronic Journal of Elementary Education
June 2026, Volume 18, Issue 4

Enhancing Elementary Students' Environmental Literacy through an Integrated Contextual Approach: Multimedia Learning Materials, Adiwiyata Values, and Post-Mining Contexts

Ayu Rahayu[a], Sri Widodo[b,*], Esther Sanda Manapa[c]

Received : 18 March 2026
Revised : 15 May 2026
Accepted : 17 June 2026
DOI : 10.26822/iejee.2026.458

[a] Ayu Rahayu, Department of Environmental Science, Hasanuddin University, Makassar, Indonesia and Faculty of Teacher Training and Education, Sembilanbelas November Kolaka University, Kolaka, Indonesia.
E-mail: yuayurahayu19@gmail.com
ORCID: https://orcid.org/0000-0002-7429-8001

[b,*] **Corresponding Author:** Sri Widodo, Department of Mining Engineering, Hasanuddin University, Makassar, Indonesia.
E-mail: sriwidodo@unhas.ac.id
ORCID: https://orcid.org/0000-0001-8613-9107

[c] Esther Sanda Manapa, Graduate School, Hasanuddin University, Makassar, Indonesia.
E-mail: esmanapa@gmail.com
ORCID: https://orcid.org/0000-0002-7451-1896

Abstract

Environmental literacy in elementary education is critical for shaping students' long-term environmental knowledge, attitudes, and behavior. However, instructional approaches that systematically integrate digital learning, environmental values, and authentic local contexts remain limited. This study aimed to evaluate the effectiveness of the Integrated Contextual Digital Environmental Learning Approach (ICDELA), a framework combining multimedia learning, Adiwiyata environmental values, and post-mining environmental contexts within a unified instructional design. A quasi-experimental non-equivalent control group design was employed with 110 fifth-grade students from elementary schools in mining-affected areas of Southeast Sulawesi, Indonesia. Environmental literacy was measured across three dimensions: environmental understanding, environmental attitude, and pro-environmental behavior. Data were analyzed using paired-sample and independent-sample t-tests, along with Cohen's d effect size. The results indicated that students in the ICDELA group achieved significantly higher post-test scores than those in the conventional learning group ($p < .001$). Effect size analysis revealed a large improvement in environmental understanding ($d = 0.81$) and moderate improvements in environmental attitude ($d = 0.54$) and pro-environmental behavior ($d = 0.52$). These findings highlight the novelty of ICDELA as an integrated framework linking multimedia-supported learning, value-based environmental education, and authentic local environmental issues, demonstrating its effectiveness in fostering environmental literacy in elementary education.

Keywords:

Environmental Literacy, Multimedia Learning Materials, Adiwiyata Values, Post-Mining Context, Elementary Education

KURA group
www.iejee.com
ISSN: 1307-9298

2026 Published by KURA Education & Publishing. This is an open access article under the CC BY-NC- ND license. (https://creativecommons.org/licenses/by/4.0/)

Introduction

Environmental degradation has become one of the most pressing global challenges in recent decades, driven by rapid industrialization, urban expansion, and intensive resource exploitation, including mining activities. These processes contribute to land degradation, water contamination, biodiversity loss, and ecosystem disruption, threatening both ecological sustainability and human well-being (Ali & Rahman, 2024; Inbit et al., 2024; Pooja, 2024). In response, education is increasingly recognized as a key strategy for fostering environmentally responsible citizens capable of understanding and addressing environmental problems (UNESCO, 2021). Consequently, environmental education has become an essential component of school curricula worldwide.

A central goal of environmental education is the development of environmental literacy (EL), which encompasses environmental knowledge, attitudes, and responsible behavior (Hollweg et al., 2011). Developing EL at the elementary level is particularly critical, as early learning experiences shape students' long-term environmental awareness and behavior (Ainin & Asafri, 2023; Collado et al., 2020). However, environmental learning in elementary schools is often delivered through abstract and textbook-based approaches, limiting students' ability to connect scientific concepts with real environmental issues in their surroundings (El Batri et al., 2019; Escobar et al., 2024). This disconnect can reduce engagement and hinder the application of environmental knowledge in real-life contexts.

To address these limitations, contextual environmental learning has been widely recommended as it links academic content with authentic environmental issues, making learning more meaningful and relevant (Collado et al., 2020; Johnson, 2002). In Indonesia, environmental education is further supported by the Adiwiyata program, which emphasizes the integration of environmental values into school culture and learning practices (Adawiah, 2019; Juraid et al., 2019; Utomo et al., 2023). In parallel, advances in educational technology have enabled the use of multimedia learning materials that enhance students' engagement and conceptual understanding through visual and interactive representations (Chen et al., 2025; Gorai, 2024; Pramesworo et al., 2025).

Despite these developments, prior research tends to address these components separately. Studies on Adiwiyata-based education often focus on specific competencies or school culture rather than systematically integrating environmental values into instructional design. Multimedia learning research in elementary education largely emphasizes general academic outcomes, with limited attention to environmental literacy. Similarly, contextual environmental learning frequently relies on global issues, while authentic local environmental problems remain underutilized as learning resources (Sarbaini et al., 2022; Stringer et al., 2022).

This fragmentation reveals a critical gap in environmental education research: the lack of a coherent instructional framework that simultaneously integrates multimedia learning, environmental values, and authentic local environmental contexts to support the development of environmental literacy in elementary education. Moreover, few studies have explored how such integration can be operationalized within structured learning processes and empirically evaluated.

One promising yet underutilized contextual resource is post-mining environments. These landscapes provide observable examples of environmental degradation and restoration, illustrating the impact of human activities on ecosystems while aligning closely with elementary science concepts such as ecosystems, biodiversity, and environmental change (Emekwisia et al., 2025; Measham et al., 2024; Pagouni et al., 2024; Talukder et al., 2024). However, their potential as contextual learning resources in elementary environmental education remains largely unexplored.

To address these gaps, this study proposes the Integrated Contextual Digital Environmental Learning Approach (ICDELA), a structured instructional framework that systematically integrates three key components: multimedia-supported conceptual learning, Adiwiyata-based environmental values, and authentic post-mining environmental contexts. Unlike previous approaches that treat these elements independently, ICDELA organizes them into a coherent learning process that simultaneously supports cognitive understanding, value formation, and behavioral development.

This study contributes to the literature in three ways. First, it advances environmental education theory by conceptualizing ICDELA as an integrated framework that bridges digital learning, value-based education, and contextual environmental learning. Second, it provides empirical evidence of the effectiveness of this approach in enhancing elementary students' environmental literacy across cognitive, affective, and behavioral dimensions. Third, it offers practical implications for educators by demonstrating how digital media and local environmental issues can be systematically incorporated into classroom instruction.

Accordingly, this study aims to evaluate the effectiveness of the Integrated Contextual Digital Environmental Learning Approach (ICDELA) in enhancing elementary students' environmental literacy.

Literature Review

To support the research objectives outlined in the introduction, this study develops its conceptual foundation based on three key concepts: environmental literacy, multimedia learning, and contextual environmental learning. Rather than treating these concepts independently, this review synthesizes prior research to identify limitations and establish the basis for the proposed ICDELA framework.

Environmental Literacy in Elementary Education

Environmental literacy (EL) is widely recognized as a central goal of environmental education, particularly at the elementary level where students begin to develop their understanding of human–environment relationships. EL encompasses the knowledge, attitudes, and behaviors required to understand environmental systems and act responsibly toward sustainability (Hollweg et al., 2011). Early development of these competencies is critical, as elementary education represents a formative stage shaping long-term environmental awareness (Ainin & Asafri, 2023; Naila et al., 2026).

In this study, EL is conceptualized through three dimensions: environmental understanding (EU), environmental attitude (EA), and pro-environmental behavior (PEB). These dimensions reflect the cognitive, affective, and behavioral components of environmental learning (Nugraha et al., 2022). However, empirical studies reveal an imbalance in practice. Many environmental education programs prioritize conceptual knowledge while giving less attention to the development of environmental attitudes and behaviors (Suratmi et al., 2024). As a result, students may acquire knowledge without translating it into responsible environmental actions.

This inconsistency highlights a key limitation in the literature: while EL is theoretically multidimensional, instructional practices often fail to integrate these dimensions holistically. Therefore, there is a need for learning approaches that explicitly connect knowledge, values, and behavior within a unified instructional process. This gap underpins the importance of designing integrated frameworks, such as ICDELA, that address all dimensions of environmental literacy simultaneously.

Multimedia Learning in Elementary Education

The integration of digital technologies has expanded opportunities for enhancing learning in elementary education. Multimedia learning materials, which combine visual and verbal representations, have been shown to improve students' conceptual understanding and engagement (Chen et al., 2025; Pramesworo et al., 2025). According to multimedia learning theory, effective learning occurs when information is processed through both visual and verbal channels in ways that support cognitive integration and reduce overload (Mayer & Moreno, 2010; Mayer, 2024).

A substantial body of research demonstrates that multimedia environments can increase motivation, engagement, and learning outcomes in primary education (Cohen & McIntyre, 2024; Gorai, 2024). However, findings across studies also indicate variability in effectiveness. While some studies report significant improvements in conceptual understanding, others suggest that technological features alone do not guarantee meaningful learning unless they are supported by appropriate pedagogical design (Purnomo, 2024).

This inconsistency suggests that multimedia learning is most effective when integrated within structured instructional frameworks rather than used as a standalone tool. Furthermore, existing studies largely focus on general academic achievement, with limited attention to environmental literacy as a multidimensional outcome. Thus, there remains a gap in understanding how multimedia learning can be purposefully designed to support not only conceptual understanding but also environmental attitudes and behaviors. Addressing this gap requires an approach such as ICDELA, which embeds multimedia learning within a broader pedagogical structure linked to environmental values and real-world contexts.

Contextual Environmental Learning and Environmental Values

Contextual learning has been widely recognized as an effective approach for connecting academic content with real-life experiences. In environmental education, this approach enables students to understand environmental issues as concrete problems within their local surroundings rather than abstract concepts (Johnson, 2002). Research shows that contextual learning can enhance students' understanding and engagement by linking scientific knowledge with authentic environmental situations (Collado et al., 2020; Gal, 2025).

In Indonesia, the integration of environmental values is further supported by the Adiwiyata Program (Peduli dan Berbudaya Lingkungan Hidup di Sekolah - PBLHS), which promotes environmentally responsible behavior through principles such as responsibility, cooperation, and sustainability (Ministry of Environment and Forestry, 2019). Previous studies indicate that incorporating these values can strengthen students' environmental attitudes and awareness (Fazira & Ramadan, 2023; Muflihaini et al., 2020; Rushayati et al., 2023; Safrizal et al., 2022). However, these efforts are often implemented at the level of school culture or isolated activities rather than being systematically embedded in instructional design.

Another limitation concerns the types of contextual issues used in environmental learning. Many studies focus on global environmental problems, while local environmental contexts, which may offer more meaningful and relatable learning experiences, remain underutilized (Sarbaini et al., 2022). Post-mining environments, for example, provide concrete and observable cases of environmental degradation and restoration, yet their potential as learning resources in elementary education has received limited attention.

These gaps indicate that contextual environmental learning and value-based education are often applied separately or inconsistently. There is a need for instructional approaches that systematically integrate environmental values with authentic local contexts in a structured learning process. This need aligns with the ICDELA framework, which combines contextual environmental exploration with value-based learning to strengthen both understanding and responsible behavior.

Conceptual Framework of the Study

Based on the preceding literature, meaningful environmental learning is most effective when conceptual understanding, environmental values, and authentic environmental contexts are systematically integrated within a coherent instructional process. In this study, these elements are operationalized through the Integrated Contextual Digital Environmental Learning Approach (ICDELA).

ICDELA is conceptualized as an instructional framework that integrates three core components:

1. Multimedia learning materials, which support students' conceptual understanding through visual and interactive representations;
2. Adiwiyata environmental values, which foster environmental awareness and responsibility; and
3. Authentic environmental contexts, particularly post-mining environments, which connect learning content with real-world environmental issues.

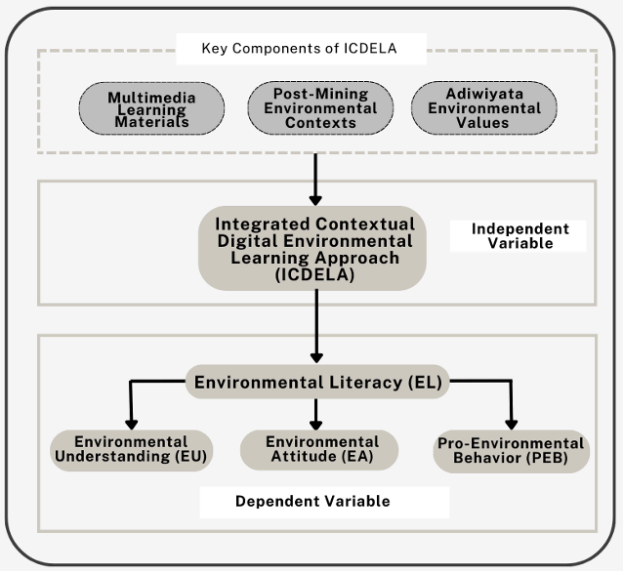
Rather than functioning independently, these components interact synergistically within ICDELA, where multimedia supports conceptual understanding, contextual learning enhances relevance, and environmental values guide reflection and behavioral orientation. This integration enables a learning process that simultaneously supports cognitive, affective, and behavioral development.

Figure 1 illustrates the structural relationships among variables in this study. The three components serve as the foundational elements of ICDELA, which functions as the independent variable. Through its implementation, ICDELA is expected to influence students' environmental literacy (EL) as the dependent variable, reflected in three dimensions: environmental understanding (EU), environmental attitude (EA), and pro-environmental behavior (PEB).

The framework assumes that integrating multimedia-supported learning, value-based reflection, and contextual environmental exploration will lead to a more comprehensive learning experience, leading to improvements across all dimensions of environmental literacy.

This conceptual model provides the basis for examining the effectiveness of ICDELA in comparison with conventional learning approaches.

Figure 1:
Conceptual Framework of the Study



This framework guides the formulation of the research hypotheses examining the effects of ICDELA on students' environmental understanding, environmental attitudes, and pro-environmental behavior.

Research Hypotheses

Based on the conceptual framework and conceptual model of this study, the following hypotheses are formulated:

H1: Students who learn using the ICDELA approach will demonstrate significantly higher environmental understanding (EU) than students who learn through conventional learning approaches (CLA).

H2: Students who learn using the ICDELA approach will demonstrate significantly higher environmental attitudes (EA) than students who learn through conventional learning approaches (CLA).

H3: Students who learn using the ICDELA approach will demonstrate significantly higher pro-environmental behavior (PEB) than students who learn through conventional learning approaches (CLA).

Method

Research Design

This study employed a quasi-experimental design with a non-equivalent control group to examine the effectiveness of the Integrated Contextual Digital Environmental Learning Approach (ICDELA) in improving elementary students' environmental literacy (Creswell, 2012). This design was selected not only due to the impracticality of random assignment in natural classroom settings, but also because it allowed for the comparison of instructional interventions under authentic educational conditions while maintaining ecological validity.

In school-based research, intact classes are typically pre-assigned, making randomization difficult to implement without disrupting the instructional process. However, the non-equivalent control group design remains appropriate when combined with strategies to ensure group comparability and control potential confounding variables. Baseline equivalence between the experimental and control groups was assessed through pre-test measures using independent-sample t-tests.

The research design consisted of two groups: an experimental group and a control group. Both groups completed a pre-test prior to the intervention and a post-test after the instructional period. The pre-test served to determine initial equivalence and to control for pre-existing differences in environmental literacy.

To enhance internal validity and minimize potential confounding variables, several measures were implemented. First, both groups followed the same curriculum content, learning objectives, and instructional duration, ensuring consistency in the scope of learning. Second, classroom teachers in both groups were briefed and coordinated prior to the intervention to ensure a shared understanding of the instructional procedures and learning goals. Third, both groups followed the same instructional sequence (introduction, exploration, discussion, and reflection), with differences limited to the instructional approach and learning materials.

To reduce teacher-related effects, the intervention was conducted by regular classroom teachers rather than external instructors, preserving natural teaching conditions while avoiding variability introduced by unfamiliar teaching personnel. In addition, coordination sessions were conducted to align instructional delivery and reduce instructional variability while ensuring consistency across groups.

The experimental group received instruction through ICDELA, which integrates multimedia learning materials, Adiwiyata environmental values, and contextual post-mining environmental issues. In contrast, the control group was taught using the Conventional Learning Approach (CLA), relying on standard textbook-based instruction without integrated multimedia or contextual components.

The structure of the non-equivalent control group design used in this study is presented in Figure 2.

Participants

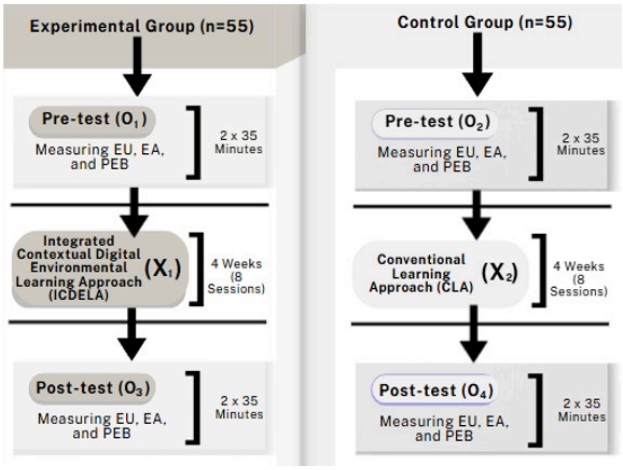
The participants were 110 fifth-grade students from two public elementary schools located in mining-affected areas of Southeast Sulawesi, Indonesia. The students were aged between 10 and 11 years and were enrolled in regular science learning programs. The sample consisted of 56 female and 54 male students.

Intact classroom sampling was employed, as classes had been administratively formed prior to the study. Four existing classes from the two schools participated in the research. In each school, one class was assigned to the experimental group and one class to the control group, resulting in two experimental classes (n = 55) and two control classes (n = 55). The assignment of classes to groups was conducted at the class level within each school, where one intact class was designated as the experimental group and the other as the control group to maintain the natural classroom structure.

Both schools followed the same national curriculum and had comparable academic environments, which helped ensure similar learning backgrounds among students prior to the intervention. All participants had prior experience using digital media in classroom learning; however, they had not previously engaged in environmental learning activities that integrated Adiwiyata environmental values with post-mining environmental contexts.

Ethical approval was obtained from the institutional research ethics committee, and permission was granted by the participating schools. Student participation was voluntary, and all data were anonymized to ensure confidentiality.

Figure 2:
Nonequivalent Control Group Pre-Test–Post-Test Design



Learning Implementation Procedure

The instructional intervention was conducted over four weeks and consisted of eight sessions integrated into the regular science learning schedule. Each session followed a structured sequence: introduction, concept exploration, discussion, and reflection. Both groups completed a pre-test prior to the intervention and a post-test after the final session to assess changes in students' environmental literacy.

All learning activities were facilitated by the regular classroom teachers. Prior to the intervention, a coordination meeting was conducted to ensure consistency in instructional procedures, learning objectives, and implementation across both groups. This process helped minimize instructional bias and ensured that differences in learning outcomes could be attributed to the instructional approach rather than variations in teaching practices.

The experimental group was taught using the Integrated Contextual Digital Environmental Learning Approach (ICDELA), implemented as a structured integration of multimedia learning, environmental values, and contextual post-mining issues. Across the eight sessions, students engaged with environmental topics progressively, beginning with human-induced environmental changes and advancing toward post-mining environmental conditions, environmental impacts, and restoration efforts.

Instructional activities in the experimental group were designed to emphasize three integrated elements:

1. Multimedia-supported learning through an interactive digital flipbook containing images, videos, animations, and contextual case studies;
2. Contextual exploration of local post-mining environmental issues to connect scientific concepts with real-world conditions; and
3. Reflective activities incorporating Adiwiyata environmental values to promote environmental awareness and responsible behavior.

These elements were embedded within each session to support students' cognitive, affective, and behavioral development.

In contrast, the control group followed the Conventional Learning Approach (CLA), which relied on standard textbook-based instruction and teacher explanations without the integration of multimedia, structured environmental values, or contextual local issues.

Although both groups followed the same instructional stages and covered the same content, they differed in their instructional approach: the experimental group used multimedia-based learning, authentic post-mining environmental contexts, and structured value integration, whereas the control group relied on conventional teacher-centered instruction without these components.

A summary of the key instructional differences between the two groups was presented in Table 1.

Table 1:
Summary of instructional differences between the experimental and control groups

Component	Experimental Group (ICDELA)	Control Group (CLA)
Learning media	Interactive multimedia digital flipbook	Printed textbook
Environmental context	Local post-mining environmental issues	General environmental examples
Environmental values	Adiwiyata environmental values integrated into learning activities	Environmental values not explicitly integrated
Learning activities	Multimedia exploration, contextual discussion, and reflection	Teacher explanation and textbook-based discussion

Research Instruments

Environmental literacy (EL) in this study was measured across three dimensions: environmental understanding (EU), environmental attitude (EA), and pro-environmental behavior (PEB), following the framework proposed by Hollweg et al. (2011). These dimensions represent the cognitive, affective, and behavioral components of environmental literacy.

The instruments were adapted from environmental learning materials in the module My Beloved Earth, My Poor Earth (Bumiku Sayang Bumiku Malang), which addresses environmental degradation, conservation, and environmental responsibility. The adaptation process involved three stages:

1. Content alignment, where items were adjusted to match fifth-grade learning objectives;
2. Contextualization, where items were modified to reflect environmental issues related to post-mining contexts; and
3. Language simplification, to ensure clarity and suitability for elementary school students.

The Environmental Understanding (EU) dimension was measured using a 10-item constructed-response test in the form of short-answer questions. Each item was designed to assess students' understanding of environmental concepts, including definitions of the environment, causes and impacts of environmental degradation, and conservation practices. Responses were evaluated using an analytic scoring rubric with a scale ranging from 0 to 2, ensuring consistency and objectivity in scoring.

Each item was assigned a specific weight based on its level of complexity, contributing proportionally to the total score. The distribution of item weights was as follows: Item 1 (10%), Item 2 (8%), Item 3 (10%), Item 4 (8%), Item 5 (10%), Item 6 (10%), Item 7 (8%), Item 8 (8%), Item 9 (14%), and Item 10 (14%). The weighting scheme was designed to reflect varying levels of cognitive demand across items.

Sample item:

"Explain what is meant by the environment and provide one example from your surroundings."

Scoring rubric:

2 = Accurate definition of the environment and one relevant example

1 = Either an accurate definition or a relevant example

0 = Both incorrect or no response

This scoring approach allowed for partial credit and captures variations in students' conceptual understanding more effectively than dichotomous scoring. All scores were subsequently converted into percentage scores prior to analysis.

The EA dimension was measured using a 10-item questionnaire based on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The items assessed environmental awareness, concern, and responsibility.

Sample item:

"I care about the condition of the environment around me."

The PEB dimension was measured using a 10-item self-report questionnaire on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The items captured students' reported engagement in environmentally responsible behaviors.

Sample item:

"I help keep the environment clean at home or at school."

The framework of the environmental literacy instrument is presented in Table 2, which outlines the constructs and indicators used to measure each dimension.

Table 2:
Environmental Literacy Measurement Framework

Construct	Indicators	
Environmental Understanding (EU)	EU1:	Understanding basic environmental concepts and environmental changes occurring on Earth
	EU2:	Identifying causes of environmental changes and environmental degradation caused by natural events and human activities
	EU3:	Explaining the impacts of environmental changes and environmental degradation on human life and environmental conditions
Environmental Attitude (EA)	EA1:	Environmental awareness toward environmental problems
	EA2:	Sense of responsibility for protecting the environment
	EA3:	Willingness to support environmental sustainability and conservation efforts
Pro-Environmental Behavior (PEB)	PEB1:	Waste management practices in daily life
	PEB2:	Resource conservation behaviors (water and energy)
	PEB3:	Participation in environmental protection activities.

Instrument Validity and Reliability

To ensure the validity and reliability of the research instruments, a series of validation procedures was conducted prior to the main data collection.

Content validity was established through expert judgment involving three experts: a lecturer in science education, a specialist in elementary education, and an experienced fifth-grade classroom teacher. Each expert evaluated the relevance, clarity, and representativeness of each item in relation to the three dimensions of environmental literacy (EU, EA, and PEB). The evaluation was conducted using a structured rating form based on a four-point relevance scale. The Content Validity Index (CVI) was calculated at the item level (I-CVI), and all items achieved values above the acceptable threshold of 0.80, indicating satisfactory content validity. Based on expert feedback, several

items were revised to improve clarity, linguistic appropriateness, and alignment with the targeted constructs.

Following content validation, the instruments were pilot tested with 33 fifth-grade students to assess reliability. The environmental understanding (EU) test, consisting of constructed-response items scored on a 0–2 scale, was analyzed using Cronbach's alpha, yielding a reliability coefficient of 0.85. The environmental attitude (EA) and pro-environmental behavior (PEB) questionnaires were also analyzed using Cronbach's alpha, resulting in coefficients of 0.88 and 0.84, respectively. These values indicate good to high internal consistency, suggesting that the instruments are reliable for measuring the intended constructs (Field, 2018).

Data Analysis

Data analysis aimed to examine the effectiveness of the Integrated Contextual Digital Environmental Learning Approach (ICDELA) in improving students' environmental literacy across three dimensions: environmental understanding (EU), environmental attitude (EA), and pro-environmental behavior (PEB).

Prior to hypothesis testing, statistical assumptions for parametric analysis were assessed. Normality of data distribution was examined using the Shapiro–Wilk test, while homogeneity of variances between groups was evaluated using Levene's test. Data were considered to meet parametric assumptions when $p > .05$. In addition, baseline equivalence between the experimental and control groups was tested using an independent-samples t-test on pre-test scores.

To evaluate the effectiveness of the intervention, two main analyses were conducted. First, a paired-samples t-test was used to examine differences between pre-test and post-test scores within each group, allowing for the assessment of within-group changes over time. Second, an independent-samples t-test was employed to compare post-test scores between the ICDELA and Conventional Learning Approach (CLA) groups, enabling the evaluation of differences in learning outcomes between instructional approaches.

To complement significance testing, effect sizes were calculated using Cohen's d to determine the magnitude of the intervention effects. Effect sizes were interpreted as small (0.20), medium (0.50), and large (≥ 0.80), following conventional benchmarks.

All statistical analyses were conducted using IBM SPSS software, with the level of significance set at $\alpha = .05$, in accordance with APA reporting standards (Field, 2018).

Result

Descriptive statistics for pre-test and post-test scores are presented in Figures 3 and 4. Overall, both groups showed improvements across all dimensions of environmental literacy (EL); however, the experimental group demonstrated consistently greater gains than the control group.

Figure 3:

Comparison of Pre-test and Post-test Mean Scores and Standard Deviations for EU

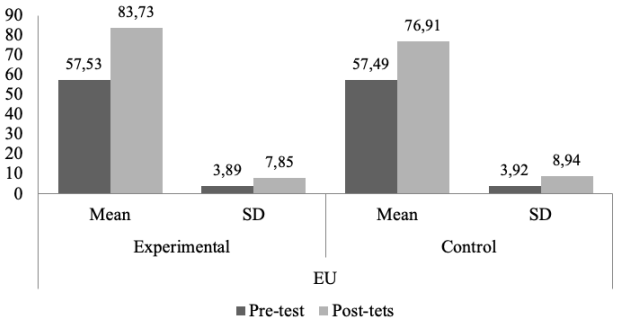
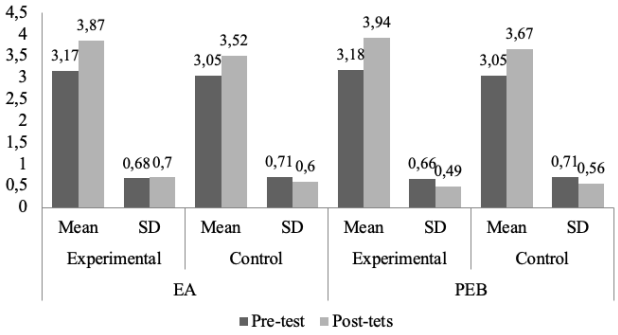


Figure 4:

Comparison of Pre-test and Post-test Mean Scores and Standard Deviations for EA and PEB



Prior to hypothesis testing, assumptions for parametric analysis were examined. The Shapiro–Wilk test indicated that all data were normally distributed ($p > .05$), and Levene's test confirmed homogeneity of variances across groups ($p > .05$), supporting the use of parametric statistical tests (see Tables 3 and 4).

Table 3:

Normality Test

Variable	Group	Pre-test (p)	Post-test (p)
EU	Experimental	.149	.108
EU	Control	.123	.369
EA	Experimental	.142	.166
EA	Control	.375	.069
PEB	Experimental	.205	.131
PEB	Control	.375	.825

Table 4:
Homogeneity Test

Variable	*p*
EU	.352
EA	.112
PEB	.193

Paired-samples t-tests revealed significant improvements from pre-test to post-test within both groups across all variables (Table 5). While these results indicate that learning occurred in both conditions, they do not differentiate the effectiveness of the instructional approaches.

Table 5:
Paired Sample t-Test

Variable	Group	*t*	*p*
EU	Experimental	23.00	< .001
EU	Control	15.45	< .001
EA	Experimental	7.99	< .001
EA	Control	11.39	< .001
PEB	Experimental	9.56	< .001
PEB	Control	6.69	< .001

To assess baseline equivalence, independent-samples t-tests on pre-test scores showed no significant differences between the experimental and control groups in environmental understanding (EU), environmental attitude (EA), and pro-environmental behavior (PEB) (Table 6). This confirms that both groups had comparable initial levels of environmental literacy.

Post-test comparisons, however, revealed statistically significant differences favoring the experimental group across all dimensions: EU ($t = 4.25$, $p < .001$), EA ($t = 2.82$, $p = .006$), and PEB ($t = 2.72$, $p = .008$) (Table 6). These findings indicate that the ICDELA approach was more effective than the conventional learning approach in enhancing students' environmental literacy.

Table 6:
Independent Samples t-Test

Variable	Pre-test		Post-test	
	t	p	t	p
EU	0.049	.961	4.25	< .001
EA	0.969	.335	2.83	.006
PEB	1.000	.320	2.72	.008

To further evaluate the magnitude of these differences, effect size analysis using Cohen's d was conducted (Table 7). The results showed a large effect for environmental understanding (d = 0.81) and moderate effects for environmental attitude (d = 0.54) and pro-environmental behavior (d = 0.52). These findings suggest that ICDELA had a particularly strong impact on students' conceptual understanding, while also producing meaningful improvements in affective and behavioral dimensions.

Table 7:
Results of Effect Size Calculation

Variable	Cohen's d	Interpretation
EU	0.81	Large
EA	0.54	Medium
PEB	0.52	Medium

From a practical perspective, the moderate effect sizes for EA and PEB indicate that the integration of environmental values and contextual learning experiences contributed to shaping students' attitudes and reported behaviors, although changes in these domains may require longer-term interventions. In contrast, the large effect observed in EU suggests that multimedia-supported and context-based learning can substantially enhance students' comprehension of environmental concepts within a relatively short instructional period.

Discussion

The findings of this study demonstrate that the Integrated Contextual Digital Environmental Learning Approach (ICDELA) was more effective than the conventional learning approach in enhancing students' environmental literacy across cognitive, affective, and behavioral dimensions. Rather than merely indicating statistical differences, these results suggest that the effectiveness of ICDELA lies in how it systematically integrates multimedia learning, contextual environmental issues, and value-based reflection into a coherent instructional process.

A key explanation for this effectiveness is the alignment between cognitive processing and contextual relevance within the ICDELA framework. The large effect observed in environmental understanding indicates that multimedia-supported learning enabled students to construct clearer mental models of environmental processes, thereby providing empirical support for Hypothesis 1. This finding is consistent with multimedia learning theory, as articulated by Mayer (2024), which posits that the integration of visual and verbal representations enhances conceptual understanding. Empirical studies further support this perspective. For instance, Ramadhani et al. (2024) found that interactive multimedia significantly improves students' conceptual comprehension and motivation, while Buchanan et al. (2019) and Lowan-Trudeau (2023) highlighted the role of digital technologies in facilitating interactive exploration of environmental issues.

However, unlike these studies, which often examine digital learning in isolation, the present findings indicate that multimedia learning becomes more impactful when embedded within authentic environmental contexts. The integration of post-mining environmental issues provided students with concrete examples of environmental change, enabling them to

connect abstract concepts with real-world situations. This supports the contextual learning perspective proposed by Johnson (2002), which emphasizes that learning becomes more meaningful when linked to learners' lived experiences.

The moderate improvements observed in environmental attitudes and pro-environmental behavior suggest a different learning dynamic. While conceptual understanding can develop relatively quickly, changes in attitudes and behavior typically require sustained engagement, reflection, and personal relevance. The improvement in environmental attitudes indicates that students developed greater awareness and concern toward environmental issues through reflective and value-based activities, consistent with the expectations outlined in Hypothesis 2. Furthermore, the observed improvement in pro-environmental behavior suggests that students began to translate their understanding and attitudes into intended actions, in line with the predictions of Hypothesis 3. The integration of Adiwiyata environmental values within discussion and reflection stages appears to have facilitated this process by encouraging students to connect environmental knowledge with ethical considerations and everyday practices. This finding aligns with the environmental literacy framework proposed by Hollweg et al. (2011), which conceptualizes environmental literacy as the integration of cognitive, affective, and behavioral components.

Support for these findings can also be seen in prior research on environmental literacy and contextual learning. Studies by Hardianti et al. (2025), Lin & Ardoin (2023), and Ninsiana et al. (2024) indicate that digital learning media facilitate access to environmental information and promote discussion, thereby supporting environmental literacy development. Meanwhile, research on contextual environmental learning by Ashlan & Firayani (2025), Ayotte-Beaudet et al. (2023), Basile & White, (2000), and Collado et al. (2020) demonstrates that real-world environmental contexts enhance students' environmental awareness and behavioral engagement.

Nevertheless, these studies tend to focus on either digital learning or contextual approaches separately. The present study extends this body of knowledge by demonstrating that their integration within a structured instructional framework produces more comprehensive outcomes across all dimensions of environmental literacy. This suggests that the effectiveness of environmental education may depend less on individual instructional strategies and more on how these strategies are systematically combined.

The instructional processes underlying these outcomes can be further illustrated through the learning sequence implemented in ICDELA. As shown in Figure 5, the digital learning materials used in Session 4 exemplify how multimedia elements, contextual environmental issues, and reflective activities are integrated within a single learning cycle. During the introduction stage, students are exposed to real-world environmental problems through video-based materials, which activate prior knowledge and situate learning in a meaningful context. The exploration stage then supports conceptual understanding through multimedia explanations of environmental processes, while the discussion stage encourages collaborative analysis of environmental issues. Finally, the reflection stage facilitates the internalization of environmental values and the translation of knowledge into behavioral intentions. This structured integration explains how ICDELA simultaneously supports cognitive, affective, and behavioral learning outcomes.

Despite these positive findings, alternative interpretations should be considered. The improved performance of the experimental group may not be solely attributable to the integrated design of ICDELA, but also to factors such as the novelty of digital learning materials or increased student engagement due to multimedia use. Additionally, the relatively short duration of the intervention may explain why improvements in environmental attitudes and behavior were moderate rather than large. These considerations suggest that while ICDELA is effective, its long-term impact requires further investigation through extended interventions and longitudinal designs.

At a theoretical level, this study contributes to environmental education by supporting a more holistic and process-oriented model of environmental literacy development. The findings indicate that cognitive, affective, and behavioral dimensions are interconnected but may develop at different rates. The stronger effect observed in environmental understanding compared to attitudes and behavior highlights the importance of designing learning experiences that provide sustained opportunities for reflection and action. This suggests that environmental literacy frameworks should emphasize the integration of learning processes rather than treating its components as separate outcomes.

Overall, the findings indicate that the effectiveness of ICDELA is not merely due to the inclusion of digital media or contextual content, but to the structured integration of conceptual learning, environmental values, and real-world environmental contexts within a unified instructional process. This integrated approach enables students not only to understand environmental issues more deeply but also to develop meaningful connections and responsible behavioral intentions toward environmental sustainability.

Figure 5:
ICDELA digital learning materials for Session 4



Educational Implications

The findings of this study highlight the importance of designing environmental learning experiences that integrate cognitive, affective, and contextual dimensions. Environmental education should move beyond knowledge transmission by incorporating structured opportunities for students to engage with real-world environmental issues, reflect on environmental values, and apply their learning in everyday contexts.

Furthermore, the results suggest that digital learning technologies are most effective when they are pedagogically integrated within a broader instructional framework. Multimedia tools should therefore be used not merely as presentation media, but as part of a learning design that supports deeper cognitive processing and meaningful engagement.

The use of local environmental contexts, such as post-mining environments, also appears to enhance the relevance of learning and strengthen students' connection to environmental issues. This finding indicates that contextualization is a critical factor in promoting meaningful environmental learning and fostering long-term environmental responsibility.

Limitations and Future Research

Despite its contributions, this study has several limitations. First, the sample was limited to two schools within a specific regional context, which may restrict the generalizability of the findings. Future studies should involve more diverse educational settings to examine the broader applicability of the ICDELA framework.

Second, the duration of the intervention was relatively short. Although significant improvements were observed, longer-term studies are needed to better understand how environmental attitudes and behaviors develop over time and whether the effects of ICDELA are sustained.

Third, pro-environmental behavior was measured using self-report instruments, which may be influenced by social desirability bias. Future research could incorporate observational methods or performance-based assessments to obtain more objective measures of students' environmental behavior.

Future research may also explore how ICDELA can be adapted to different subject areas and educational levels, as well as how emerging technologies, such as simulations or game-based learning, can further enhance environmental literacy.

Conclusion

This study demonstrates that the Integrated Contextual Digital Environmental Learning Approach (ICDELA) is more effective than conventional instruction in enhancing elementary students' environmental literacy across cognitive, affective, and behavioral dimensions. The findings confirm that integrating multimedia learning, environmental values, and authentic local environmental contexts within a structured instructional framework significantly improves students' environmental learning outcomes.

The primary contribution of this study lies in the development and empirical validation of ICDELA as an integrated instructional framework. Unlike approaches that apply digital media or contextual learning separately, ICDELA systematically combines these elements into a coherent pedagogical design that supports holistic environmental literacy development.

These findings highlight the importance of designing environmental learning experiences that are not only informative but also contextually relevant and value-oriented. In this regard, ICDELA offers a practical and adaptable model for enhancing environmental education, particularly in contexts where environmental issues are closely related to students' lived experiences.

Overall, this study underscores the significance of integrated, context-based digital learning approaches in advancing environmental literacy and provides a meaningful contribution to both educational theory and classroom practice.

Statement on the Use of AI Assistance

Artificial intelligence tools were used solely to improve the clarity and readability of the manuscript. All ideas, analyses, and interpretations are the sole responsibility of the author. The final version of the manuscript has been thoroughly reviewed and verified by the author to ensure its accuracy and alignment with the original research data.

References

Adawiah, R. (2019). Implementation of Adiwiyata program to build environmental awareness. *Journal of Wetlands Environmental Management*, *7*(2), 106. https://doi.org/10.20527/jwem.v7i2.196

Ainin, D. T., & Asafri, H. (2023). Improving environmental literacy through primary education: Preparing students as environmental advocates. *PPSDP International Journal of Education*, *2*(2), 110–118. https://doi.org/10.59175/pijed.v2i2.114

Ali, I., & Rahman, A. (2024). Environmental degradation: Causes, effects and solutions. *International Journal for Multidisciplinary Research*, *6*(3), 1–10. https://doi.org/10.36948/ijfmr.2024.v06i03.20366

Ashlan, S., & Firayani, F. (2025). Contextual learning of science based on environmental problems around schools. *Scientica Education Journal*, *2*(4), 1–9. https://doi.org/10.62872/1c6bxn45

Ayotte-Beaudet, J. P., Chastenay, P., Beaudry, M. C., L'Heureux, K., Giamellaro, M., Smith, J., Desjarlais, E., & Paquette, A. (2023). Exploring the impacts of contextualised outdoor science education on learning: The case of primary school students learning about ecosystem relationships. *Journal of Biological Education*, *57*(2), 277–294. https://doi.org/10.1080/00219266.2021.1909634

Basile, C., & White, C. (2000). Environmental literacy: Providing an interdisciplinary context for young children. *Contemporary Issues in Early Childhood*, *1*(2), 201–208. https://doi.org/10.2304/ciec.2000.1.2.7

Buchanan, J., Pressick-Kilborn, K., & Maher, D. (2019). Promoting environmental education for primary school-aged students using digital technologies. *Eurasia Journal of Mathematics, Science and Technology Education*, *15*(2). https://doi.org/10.29333/ejmste/100639

Chen, C., Chai, M., & Lin, P. (2025). Exploring the impact of interactive multimedia e-books on the effectiveness of environmental learning, pro-environmental attitudes, and behavioural intentions among primary school students. *Journal of Computer Assisted Learning*, *41*. https://doi.org/10.1111/jcal.70087

Cohen, L., & McIntyre, A. (2024). Integrating technology in elementary education : Enhancing student engagement in the digital age. *International Education and Research Journal. 10*(8), 16–18. https://doi.org/10.21276/IERJ24297768747793

Collado, S., Rosa, C. D., & Corraliza, J. A. (2020). The effect of a nature-based environmental education program on children's environmental attitudes and behaviors: A randomized experiment with primary schools. *Sustainability (Switzerland)*, *12*(17). https://doi.org/10.3390/SU12176817

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. Pearson Education.

El Batri, B., Alami, A., Zaki, M., Nafidi, Y., & Chenfour, D. (2019). Promotion of the environmental knowledge and behavior through the moroccan syllabus of sciences in the middle school. *International Electronic Journal of Elementary Education*, *11*(4), 371–381. https://doi.org/10.26822/iejee.2019450795

Emekwisia, C. C., Ogunsiji, T. O., Bauna, F. K., Otsabomhe, G. O., Akinbamilowo, O. O., Olagunju, A. R., & Akagu, E. E. (2025). Comparative analysis of environmental impacts associated with surface and underground mining operations. *South Asian Research Journal of Engineering and Technology*, *7*(04), 121–125. https://doi.org/10.36346/sarjet.2025.v07i04.005

Escobar, C. T., Marchesini, R., Soares, M. de F. de S., Ramos, C. A. S., Batista, M. da C., & De Melo, P. A. B. (2024). Educação ambiental nas escolas: Desafios e práticas inovadoras. *Aracê*, *6*(3), 5297–5311. https://doi.org/10.56238/arev6n3-061

Fazira, N., & Ramadan, Z. H. (2023). Implementation of the Adiwiyata program to build environmental caring character in elementary school students. *Aulad: Journal on Early Childhood*, *6*(3), 386–391. https://doi.org/10.31004/aulad.v6i3.549

Field, A. (2018). *Discovering statistics using IBM SPSS statistics (5th ed.)*. SAGE Publications Inc.

Gal, A. (2025). Echoes in memory: The lasting imprint of adult experiences from environmental education in fifth grade. *Frontiers in Education*, *10*. https://doi.org/10.3389/feduc.2025.1629969

Gorai, N. (2024). Enhancing learning and engagement: The integration of gamification in elementary education. *Futuristic Trends in Social Sciences Volume 3 Book 3*, *3*, 79–87. https://doi.org/10.58532/v3bbso3p2ch1

Hardianti, F., Kumorotomo, W., Setianto, W. A., Yazid, T. P., & Handayani, B. (2025). Green digital literacy: Inclusive policy innovation for children's environmental awareness. *E3S Web of Conferences*, *671*, 02008. https://doi.org/10.1051/e3sconf/202567102008

Hollweg, K. S., Taylor, J. R., Bybee, R. W., Marcinkowski, T. J., McBeth, W. C., & Zoido, P. (2011). *Developing a framework for assessing environmental literacy*. North American Association for Environmental Education. https://naaee.org/sites/default/files/inline-files/devframewkassessenvlitonlineed.pdf

Inbit, M. J. O., Alkolany, M. abdulhassan eliwi, Kazem, A. A. A., Hussein, H. H., & Brism, R. A. A. mageed. (2024). The impact of human activities on environmental sustainability. *European Journal of Medical Genetics and Clinical Biology*, *1*(8), 119–141. https://doi.org/10.61796/jmgcb.v1i8.832

Johnson, E. B. (2002). *Contextual teaching and learning: What it is and why it's here to stay*. Corwin Press.

Juraid, Hamzah, B., Mahpudz, A., & Khaldun, R. (2019). Implementation and development of Adiwiyata schools to realize character of students care for environment. *International Journal of Scientific and Technology Research*, *8*(10), 1226. https://www.scopus.com/inward/record.ur i?partnerI D=HzOxMe3b&scp=85074013250&origin=inward

Lin, V. J., & Ardoin, N. M. (2023). Connecting technologies and nature: Impact and opportunities for digital media use in the context of at-home family environmental learning. *Journal of Environmental Education*, *54*(1), 72–83. https://doi.org/10.1080/00958964.2022.2152411

Lowan-Trudeau, G. (2023). Digital technologies and environmental education. *Journal of Environmental Education*, *54*(1), 1–7. https://doi.org/10.1080/00958964.2022.2152413

Mayer, R. E. (2024). The past, present, and future of the cognitive theory of multimedia learning. *Educational Psychology Review*, *36*(1), 1–25. https://doi.org/10.1007/s10648-023-09842-1

Mayer, R. E., & Moreno, R. M. (2010). Nine ways to reduce cognitive load in multimedia leaming. *Educational Psychologist: A Special Issue of Educational Psychologist: 38*(1), 43–52. https://doi.org/10.1207/S15326985EP3801_6

Measham, T., Walker, J., Haslam McKenzie, F., Kirby, J., Williams, C., D'Urso, J., Littleboy, A., Samper, A., Rey, R., Maybee, B., Brereton, D., & Boggs, G. (2024). Beyond closure: A literature review and research agenda for post-mining transitions. *Resources Policy*, *90*(October 2023), 104859. https://doi.org/10.1016/j.resourpol.2024.104859

Ministry of Environment and Forestry. (2019). *Ministerial Regulation of Republic Indonesia Number P.52/MENLHK/SETJEN/KUM.1/9/2019 concerning the Movement of Environmental Care and Culture in Schools.* https://peraturan.bpk.go.id/Details/297090/permen-lhk-no-52-tahun-2019

Muflihaini, M. A., Ertando, A., & Suryadarma. (2020). How is the attitude of students' environmental literacy through the myth of beringin (Ficus sp.) in Adiwiyata school? *Journal of Physics: Conference Series*, *1440*(1). https://doi.org/10.1088/1742-6596/1440/1/012066

Naila, I., Suwono, H., & Susilo, H. (2026). Trend research and future directions of environmental literacy education in elementary school: A systematic literature review. *Multidisciplinary Reviews*, *9*(5). https://doi.org/10.31893/multirev.2026161

Ninsiana, W., Septiyana, L., & Suprihatin, Y. (2024). Introducing eco-literacy to early childhood students through digital learning. *Journal of Education and Learning*, *18*(1), 89–96. https://doi.org/10.11591/edulearn.v18i1.20678

Nugraha, L., Saud, U. S., Hartati, T., & Damaianti, V. S. (2022). Profile of learning environmental literacy in elementary school. *PrimaryEdu : Journal of Primary Education*, *6*(2), 211–222. https://doi.org/10.22460/pej.v6i2.3139

Pagouni, C., Pavloudakis, F., Kapageridis, I., & Yiannakou, A. (2024). Transitional and post-mining land uses: A global review of regulatory frameworks, decision-making criteria, and methods. *Land*, *13*(7), 1051. https://doi.org/10.3390/land13071051

Pooja. (2024). Environmental degradation: Causes, Impacts and mitigation. *Journal of Advances in Science and Technology*, *20*(1), 220–223. https://doi.org/10.29070/94vmdz61

Pramesworo, I. S., Wajnah, W., Malik, A., Lamatokan, S. C., & Nugroho, A. Y. (2025). The Impact of interactive learning methods on student motivation and achievement in elementary schools. *Jurnal Pendidikan Sosiologi Dan Humaniora*, *16*(1), 31–39. https://doi.org/10.26418/j-psh.v16i1.90763

Purnomo, R. (2024). Utilization of digital technology in the learning process in elementary schools: A literature review of challenges and opportunities for teachers. *Ludi Litterarri*, *1*(2), 17–25. https://doi.org/https://doi.org/ 10.62872/9ztfw245

Ramadhani, R. P., Setyowati, R. N., & Kristanto, A. (2024). Use of interactive multimedia to improve digital literacy in elementary schools. *International Journal of Emerging Research and Review*, *2*(2), 000058. https://doi.org/10.56707/ijoerar.v2i2.58

Rushayati, S. B., Hermawan, R., & Ginoga, L. N. (2023). The role of Adiwiyata school in the change of students' knowledge, attitude, and behavior towards the environment. *Jurnal Pengelolaan Sumberdaya Alam Dan Lingkungan*, *13*(1), 122 – 128. https://doi.org/10.29244/jpsl.13.1.122-128

Safrizal, S., Sudarmono, S., & Yulia, R. (2022). Developing students science literacy in Adiwiyata school: Case study inpadang city, Indonesia. *Journal of Turkish Science Education*, *19*(4), 1192–1205. https://doi.org/10.36681/tused.2022.169

Sarbaini, Hernawan, A. H., Darmawan, D., & Ali, M. (2022). Environmental education based on local values: Its integration in the indonesian elementary school curriculum. *International Journal of Education and Practice*, *10*(4), 322–333. https://files.eric.ed.gov/fulltext/EJ1390638.pdf

Stringer, L. R., Lee, K. M., Sturm, S., & Giacaman, N. (2022). A systematic review of primary school teachers' experiences with digital technologies curricula. *Education and Information Technologies*, *27*(9), 12585–12607. https://doi.org/10.1007/s10639-022-11127-z

Suratmi, S., Supriatna, N., Sopandi, W., & Wulan, A. R. (2024). Prospective elementary school teachers environmental literacy: What, why, and how?. *KnE Social Sciences*, *2024*, 1382–1393. https://doi.org/10.18502/kss.v9i13.16078

Talukder, P., Ray, R., Sarkar, M., Das, A., & Chakraborty, S. (2024). Adverse effects of mining pollutants on terrestrial and aquatic environment and its remediation. *Environmental Quality Management*, *33*(4), 595–610. https://doi.org/ https://doi.org/10.1002/tqem.22121

UNESCO. (2021). *Learn for our planet: A global review of how environmental issues are integrated in education*. https://unesdoc.unesco.org/ark:/48223/pf0000377362

Utomo, M. H., Suharti, L., Sasongko, G., & Sugiarto, A. (2023). Delevoping green behaviour in indonesia: why does Adiwiyata school matter?. *Journal of Sustainability Science and Management*, *18*(5), 33 – 51. https://doi.org/10.46754/jssm.2023.05.003