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TRANSFORMATIVE ECOPEDAGOGY IN HISTORY LEARNING VIA WEB-BASED INTERACTIVE MULTIMEDIA: A MIXED-METHODS STUDY OF STUDENT DEVELOPMENT IN ECOLITERACY

[1]Leni Marpelina, [2]Sariyatun & [3]Andayani
[1&2]Department of History Education, Universitas Sebelas Maret, Surakarta, Indonesia
[3]Department of Indonesian Language Education, Universitas Sebelas Maret, Surakarta, Indonesia

[1]*Corresponding author*: *lenimarpelina@student.uns.ac.id*

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ABSTRACT

Purpose – The growing problem of ecological crisis and persistent environmental degradation highlight the need for learning approaches that foster students' ecoliteracy. This study examines the development of student ecoliteracy following the implementation of a web-based interactive multimedia platform based on transformative ecopedagogy in history learning. It explores the learning process through which historical understanding develops into ecological awareness and action-oriented thinking.

Methodology – A mixed-methods explanatory design was employed, involving 144 high school students from four public high schools in Soloraya, Indonesia. The quantitative phase utilized a one-group pretest–posttest pre-experimental design to examine changes in students' ecoliteracy following the implementation of a web-based interactive multimedia platform in history learning. Quantitative data were analyzed using paired sample *t*-tests to assess differences between pretest and posttest scores. The magnitude of improvement was measured using normalized gain (N-Gain), while Cohen's *d* was calculated to determine the standardized magnitude of change. Qualitative data were collected through classroom observations and semi-structured interviews with seven purposively selected students, and analyzed using thematic analysis to explain the quantitative findings.

Findings – The quantitative results indicated a statistically significant increase in students' ecoliteracy scores following the implementation ($p < .001$). Students achieved a mean post-test score of 84.20, with an overall high normalized gain (N-Gain = 0.73). The standardized magnitude of change was very large (Cohen's $d = 2.79$). Qualitative findings identified a learning progression in which students developed ecoliteracy through successive stages of problem recognition, historical meaning-making, critical reflection, and action-oriented thinking. This progression explains why students demonstrated stronger gains in ecological knowledge, environmental awareness, and human–environment interaction in the application of ecological concepts, suggesting that ecological action develops through a gradual process of cognitive transformation rather than from information acquisition alone.

Novelty – This study identifies and explains a pedagogical mechanism through which students develop ecoliteracy, progressing from problem recognition and historical meaning-making to critical reflection and action-oriented thinking. Rather than focusing primarily on the development or effectiveness of a digital learning product, the study positions transformative ecopedagogy learning as a process-oriented pedagogical framework that connects historical meaning-making with ecological awareness, critical reflection, and action-oriented thinking.

Significance – The instructional mechanism identified in this study positions transformative ecopedagogy learning as a pedagogical framework for designing history learning that systematically transforms historical understanding into ecological awareness and action-oriented thinking. The framework emphasizes the learning process rather than the development or effectiveness of a specific digital technology or local context. However, its applicability across diverse historical topics, environmental issues, and educational settings requires further investigation.

Keywords: Ecoliteracy, history learning, action-oriented thinking, transformative ecopedagogy learning, web-based interactive multimedia.

INTRODUCTION

The balance between humans and nature is essential for sustaining ecosystems. However, the current ecological crisis indicates that this balance is increasingly disrupted by irresponsible human behavior toward the environment (Ricoy & Sánchez-Martínez, 2022). One of the most visible indicators of this disruption is the significant increase in waste production. This trend has become a major environmental concern in Indonesia due to its ecological and social consequences. According to data from the National Waste Management Information System (SIPSN) of the Ministry of Environment and Forestry (KLHK), Indonesia generated 35.83 million tons of waste in 2022. This volume represented a 21.7% increase compared to 2021, marking the highest level in the past four years (Ministry of Environment and Forestry, 2023). This growing environmental problem is closely associated with population growth and consumer-oriented lifestyles, particularly among the younger generations (Erdianto et al., 2019).

These conditions indicate that ecological awareness among students remains relatively low. Many students still demonstrate environmentally indifferent behaviors, such as excessive use of single-use plastics, limited recycling practices, and a lack of understanding of how human activities have historically contributed to

environmental degradation (Rudd et al., 2021). Education, therefore plays a crucial role in fostering ecological awareness and responsible environmental behavior. In this context, history education offers an important opportunity to integrate ecological perspectives because historical narratives often reveal how past human decisions regarding natural resource exploitation have shaped current environmental conditions. Integrating ecoliteracy into history learning can encourage students not only to understand historical events, but also to critically analyze their environmental consequences and sustainability implications (Sigit, 2023).

However, history learning in many classrooms still relies heavily on traditional teaching methods, such as lectures and textbooks. These approaches often provide limited opportunities for students to actively explore the relationship between historical events and contemporary environmental challenges (Atukunda & Maja, 2022; Sayono et al., 2020). This limitation becomes more significant considering the characteristics of today's digital-native learners. Younger generations of students tend to be more responsive to technology-based learning environments that are interactive, visual, and dynamic (Annuš et al., 2023). Therefore, integrating digital learning technologies into history education may offer new opportunities to make history learning more engaging while simultaneously fostering ecological awareness.

Interactive web-based learning environments have the potential to support more exploratory and contextual learning experiences. Prior studies show that interactive multimedia can enhance students' engagement and understanding of complex concepts by integrating visual, textual, and interactive elements (Suripah & Susanti, 2022; Budiarto et al., 2024). However, most existing research tends to examine interactive multimedia in history learning and ecoliteracy education separately. Limited studies have explored how web-based interactive multimedia can integrate ecoliteracy within history education to promote sustainability-oriented learning. Preliminary research has emphasized that rethinking ecopedagogy in digital history environments is essential for moving beyond traditional narratives toward a more critical ecological consciousness (Marpelina et al., 2025). Addressing this gap, the present study examines how students' ecoliteracy develops through a web-based interactive multimedia platform which is facilitated by transformative ecopedagogy learning. The platform integrates historical narratives with ecological perspectives to help students understand the long-term relationships between human activities and environmental sustainability. Drawing on constructivist learning theory (Nardo, 2021) and critical pedagogy (Shih, 2018)**,** this study aims to create a learning environment that not only enhances students' understanding of history, but also fosters critical ecological awareness.

Therefore, the present study examines students' ecoliteracy development through a web-based interactive multimedia platform in history learning, focusing on both changes in ecoliteracy and the learning process underlying these changes. This study contributes to technology-enhanced history learning by examining how transformative ecopedagogy learning facilitates the integration of ecoliteracy into history learning. Specifically, this study addresses the following research questions:

> RQ1: To what extent does students' ecoliteracy change following the implementation of a web-based interactive multimedia platform in history learning?
>
> RQ2: How does students' ecoliteracy develop through the learning process which has been facilitated by a web-based interactive multimedia platform in history learning?

LITERATURE REVIEW

Web-Based Interactive Multimedia in History Learning

Web-based interactive multimedia enhances learning by integrating visual, auditory, and interactive elements, improving engagement and outcomes (Moreno & Mayer, 2007; Muir et al., 2022). In history education, such a multimedia platform shifts passive learning toward active, student-centered experiences that boost motivation and conceptual understanding (Herrera Córdova et al., 2024; Montero Reyes et al., 2024). These benefits are often explained through the cognitive theory of multimedia learning (CTML), which emphasizes dual-channel processing and reduced cognitive load. However, the CTML prioritizes cognitive efficiency over deeper meaning-making and critical awareness (Fiorella & Mayer, 2021; Schneider et al., 2022), a limitation especially relevant in history learning, where students must interpret historical facts in relation to contemporary issues. Beyond information delivery, interactive multimedia through simulations, digital storytelling, and inquiry-based exploration can foster higher-order thinking such as critical analysis and historical reasoning (Clark & Mayer, 2023; Makransky & Petersen, 2021; Sung, 2020). Yet research has largely focused on engagement and cognition, leaving the role of multimedia in developing ecoliteracy, particularly students' understanding of the interconnections among historical processes, human activity, and environmental systems underexplored. Compounding this, history instruction still emphasizes content coverage and memorization over inquiry and real-world problem-solving (Burgos-Videla et al., 2025; Stoel et al., 2017), leaving students ill-equipped to connect historical knowledge with environmental challenges. The present study, therefore, examines how a web-based interactive multimedia platform can support the development of ecoliteracy in the context of history learning.

The Integration of Ecoliteracy in History Education

Ecoliteracy is a foundational competence enabling individuals to understand the interconnection between human and natural systems, coupled with a commitment to sustainable action (Desfandi, 2017; Sigit, 2023), encompassing cognitive, affective, and practical dimensions (Wulandari et al., 2024). Scholars increasingly frame it as a holistic construct integrating knowledge, values, and action (Ardoin et al., 2020; Koyama & Watanabe, 2023). Though typically associated with science education, ecoliteracy offers a unique value in history learning, which provides a temporal lens for examining long-term human-environment interactions for instance, how industrialization, colonization, and resource exploitation have shaped present ecological conditions. This positions history education as a means to move students beyond factual recall toward ethical reflection, evaluating the consequences of human action and developing responsibility toward sustainability (Koyama & Watanabe, 2023). Despite this potential, ecoliteracy integration in history curricula remains limited, as instruction continues to prioritize content coverage over interdisciplinary, real-world relevance. This gap between ecoliteracy's theoretical importance and its practical implementation calls for repositioning ecoliteracy as a central, not peripheral, learning objective in history education.

Ecopedagogy and Critical Pedagogy in Digital Environments

Ecopedagogy and critical pedagogy together offer a framework for cultivating ecological consciousness and critical awareness. Critical pedagogy emphasizes questioning dominant narratives and power

structures, while ecopedagogy extends this toward concerns with sustainability and human–environment ethics (Misiaszek, 2020b; Shih, 2018), both increasingly relevant to addressing challenges, such as climate change (Kahn, 2010; Kopnina, 2020). In digital learning environments, a web-based interactive multimedia platform can function not merely as an engagement tool, but as a means for critical inquiry and participatory learning (Lazaris, 2025), enabling students to explore historical and environmental issues from multiple perspectives. Embedding ecopedagogical principles into digital history learning specifically allows students to critically analyze how historical events and policies have shaped current environmental conditions, enhancing sustainability awareness and engagement with environmental justice (Marpelina et al., 2025; Misiaszek, 2023). However, this integration remains underdeveloped in practice, as digital learning designs still prioritize content delivery and engagement over critical reflection and ecological awareness (Kopnina, 2020), leaving the transformative potential of digital technology for ecoliteracy largely unrealized, particularly in history education. Taken together, while prior research has examined multimedia learning, critical pedagogy, and environmental literacy separately, limited work has systematically integrated these elements to foster ecological understanding within disciplinary contexts. This study, therefore examines changes in students' ecoliteracy following the implementation of a web-based interactive multimedia platform in history learning.

METHODOLOGY

Research Design

This study employed an explanatory mixed-methods design (Creswell & Plano Clark, 2023) which conducted the research in two phases sequentially. The first phase used a one-group pretest–posttest pre-experimental design to examine changes in students' ecoliteracy following the web-based interactive multimedia intervention. Quantitative analysis identified the magnitude and variation of improvement across ecoliteracy indicators. The second phase used classroom observations and semi-structured interviews to explain the quantitative findings, particularly students' ecoliteracy development processes and the varying improvement across indicators, including the moderate gain in the application of ecological concepts. Integration was achieved at the interpretation stage, where qualitative evidence informed meta-inferences about how the intervention supported students' ecoliteracy development.

Participants

The participants consisted of 144 high school students from four public high schools in Soloraya, Indonesia. The schools were selected purposively based on the following three criteria: availability of digital learning facilities, teachers' readiness to implement web-based instruction, and comparable history curriculum implementation. Each school contributed one intact class (n = 36), resulting in four intervention classes without random assignment. This intact-group approach was used to preserve the natural classroom setting and maintain consistent implementation of the intervention. Student participants were selected based on two inclusion criteria: (1) enrollment in the participating history classes and (2) regular access to digital devices during the intervention. To reduce potential selection bias, participating classes were drawn from the same grade level and had comparable prior exposure to the history curriculum before the intervention.

For the qualitative phase, seven students were purposively selected for semi-structured interviews following completion of the intervention. The participants were chosen to represent diverse learning outcomes based on their post-test performance, comprising students with high, moderate, and lower levels of ecoliteracy achievement. Classroom participation and teacher recommendations were also considered to ensure that the selected participants reflected a range of learning experiences during the implementation of the transformative ecopedagogy learning framework. This maximum variation sampling strategy was employed to obtain rich and diverse perspectives that could explain and complement the quantitative findings.

The Multimedia Intervention

The intervention used a web-based interactive multimedia platform entitled Alam Berkisah (https://alamberkisah.com/), integrating environmental history and ecoliteracy through the following four modules: Human–nature interaction, industrial resource exploitation, ecosystem change timelines, and reflective sustainability quizzes. The intervention was implemented in two 90-minute sessions using the transformative ecopedagogy learning syntax which comprises problematization, dialogic reflection, interactive exploration, critical reflection, transformative action, collaborative synthesis, and perspective reconstruction. Students engaged in guided inquiry, multimedia exploration, discussion, and reflective problem-solving, while the teacher facilitated activities and critical reflection. To ensure consistency, implementation followed a standardized lesson protocol and was monitored using a fidelity checklist addressing instructional adherence, student engagement, and completion of core activities. A summary of the intervention procedures is as presented in Table 1.

Table 1

Intervention Procedures and Instructional Fidelity

Session	Learning stage	Main student activities	Teacher role	Expected ecoliteracy outcome
Session 1 (90 min)	Problematization	Identify environmental issues from historical cases	Prompt inquiry and contextual discussion	Initial ecological awareness
	Dialogic Reflection	Discuss causes of socio-ecological problems	Facilitate guided reflection	Recognition of human–environment relations
	Interactive Exploration	Explore multimedia modules and timelines	Guide navigation and inquiry	Conceptual understanding
Session 2 (90 min)	Critical Reflection	Analyze historical causes and consequences	Support analytical discussion	Ecological reasoning
	Transformative Action	Propose sustainability solutions	Facilitate solution-building	Application of ecological concepts
	Collaborative Synthesis	Present and reconstruct perspectives	Moderate synthesis discussion	Integrated ecoliteracy understanding
	Perspective Reconstruction	Re-evaluate and reconstruct perspectives on history, nature, and students' roles in society	Facilitate reflective perspective reconstruction	Reconstructed perspectives on human–environment relationships

Data Collection Instruments

Data was collected using three instruments. First, an ecoliteracy test consisting of 20 multiple-choice items was used to assess four indicators as follows: ecological knowledge (Items 1–5), environmental awareness (Items 6–10), human–environment interaction (Items 11–15), and application of ecological concepts (Items 16–20). Each correct response received one point, whereas each incorrect response received a zero point. Each indicator consisted of five items, and indicator scores were calculated by multiplying the number of correct responses by five, resulting in scores ranging from 0 to 25 for each indicator. The overall ecoliteracy score ranged from 0 to 100. The instrument underwent expert review by three specialists to establish content validity (Aiken's V = 0.87). Internal consistency reliability was assessed through a pilot study involving 32 students, yielding a Cronbach's alpha coefficient of 0.81, indicating good reliability. A summary of the ecoliteracy test is as presented in Table 2.

Table 2

Structure of the Ecoliteracy Test Instrument

Indicator	Item numbers	Example focus	Raw score	Indicator score
Ecological Knowledge	1–5	Understanding environmental history concepts	0–5	0–25
Environmental Awareness	6–10	Awareness of environmental issues	0–5	0–25
Human–Environment Interaction	11–15	Cause-effect relationships in socio-ecological systems	0–5	0–25
Application of Ecological Concepts	16–20	Applying ecological ideas to problem situations	0–5	0–25

Classroom observations were conducted throughout both intervention sessions using a structured observation guide to document student engagement, interaction with multimedia, participation in collaborative tasks, and responses during reflective activities. Semi-structured interviews were subsequently conducted with seven purposively selected students representing diverse learning outcomes to supplement the quantitative findings. The interviews explored how students connected historical content with environmental issues, the challenges they encountered in applying ecological concepts, and their perceptions of the multimedia-supported learning process.

Data Analysis

Quantitative data were analyzed using paired sample t-tests to examine differences between pre-test and post-test scores following confirmation of normality assumptions. The magnitude of improvement was assessed using normalized gain (N-Gain), while effect size was calculated using Cohen's *d* ($d = t/\sqrt{n}$) to estimate the strength of the intervention-related change. Qualitative data from classroom observations and semi-structured interviews were analyzed using thematic analysis through the following six stages: familiarization, coding, theme development, theme review, theme definition, and reporting (Braun & Clarke, 2006). The analysis focused on identifying themes that captured the students' ecoliteracy development and variations across the four indicators, particularly the comparatively lower improvement in the application of ecological concepts. Trustworthiness was enhanced through data source triangulation,

member checking, and iterative comparison between observation records and interview data. Finally, qualitative themes were integrated with the quantitative findings during the interpretation stage to develop meta-inferences that explained the observed statistical patterns.

RESULTS

Student Ecoliteracy after Intervention

Descriptive Statistics of Ecoliteracy Scores

Table 3

Descriptive Statistics of Ecoliteracy Scores (n = 144)

Indicator	Pre-test (M)		Post-test (M)		Mean Diff.	95% CI
	M	SD	M	SD		
Ecological Knowledge	39.72	24.69	82.78	17.48	43.06	[38.43, 47.68]
Environmental Awareness	40.28	24.69	85.00	16.81	44.72	[40.15, 49.29]
Human–Environment Interaction	42.22	25.81	87.08	16.30	44.86	[40.19, 49.53]
Application of Ecological Concepts	41.81	25.13	81.94	19.69	40.14	[35.11, 45.17]
Overall Mean	41.01	12.84	84.20	8.90	43.19	[40.67, 45.72]

Notes. M = mean; SD = standard deviation; Mean Diff. = mean difference; 95% CI = 95% confidence interval.

Students demonstrated substantial improvements across all ecoliteracy indicators following the implementation of the web-based interactive multimedia intervention (see Table 3). The overall mean score increased from 41.01 (SD = 12.84**)** on the pre-test to 84.20 (SD = 8.90) on the post-test, yielding a mean difference of 43.19, with a 95% confidence interval of 40.67-45.72. These findings indicate a consistent improvement in students' ecoliteracy after participating in the intervention. At the indicator level, all four dimensions showed positive gains. The largest improvement was observed in Human–Environment Interaction (Mean Difference = 44.86**,** 95% CI 40.1-49.53**)**, followed by Environmental Awareness (Mean Difference = 44.72, 95% CI 40.15-49.29), Ecological Knowledge (Mean Difference = 43.06**,** 95% CI 38.43-47.68), and Application of Ecological Concepts (Mean Difference = 40.14**,** 95% CI 35.11-45.17). Overall, students consistently showed improved performance across all dimensions of ecoliteracy following the intervention, although the magnitude of improvement varied slightly among indicators.

Data Normality and Statistical Assumptions

Table 4

Data Normality and Statistical Assumptions

Variable	N	Statistic	p-value	Interpretation
Pre-test Scores	144	0.969	0.083	Normally Distributed
Post-test Scores	144	0.951	0.100	Normally Distributed

Prior to conducting inferential statistical analysis, a normality test was performed to ensure that the data met the necessary assumptions for parametric testing. As shown in Table 4, the Shapiro-Wilk test was applied to the scores of all 144 participants. The results indicate that both pre-test scores (Statistic = 0.969, p = 0.083) and post-test scores (Statistic = 0.951, p = 0.100) were normally distributed, as the p-values for both variables exceeded the 0.05 significance threshold. Consequently, the data was confirmed to be suitable for further analysis using the paired sample t-test.

Paired Sample T-Test

Table 5

Paired Sample t-Test Results

Variable	Mean difference	SD (Difference)	t	df	p-value
Pre-test vs Post-test	43.19	15.48	33.48	143	<0.001

Notes. SD = standard deviation; t = t-statistic; df = degrees of freedom; p = p-value.

A paired samples t-test was conducted to compare students' ecoliteracy scores before and after the implementation of the web-based interactive multimedia. The analysis revealed a statistically significant improvement in students' ecoliteracy following the implementation of the instructional framework (t (143) = 33.48, p <0.001). The mean score increased by 43.19 points (SD = 15.48), indicating a substantial improvement in students' ecoliteracy after participating in the learning activities. These findings indicate that students demonstrated significant improvements in ecoliteracy following the implementation of the web-based interactive multimedia. The large mean difference indicates that the students achieved higher ecoliteracy scores after the intervention across the measured dimensions.

Magnitude of Improvement (N-Gain)

Table 6

Magnitude of Improvement Based on N-Gain

Indicator	N-gain (g)	Category
Ecological Knowledge	0.71	High
Environmental Awareness	0.75	High
Human–Environment Interaction	0.78	High
Application of Ecological Concepts	0.69	Moderate
Overall Mean	0.73	High

Notes. N-gain classification follows Hake, (1999) : $g \geq 0.70$ = High; $0.30 \leq g < 0.70$ = Moderate; $g < 0.30$ = Low. N-gain was computed individually for each student using g = (post-pre)/ (100-pre), and the resulting scores were averaged across all participants (n = 144).

To evaluate the practical magnitude of improvement in students' ecoliteracy, the normalized gain (N-Gain) was calculated. As presented in Table 6, the overall N-Gain reached 0.73, indicating a high level of improvement according to Hake's (1999) classification. At the indicator level, Human–Environment Interaction demonstrated the highest normalized gain (g = 0.78), followed by Environmental Awareness (g = 0.75) and Ecological Knowledge (g = 0.71), all of which were categorized as High. In contrast, Application of Ecological Concepts achieved a moderate normalized gain (g = 0.69). These findings suggest that the web-based interactive multimedia was associated with particularly strong gains in students' ecological understanding and awareness, while the ability to apply ecological concepts to practical situations developed more gradually.

Effect Size Analysis (Cohen's d)

The effect size analysis was conducted to determine the magnitude of change in students' ecoliteracy following the intervention. Cohen's d for paired samples was calculated by dividing the mean difference by the standard deviation of the difference scores. The analysis yielded a Cohen's d value of 2.79, indicating a very large effect size. This finding indicates a very large magnitude of change in students' ecoliteracy following the implementation of the web-based interactive multimedia.

Qualitative Insights into Students' Ecoliteracy Development

The qualitative findings not only illustrate students' progressive ecoliteracy development, but also help explain the quantitative patterns observed across indicators. Thematic analysis of interview and classroom observation data generated three interrelated themes that trace students' trajectory from initial awareness, through structured eco-historical reasoning, to the challenge of translating understanding into concrete action.

Cognitive Disequilibrium and Initial Awareness

The first theme emerged during the Problematization and Dialogic Reflection phases of the *Alam Berkisah* platform. Classroom observation in Class B recorded that after watching videos on Bengawan Solo's pollution and encountering reflective prompts such as *"Apa yang kamu rasakan?"* (What do you feel?) and *"Menurutmu siapa yang salah?"* (Who do you think is at fault?), students paused in silence before writing their responses, suggesting a moment of genuine reflection rather than routine task completion (Observation, Class B, Session 1).

Interview data reinforced this observation. Student A recalled initially viewing the history class as "just about memorizing war dates," but described a shift in perspective once the platform asked whether river pollution today was connected to the past, realizing that "the heavy waste in Bengawan Solo today is actually connected to long-term industrial changes over time." Student E reported a similar reorientation triggered by the prompt *"Siapa yang paling terdampak?"* (Who is the most impacted?), stating that it made her recognize river pollution in Surakarta as "a shared historical crisis," prompting a sudden sense of personal concern. Student B connected this directly to local history, expressing shock at the contrast between the prosperous trading past of Bandar Kabanaran Laweyan and the degraded state of the river

today, and concluding that the present ecological crisis is "a direct consequence of unmanaged past economic choices."

Together, these accounts indicate that the platform's reflective prompts functioned as a catalyst, moving students from passive historical recall toward active emotional and cognitive engagement with environmental issues. This qualitative trajectory is consistent with the quantitative findings: Environmental Awareness increased substantially from a pre-test mean of 40.28 to a post-test mean of 85.00, corresponding to a high N-Gain of 0.75.

Structured Exploration and Eco-Historical Reasoning

The second theme was evident during the Interactive Exploration and Critical Reflection phases. Observation in Class A recorded that as students cross-referenced historical texts about Bandar Kabanaran Laweyan in the 1500s with current news on textile and ethanol waste dumping along local Surakarta rivers, they worked actively and collaboratively rather than passively when receiving information.

Student C described this process as reducing cognitive strain, noting that "connecting the past activities to modern river damage became very easy" once guided by the Interactive Exploration menu. Student F echoed this, explaining that the chronological prompt *"Bagaimana dampaknya?"* (What is the impact?) "Made it easy to connect the dots," allowing a clear trace from historical economic choices to present-day impacts on the Kali Pepe and Kali Jenes rivers. Student D highlighted the role of visual and spatial materials, stating that maps and archival documents "helped me visualize the changes over time" and allowed a shift from "just reading dry text" to logically mapping how local industries altered the rivers' condition.

These accounts suggest that the platform's sequential, scaffolded structure transformed complex socio-environmental variables into an intuitive discovery process, reducing aimless exploration and mental fatigue. This finding aligns with the substantial quantitative gains observed in ecological knowledge (N-Gain = 0.71, high category) and human–environment interaction (N-Gain = 0.78, high category), suggesting that structured digital scaffolding supported students' eco-historical reasoning.

Challenges in Applying Ecological Concepts

The third theme captures a more cautionary pattern that emerged during the transformative action, collaborative synthesis, and perspective reconstruction stages. Observation in Class C noted that student pacing slowed markedly at this stage: when prompted to propose localized, practical sustainability actions or policy recommendations based on historical lessons, students hesitated and spent considerably longer time discussing ideas among peers than in earlier phases.

Student D, who had found the earlier dialogic reflection stage straightforward, acknowledged difficulty at this later point, explaining that when the platform required writing down concrete solutions to fix industrial waste, "I got stuck," adding that "designing a practical solution on the spot was hard" even though the river's damage was clearly understood. Student B attributed part of this difficulty to time constraints, explaining that "the short duration of the session made it highly demanding to propose realistic sustainability solutions," and noting that "understanding the historical cause of ecosystem breakdown was

much easier than creating actionable interventions on the spot." Student G described a similar struggle in translating analysis into policy, noting that formulating "logical real actions" felt markedly different from analyzing historical articles, since constructing a real policy proposal "requires a lot of guiding steps that we didn't know yet".

This hesitation points to a cognitive bottleneck between historical-ecological understanding and the practical demands of action-oriented problem-solving. It helps explain why application of ecological concepts recorded the lowest, though still meaningful, quantitative gain among the four ecoliteracy indicators, with an N-Gain of 0.69, which was classified as moderate. While the platform's digital media appeared to support conceptual reasoning, moving from understanding to formulating concrete solutions evidently required a distinct, higher tier of action-oriented scaffolding to help bridge the well-documented pro-environmental behavior gap.

Overall, the integration of quantitative and qualitative findings indicates that the web-based interactive multimedia intervention was associated with substantial improvements across all dimensions of ecoliteracy. The three themes collectively illustrate students' progression from initial ecological awareness, through structured eco-historical reasoning, to the more demanding task of applying ecological concepts in authentic contexts. While the strongest gains were observed in human–environment interaction and environmental awareness, the comparatively lower, though still moderate, gain in the application dimension suggests that translating ecological knowledge into practical action remains a more demanding learning process, one that may benefit from additional scaffolding in future iterations of the intervention.

DISCUSSION

Rather than treating the four ecoliteracy dimensions examined quantitatively in this study as discrete outcomes to be discussed in turn, the following sections interpret them as part of a cumulative developmental trajectory generated by a single pedagogical mechanism within the transformative ecopedagogy learning framework. This synthesizing orientation extends recent theorizing that positions ecoliteracy as a multidimensional competency spanning ecological knowledge, critical thinking, environmental awareness, and active participation (Murti et al., 2025), and responds to calls within ecopedagogy scholarship for critical, place-based pedagogies capable of translating environmental understanding into civically engaged climate action (Iyengar et al., 2025). Read together, the findings below suggest that meaning-making in history functions as the generative starting point from which critical consciousness, affective awareness, and ultimately ecological agency progressively emerge.

Meaning-Making in History as a Foundation for Ecological Knowledge

The findings show that students demonstrated substantial improvements in ecological knowledge following the implementation of the transformative ecopedagogy learning framework. This improvement was not solely influenced by the medium through which information was delivered, but rather by the pedagogical design that guided students in their understanding of the relationship between historical events and environmental issues. Through the stages of problematization, dialogic reflection, and interactive exploration, students were encouraged to identify ecological issues, discuss diverse historical perspectives,

and critically explore historical and environmental sources. This series of learning experiences facilitated the development of meaning-making in history, enabling students to construct meaning from historical events through their connection to human and environmental dynamics, allowing them not only to understand historical facts, but also to interpret the ecological consequences of human activities over time. Meaning-making in history, thus serves as the primary pedagogical mechanism explaining why ecological knowledge develops more deeply through interpretation rather than merely through the reception of factual information. This mechanism aligns with Popa's (2023) concept of "Meaningful History," which emphasizes the importance of connecting the past, present, and future, as well as Moser and Zimmermann's (2025) perspective on the importance of classroom dialogue in constructing historical interpretations. The present study expands upon both of these perspectives by demonstrating that meaning-making in history not only fosters understanding of historical events, but also shapes ecological knowledge, positioning the transformative ecopedagogy learning framework as a pedagogical approach that integrates digital technology and meaning-making in history, making history a relevant tool for addressing sustainability challenges.

Cultivating Critical Consciousness: Developing Ecological Awareness through History

Similarly, the findings show that students demonstrated improvements in ecological awareness following the implementation of the transformative ecopedagogy learning framework. Ecological awareness developed not merely through the transmission of environmental knowledge, but through students' learning experiences that encouraged reflection on the relationships between historical events, human activities, and environmental change. The stages of dialogic reflection and critical reflection facilitated discussion of diverse historical perspectives, evaluation of the ecological consequences of human actions, and reflection on their implications for present environmental conditions. They helped foster critical consciousness, or students' ability to understand environmental issues as the outcome of long-term historical and social processes. In tracing changes in the Bengawan Solo River over time, students also discussed the social and ecological impacts of human decisions across historical periods, prompting them to question the causes of environmental degradation, the victims affected, and humanity's responsibility for sustainability. Critical consciousness, therefore explains why ecological awareness is built through critical reflection on historical experience rather than through understanding environmental facts alone.

These findings align with contemporary perspectives on critical consciousness, which define it as the ability to understand, critique, and act against oppressive social structures and systemic forces (Pinedo et al., 2024). In the field of ecology, Misiaszek (2020a) similarly emphasizes that ecopedagogy serves to build critical awareness of the relationship between humans, power, and environmental crises. This study supports and expands upon both perspectives by demonstrating that critical consciousness can serve as a pedagogical bridge connecting history education with the development of ecological awareness. In practical terms, these findings contribute to the development of an instructional framework for history education: enhancing ecological awareness depends not only on the presentation of content, but also on instructional designs that systematically facilitate dialogue, critical reflection, and historical interpretation. Thus, the transformative ecopedagogy learning framework expands the function of history education not merely as a means of understanding the past, but also as a vehicle for building critical ecological awareness as the foundation for responsible decision-making regarding environmental sustainability.

Fostering Reflection in History and Ecological Commitment for Human-Environment Interaction

The findings further show that students demonstrated improvements in human-environment interaction following the implementation of the transformative ecopedagogy learning framework. This development occurred not only through understanding the importance of preserving nature, but also through reflecting on the historical relationship between human activities and environmental change. The stages of critical reflection and transformative action enabled students to evaluate the ecological consequences of historical events, reflect on sustainability values, and connect them to present environmental responsibilities, fostering historical reflection and ecological commitment as pedagogical mechanisms underlying this interaction (Dickmann & Consorte-McCrea, 2025). Examining how past human activities shaped the current condition of the Bengawan Solo River moved students beyond factual understanding toward reflecting on the moral and ecological consequences of human action. This process helped students to view themselves as part of a reciprocal human-environment relationship, consistent with Hung's (2017) conception of ecopedagogy as an ecological approach to education that reconnects humans with the environment. These findings align with the standpoint of Ammert et al. (2020), who identify historical consciousness as history education's primary goal, and through students' ability to reflect on connections among past, present, and future. Similarly in Nuttall (2021), the researcher emphasizes history education's role in helping students understand contemporary issues while developing a future-oriented mindset; and with Cairns and Garrard (2024), who show that history's relevance depends on connecting historical experience with present sustainability challenges. The present study supports and extends these perspectives by demonstrating that historical reflection not only strengthens historical understanding, but transforms it into ecological commitment, fostering human-environment interaction through the transformative ecopedagogy learning framework, which positions history education as a means of building more responsible human-environment relationships through sustainability-oriented historical reflection.

Developing Ecological Agency for the Application of Ecological Concepts

Finally, the results show that the transformative ecopedagogy learning framework has improved students' application of ecological concepts, enabling them not only to understand these concepts theoretically, but to apply them in analyzing environmental issues, evaluating alternative solutions, and connecting sustainability values to concrete daily actions. The collaborative synthesis and perspective reconstruction stages helped students to integrate diverse historical and ecological perspectives, develop solutions to environmental problems, and reconstruct their views on the human-environment relationship, thus fostering ecological agency as the pedagogical mechanism underlying this application. Rather than being directly instructed to apply ecological concepts, students first engaged in meaning-making in history, developed critical consciousness, and reflected on the consequences of human actions for the environment, a process that fostered ecological commitment, which subsequently evolved into ecological agency: enhancing students' capacity to use ecological knowledge to analyze problems, evaluate solutions, and take responsible action toward sustainability (Andersson et al., 2025). This aligns with the view that sustainability education must develop students' ability to transform knowledge into concrete action through reflective, participatory, and socially transformative learning (Kopnina & Bedford, 2024; Oinonen et al., 2024).

This finding aligns with that in Chen and Liu (2020), who argue that sustainability education aims not merely to improve knowledge and attitudes, but to develop "action competence" – learners' ability to make decisions and act on environmental issues. This view has been reinforced by Andersson et al. (2025), who define action competence as the capacity to participate reflectively and responsibly in addressing sustainability challenges, and by Oinonen et al. (2024), who emphasize that sustainable action develops not only through knowledge, but through individuals' willingness, beliefs, and ability to participate in social change. The present study supports and extends these perspectives by showing that ecological agencies in history learning develop through transformative ecopedagogy learning, such that students' ability to apply ecological concepts builds gradually through historical meaning-making, critical consciousness, historical reflection, and ecological commitment.

These findings contribute to the development of an instructional framework for history education by demonstrating that students' ability to apply ecological concepts does not emerge immediately after acquiring knowledge about environmental issues, but rather develops through a learning process that begins with meaning-making in history, followed by critical consciousness, historical reflection, and ecological commitment, ultimately leading to the formation of ecological agency. Each stage serves a complementary function, ensuring that the learning process not only builds understanding in history, but also transforms it into students' capacity to make decisions and take action to address sustainability challenges. Thus, the transformative ecopedagogy learning framework offers an instructional framework that explains how history learning grounded in local environmental history can develop ecological agency and equip students with the ability to apply ecological concepts to address sustainability challenges in real-life contexts.

Beyond its empirical contribution, the present study carries broader theoretical and pedagogical implications. Theoretically, it extends Murti et al.'s (2025) synthesized the ecoliteracy competency framework with ecological knowledge, critical thinking, environmental awareness, and active participation by showing that these domains can be cultivated sequentially through a single pedagogical mechanism grounded in historical meaning-making, rather than trained as independent competencies. Pedagogically, it responds to calls within ecopedagogy scholarship to move environmental learning beyond standardized content-delivery models toward critical, place-based, justice-oriented pedagogies (Iyengar et al., 2025). A transformative ecopedagogy learning framework is able to operationalize this call within history education by demonstrating that historical narratives of human-environment relations can serve as a generative entry point for ecological competency development. For technology-enhanced learning, the findings suggest that it is the pedagogical architecture embedded within web-based interactive multimedia, not the technology itself that drives ecoliteracy gains, aligning with a broader shift in educational technology research toward design-based, mechanism-oriented inquiry. Collectively, these implications position history education not merely as a vehicle for factual transmission, but as a disciplinary space uniquely suited to cultivating the historical consciousness required for present-day ecological action.

LIMITATIONS OF THE STUDY

This study has several limitations that should be considered. First, the one-group pretest–posttest design did not include a comparison or control group; consequently, the observed improvements in students' ecoliteracy cannot be attributed exclusively to the intervention. Future studies employing controlled quasi-

experimental or experimental designs are needed to provide evidence of causal inference. Second, the study focused on students' ecological agency during the implementation period. Consequently, the long-term sustainability of this agency beyond classroom learning remains to be investigated through longitudinal research. Third, the instructional framework was examined within the context of senior secondary history education. Future research may explore its application across different educational levels, subject areas, and local environmental histories to further evaluate its broader educational applicability.

CONCLUSION

The findings indicate that there are improvements in students' ecoliteracy when they learn local environmental history using a web-based interactive multimedia platform which operates under the framework of transformative ecopedagogy learning. The findings show improvements across four dimensions of ecoliteracy, namely ecological knowledge, environmental awareness, human-environment interaction, and the application of ecological concepts. These improvements are reflected in a progressive pedagogical process in which students construct historical meaning-making, develop critical consciousness, engage in historical reflection, strengthen ecological commitment, and ultimately develop ecological agency that enables them to apply ecological concepts in addressing environmental challenges. This study extends the literature on ecopedagogy by proposing transformative ecopedagogy learning as a historical-pedagogical instructional framework that explains how history learning can foster sustainability-oriented learning outcomes while illuminating the learning processes underlying changes in students' ecoliteracy. The findings indicate that ecoliteracy does not emerge solely from acquiring environmental knowledge, but develops through interconnected learning processes that progressively transform historical understanding into ecological awareness, responsible human-environment interaction, and sustainability-oriented action. The proposed framework offers practical implications for history education by demonstrating how local environmental history can be integrated into inquiry-based digital learning to promote students' ecological agency and sustainability competencies. The framework emphasizes pedagogical processes that connect historical learning with ecological understanding and action. However, its applicability across diverse historical, cultural, and environmental settings requires further investigation.

CONFLICT OF INTEREST STATEMENT

No potential conflict of interest was reported by the authors.

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REFERENCES

Ammert, N., Sharp, H., Löfström, J., & Edling, S. (2020). Identifying aspects of temporal orientation in students' moral reflections. *History Education Research Journal*, *17*(2), 132-150. https://doi.org/10.14324/herj.17.2.01

Andersson, P., Augustine, L., & Rampazzo Gambarato, R. (2025). Advancing social sustainability through the development of action competence: A scoping literature review. *Sustainability*, *17*(8), 3661. https://doi.org/10.3390/su17083661

Annuš, N., Takáč, O., Štempeľová, I., & Dancsa, D. (2023). Z and alpha generation teaching methods: Digitalization of learning material. *International Journal of Advanced Natural Sciences and Engineering Researches*, *7*(4), 224–229. https://doi.org/10.59287/ijanser.704

Ardoin, N. M., Bowers, A. W., & Gaillard, E. (2020). Environmental education outcomes for conservation: A systematic review. *Biological Conservation*, *241*, 108224. https://doi.org/10.1016/j.biocon.2019.108224

Atukunda, J., & Maja, M. M. (2022). Computer practice module lecturers' experiences of internal continuous assessment at technical vocational education and training colleges. *International Journal of Educational Methodology*, *8*(1), 151–162. https://doi.org/10.12973/IJEM.8.1.151

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Budiarto, M. K., Asrowi, Gunarhadi, Karsidi, R., & Rahman, A. (2024). E-Learning platform for enhancing 21st century skills for Vocational School students: A systematic literature review. *Electronic Journal of E-Learning*, *22*(5), 76–90. https://doi.org/10.34190/ejel.22.5.3417

Burgos-Videla, C., Parada-Ulloa, M., & Martínez-Díaz, J. (2025). Critical thinking in the classroom: The historical method and historical discourse as tools for teaching social studies. *Frontiers in Sociology*, *10*, 1526437. https://doi.org/10.3389/fsoc.2025.1526437

Cairns, R., & Garrard, K. A. (2024). 'Learning from history is something that is important for the future': Why Australian students think history matters. *Policy Futures in Education*, *22*(3), 369–382. https://doi.org/10.1177/14782103231177615

Chen, S. Y., & Liu, S. Y. (2020). Developing students' action competence for a sustainable future: A review of educational research. *Sustainability*, *12*(4), 1374. https://doi.org/10.3390/su12041374

Clark, R. C., & Mayer, R. E. (2023). *E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning* (5th ed.). John Wiley & Sons.

Creswell, J. W., & Plano Clark, V. L. (2023). Revisiting mixed methods research designs twenty years later. In C. N. Poth (Ed.). *The Sage Handbook of Mixed Methods Research Designs*. https://doi.org/10.4135/9781529682663.n6

Desfandi, M. (2017). Building ecoliteracy through Adiwiyata program (study at Adiwiyata School in Banda Aceh). *Indonesian Journal of Geography*, *49*(1), 51–56. https://doi.org/10.22146/ijg.11230

Dickmann, I., & Consorte-McCrea, A. (2025). The role of ecopedagogy in the development of sustainability responsible students. In W. Leal Filho, B. Gasparetto Rebelatto, A. Annelin & G.O. Boström (Eds.), *Competence Building in Sustainable Development* (pp. 379-398). Springer. https://doi.org/10.1007/978-3-031-80380-2_18

Erdianto, A., Rofiqo Irwan, S. N., & Kastono, D. (2019). Fungsi ekologis vegetasi Taman Denggung Sleman sebagai pengendali iklim mikro dan peredam kebisingan. *Vegetalika*, *8*(3), 139-152. https://doi.org/10.22146/veg.41374

Fiorella, L., & Mayer, R. E. (2021). The generative activity principle in multimedia learning. In R. E. Mayer & L. Fiorella (Eds.), *The Cambridge handbook of multimedia learning* (3rd ed., pp. 339–350). Cambridge University Press. https://doi.org/10.1017/9781108894333.036

Hake, R. R. (1999). *Analysing change/gain score*. American Education Research Association's Devision D.

Herrera Córdova, A. V., Pardo Capa, L. E., Torrales Avilés, O. M., Villalta Leon, B. A., & Avilés Haiman, E. L. (2024). The use of Genially as an interactive didactic resource in History teaching: Impact on students motivation and comprehension. *Seminars in Medical Writing and Education, 3*, 651. https://doi.org/10.56294/mw2024651

Hung, R. (2017). Towards ecopedagogy: An education embracing "ecophilia." *Educational Studies in Japan: International Yearbook, 11*, 43–56. https://doi.org/10.7571/esjkyoiku.11.43

Iyengar, R., Iftekhar, S. N., Witenstein, M., & Chand, K. (2025). Ecopedagogy as a lever for climate justice towards a just transition. *Current Issues in Comparative Education, 27*(1), 197-215. https://doi.org/10.52214/cice.v27i1.13342

Kahn, R. V. (2010). *Critical pedagogy, ecoliteracy, & planetary crisis: The ecopedagogy movement*. Peter Lang.

Kopnina, H. (2020). Education for the future? Critical evaluation of education for sustainable development goals. *Journal of Environmental Education, 51*(4), 280–291. https://doi.org/10.1080/00958964.2019.1710444

Kopnina, H., & Bedford, T. (2024). From pseudo to genuine sustainability education: Ecopedagogy and degrowth in business studies courses. *Australian Journal of Environmental Education, 40*(3), 574-587. https://doi.org/10.1017/aee.2023.39

Koyama, D., & Watanabe, T. (2023). Why a dispositional view of ecological literacy is needed. *Teaching in Higher Education, 28*(5), 1108–1117. https://doi.org/10.1080/13562517.2023.2198637

Lazaris, D. (2025). Environmental education and digital tools: A case study of pollution of local ecosystems by students as future ecologically responsible citizens. *European Journal of Health and Biology Education, 14*(1), 1–15. https://doi.org/10.29333/ejhbe/16721

Makransky, G., & Petersen, G. B. (2021). The cognitive affective model of immersive learning (CAMIL): A theoretical research-based model of learning in immersive virtual reality. *Educational Psychology Review, 33*(3), 937–958. https://doi.org/10.1007/s10648-020-09586-2

Marpelina, L., Sariyatun, S., & Andayani, A. (2025). Rethinking ecopedagogy in web-based history learning: A critical examination of its impact on students' ecoliteracy. *Ianna Journal of Interdisciplinary Studies, 7*(2), 773–788. https://doi.org/10.5281/zenodo.15599671

Ministry of Environment and Forestry. (2023). *National waste generation data 2022* [National Waste Management Information System]. https://sampahnasional.kemenlh.go.id/portal-indikatif/data/timbulan-sampah

Misiaszek, G. W. (2020a). *Ecopedagogy: Critical environmental teaching for planetary justice and global sustainable development*. Bloomsbury Publishing Plc. https://doi.org/10.5040/9781350083820

Misiaszek, G. W. (2020b). Ecopedagogy: Teaching critical literacies of 'development', 'sustainability', and 'sustainable development.' *Teaching in Higher Education, 25*(5), 615–632. https://doi.org/10.1080/13562517.2019.1586668

Misiaszek, G. W. (2023). *Freire and environmentalism: Ecopedagogy* (1st ed.). Bloomsbury Academic. https://doi.org/10.5040/9781350292130

Montero Reyes, Y., Herrera Córdova, A. V., Pardo Capa, L. E., Torrales Avilés, O. M., & Villalta Leon, B. A. (2024). Interactive strategies for teaching history: The impact of Genially on motivation and learning. *Seminars in Medical Writing and Education*, *3*, 634. https://doi.org/10.56294/mw2024634

Moreno, R., & Mayer, R. E. (2007). Interactive multimodal learning environments. *Educational Psychology Review, 19*(3), 309–326. https://doi.org/10.1007/s10648-007-9047-2

Moser, M., & Zimmermann, M. (2025). Meaning-making through dialogic classroom discourse in History classes: Multi-perspective case studies from a teacher professional development program. *Journal of Social Studies Research*, *49*(1), 51–70. https://doi.org/10.1177/23522798241278284

Muir, T., Wang, I., Trimble, A., Mainsbridge, C., & Douglas, T. (2022). Using interactive online pedagogical approaches to promote student engagement. *Education Sciences*, *12*(6), 415. https://doi.org/10.3390/educsci12060415

Murti, W., Rohman, F., Sapta Sari, M., & Ibrohim, I. (2025). Ecoliteracy competencies: A systematic literature review of domains, approaches, and impacts in education. *Eurasia Journal of Mathematics, Science and Technology Education*, *21*(8), em2677. https://doi.org/10.29333/ejmste/16658

Nardo, A. (2021). Exploring a Vygotskian theory of education and its evolutionary foundations. *Educational Theory*, *71*(3), 331–352. https://doi.org/10.1111/edth.12485

Nuttall, D. (2021). What is the purpose of studying History? Developing students' perspectives on the purposes and value of history education. *History Education Research Journal*, *18*(1), 89–108. https://doi.org/10.14324/HERJ.18.1.06

Oinonen, I., Seppälä, T., & Paloniemi, R. (2024). How does action competence explain young people's sustainability action? *Environmental Education Research*, *30*(4), 499–518. https://doi.org/10.1080/13504622.2023.2241675

Pinedo, A., Diemer, M. A., & Frisby, M. B. (2024). Critical consciousness and youth political activism. *Annual Review of Developmental Psychology*, *6*(1), 351-372. https://doi.org/10.1146/annurev-devpsych-010923-113449

Popa, N. (2023). How meaning making cultivates historical consciousness: Identifying a learning trajectory and pedagogical guidelines to promote it. *The Social Studies*, *114*(4), 139–159. https://doi.org/10.1080/00377996.2022.2140641

Ricoy, M.-C., & Sánchez-Martínez, C. (2022). Raising ecological ewareness and digital literacy in primary school children through gamification. *International Journal of Environmental Research and Public Health*, *19*(3), 1149. https://doi.org/10.3390/ijerph19031149

Rudd, J. R., Woods, C., Correia, V., Seifert, L., & Davids, K. (2021). An ecological dynamics conceptualisation of physical 'education': Where we have been and where we could go next. *Physical Education and Sport Pedagogy*, *26*(3), 293–306. https://doi.org/10.1080/17408989.2021.1886271

Sayono, J., Jauhari, N., Ayundasari, L., & Sulistyo, W. D. (2020). Development of projo bale model based on android application in history and local wisdom studies of Malang. *International Journal of Emerging Technologies in Learning*, *15*(7), 4-16. https://doi.org/10.3991/IJET.V15I07.13219

Schneider, S., Beege, M., Nebel, S., Schnaubert, L., & Rey, G. D. (2022). The cognitive-affective-social theory of learning in digital environments (CASTLE). *Educational Psychology Review*, *34*(1), 1–38. https://doi.org/10.1007/s10648-021-09626-5

Shih, Y.-H. (2018). Some critical thinking on Paulo Freire's critical pedagogy and its educational implications. *International Education Studies, 11*(9), 64. https://doi.org/10.5539/ies.v11n9p64

Sigit, D. V. (2023). Ecoliteracy's contribution to creative thinking: A study of senior high school students. *Journal of Turkish Science Education, 20*(2), 356–368. https://doi.org/10.36681/tused.2023.020

Stoel, G., Logtenberg, A., Wansink, B., Huijgen, T., Van Boxtel, C., & Van Drie, J. (2017). Measuring epistemological beliefs in history education: An exploration of naïve and nuanced beliefs. *International Journal of Educational Research, 83*, 120–134. https://doi.org/10.1016/j.ijer.2017.03.003

Sung, P.-F. (2020). Historical consciousness matters: National identity, historical thinking and the struggle for a democratic education in Taiwan. *Journal of Curriculum Studies, 52*(5), 685–701. https://doi.org/10.1080/00220272.2020.1789225

Suripah, S., & Susanti, W. D. (2022). Alternative learning during a pandemic: Use of the website as a mathematics learning media for student motivation. *Infinity Journal, 11*(1), 17. https://doi.org/10.22460/infinity.v11i1.p17-32

Wulandari, R., Iswara, A. P., Qadafi, M., Prayogo, W., Astuti, R. D. P., Utami, R. R., Jayanti, M., Awfa, D., Suryawan, I. W. K., Fitria, L., & Andhikaputra, G. (2024). Water pollution and sanitation in Indonesia: A review on water quality, health and environmental impacts, management, and future challenges. *Environmental Science and Pollution Research, 31*, 65967-65992. https://doi.org/10.1007/s11356-024-35567-x