



Climate-Integrated EFL Instruction: A Design-Based Study to Develop Ecoliteracy and Scientific Reading Comprehension

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Received 22/01/2026	ABSTRACT Climate change, as a global emergency, increasingly shapes the lived experiences of teachers and students, necessitating multidisciplinary and pedagogically innovative educational responses that foster climate change awareness. This study examines the integration of climate change education into English language teaching in a rural public junior high school located in a deforested area dominated by palm oil plantations and mining activities. The intervention was implemented in an eighth-grade classroom using an inquiry-based learning approach to explore four core dimensions of climate change: causes, impacts, adaptation, and mitigation. The study pursued two main objectives: (1) to cultivate students' ecoliteracy and
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	scientific reading comprehension, and (2) to develop students' ecological awareness and eco-identity. Employing a design-based research, data were collected through quantitative measures (pre-test, mid-intervention test, and post-test) and qualitative sources (classroom observations and reflective journals). Quantitative data were analyzed using ANOVA and Tukey's HSD tests, while qualitative data were examined through thematic analysis. The findings indicate a statistically significant improvement in students' ecological scientific reading comprehension between pre- and post-intervention, with 64.71% of students demonstrating substantial learning gains. Qualitative findings further reveal a balanced development of ecological knowledge, values, and action-oriented dispositions, contributing to the formation of positive eco-identities among students. Keywords: climate change education, ecoliteracy, eco-identity, English language teaching (ELT), reading comprehension
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Introduction

Climate change constitutes one of the most urgent and complex challenges of the 21st century, requiring coordinated responses that extend beyond scientific and technological domains to include educational transformation. Increasingly, scholars argue that education must play a central role in preparing learners to understand, critically evaluate, and respond to environmental challenges through informed and responsible action (Huot & Em, 2025). This shift calls for interdisciplinary approaches that not only transmit knowledge about climate systems but also cultivate the cognitive, ethical, and identity-oriented dimensions of sustainability. Within this agenda, climate change education (CCE) is no longer viewed as the sole responsibility of science disciplines; rather, it demands integration across curricular domains to support holistic and actionable forms of learning.

In this regard, English language teaching (ELT) occupies a uniquely strategic position. As English functions as the primary medium through which global scientific knowledge and environmental discourses circulate, ELT classrooms represent critical sites for mediating learners' access to climate-related knowledge. Recent scholarship suggests that integrating sustainability-oriented content into language instruction can simultaneously enhance language proficiency and foster learners' environmental awareness and engagement (Nurhaliza et al., 2024). However, much of this work remains at the level of thematic inclusion, with limited attention to how

language pedagogy can systematically support the development of disciplinary forms of literacy required to engage with complex scientific knowledge. Consequently, the transformative potential of ELT as a site for interdisciplinary and sustainability-oriented learning remains under-theorized and under-empirically under-examined.

From a literacy perspective, this limitation is particularly salient. Contemporary understandings of academic literacy emphasize that reading in disciplinary contexts involves more than comprehension; it requires engagement with specialized discourse practices, including interpreting technical vocabulary, analyzing causal and systemic relationships, and synthesizing information across multimodal sources. These competencies are central to scientific literacy and are indispensable for meaningful engagement with climate change issues (Silvhiany et al., 2026). Yet, in many ELT contexts, instructional practices continue to privilege narrative and general interest texts, offering limited opportunities for learners to engage with scientific texts that demand higher-order reading strategies. This disconnect constrains learners' ability to access and critically engage with climate-related knowledge, thereby limiting the broader educational goal of fostering informed and active global citizens.

The Indonesian context exemplifies this tension between policy ambition and pedagogical practice. National educational reforms, as reflected in the Computer-Based National Assessment, emphasize the development of literacy, numeracy, and character, alongside the integration of sustainability and CCE. Nevertheless, findings from the 2024 Learning Environment Survey indicate that classroom instruction remains insufficiently contextualized and has yet to meaningfully incorporate environmental themes into everyday pedagogical practices (Kementerian Pendidikan Dasar dan Menengah, 2025). This gap suggests that while policy frameworks increasingly recognize the importance of interdisciplinary and sustainability-oriented learning, there is a lack of empirically grounded pedagogical models that demonstrate how such integration can be enacted in classroom settings—particularly within ELT.

Although a growing body of research has explored ecoliteracy and environmental education, existing studies have largely focused on science classrooms or on raising general environmental awareness. Comparatively little attention has been paid to how ELT can foster students' engagement with scientific texts as a means of developing both language proficiency and ecological understanding. Moreover, the potential of indigenous knowledge systems as pedagogical resources for CCE in language classrooms remains insufficiently explored (Datta et al., 2024), despite their recognized role in shaping contextually grounded and culturally responsive understandings of sustainability. Addressing these gaps requires a reconceptualization of ELT

as a site where language learning, scientific literacy, and ecological meaning-making intersect.

Responding to this need, the present study advances an integrated pedagogical approach that positions CCE as both content and context for language learning. Drawing on scientific and multimodal texts, including those grounded in indigenous knowledge, the study seeks to examine how ELT can support learners' development of ecoliteracy, scientific reading comprehension, and eco-identity. Specifically, the study pursues two objectives: (1) to investigate the extent to which the integration of CCE into ELT enhances students' ecoliteracy and scientific reading comprehension, and (2) to explore how engagement with climate change mitigation texts grounded in indigenous knowledge contributes to the development of students' ecological awareness and eco-identity.

Guided by these objectives, the study addresses the following research questions:

1. How does the integration of climate change education into English language teaching influence students' ecoliteracy and scientific reading comprehension?
2. How do climate change mitigation texts grounded in indigenous knowledge contribute to students' ecological awareness and eco-identity in the English as a foreign language classroom?

Building on these theoretical and empirical considerations, the following section presents the conceptual framework that underpins the study, illustrating how multimodal climate-related input, deep learning processes, and culturally grounded resources interact to support students' literacy development and eco-identity formation within a Design-Based Research (DBR) paradigm.

Literature Review

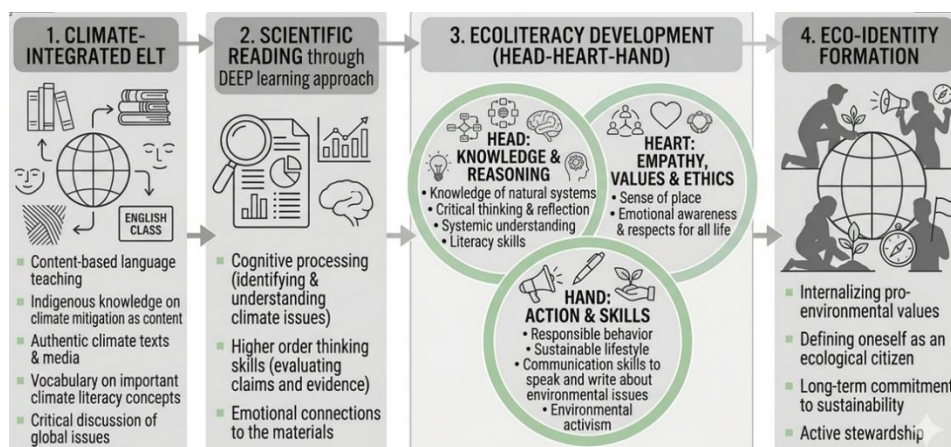
Recent scholarship positions CCE as a cross-curricular requirement rather than a concern for one specific subject, reflecting global calls for education systems to respond to ecological crises through transformative and integrative learning approaches (Sakhiyya et al., 2025). Within this shift, English as a Foreign Language (EFL) education—particularly at the secondary level—offers a strategic yet underexplored site for embedding climate-related knowledge, values, and identity formation. While prior studies show that integrating environmental content into language classrooms can enhance learners' motivation, critical engagement, and awareness of global issues (Micalay-Hurtado & Poole, 2022), research has largely treated language development and sustainability education as parallel rather than fully

integrated goals. Consequently, there remains limited empirical work examining how CCE can be systematically embedded in EFL to simultaneously support scientific literacy, ecoliteracy, and identity-oriented outcomes, and through culturally grounded pedagogies.

To synthesize the intersecting components of CCE and English language learning, Figure 1 presents a comprehensive conceptual framework. The model illustrates how integrating climate concepts into ELT provides the foundational context for students to engage in scientific reading through a deep learning approach. This pedagogical process facilitates holistic ecoliteracy development across cognitive (head), affective (heart), and behavioral (hand) dimensions. Ultimately, this structured pathway fosters the internalization of pro-environmental values, culminating in the formation of a lasting eco-identity and active stewardship.

Figure 1

Theoretical Model of Eco-Identity Formation via Climate-Integrated Language Teaching



Ecoliteracy provides a critical conceptual foundation for such integration. Defined as learners' capacity to understand ecological systems, recognize interdependence between human and natural worlds, and act responsibly within these systems (Capra, 2007), ecoliteracy extends beyond cognitive knowledge to include affective and behavioral dimensions (Kemp et al., 2022). Central competencies—such as systems thinking, environmental awareness, and responsible action—position ecoliteracy as a multifaceted outcome that can be cultivated across disciplines. Within this framework, CCE functions as a key domain through which ecoliteracy is implemented. CCE is often conceptualized through four interconnected dimensions—

causes, effects, adaptation, and mitigation (Teixeira & Crawford, 2022)—which collectively emphasize not only scientific understanding but also learners’ sense of agency and responsibility (Silvhiany et al., 2024). However, the realization of these outcomes depends on pedagogical approaches that move beyond surface-level knowledge transmission toward deeper, meaning-oriented learning processes.

In this regard, integrating CCE into ELT aligns closely with the principles of deep learning, which emphasize meaningful understanding, knowledge transfer, and higher-order thinking. Deep learning frameworks highlight competencies such as critical thinking, communication, collaboration, and global citizenship (Fullan et al., 2018), all of which match the transformative goals of climate education. Within language classrooms, these competencies are particularly relevant for engaging with scientific texts, which require learners to interpret, analyze, and synthesize complex information rather than rely on literal comprehension. Content-based and literacy-oriented approaches in EFL have demonstrated potential in supporting such outcomes by linking language development with disciplinary knowledge (Barros-Del Río & Mediavilla-Martínez, 2025). However, without carefully designed instructional scaffolding, the integration of complex scientific content may remain inaccessible to learners, especially at the lower secondary level.

One promising pathway for supporting deep learning in this context is the use of multimodal scientific texts. Multimodality enables learners to construct meaning through the interaction of linguistic, visual, and symbolic representations, thereby making abstract scientific concepts more accessible (Jabeen et al., 2023). Studies indicate that multimodal texts—such as illustrated informational texts and visual-rich scientific materials—can enhance comprehension of complex processes, including cause–effect relationships in environmental systems (Jasmine et al., 2025; Putri et al., 2024). In CCE, such texts support learners in visualizing dynamic processes and engaging more deeply with mitigation and adaptation strategies. Importantly, multimodal resources also create opportunities for integrating indigenous knowledge systems, which often convey ecological understanding through narrative, symbolism, and visual representation. This integration is particularly relevant in contexts like Indonesia, where local ecological knowledge reflects long-standing relationships between communities and their environments.

Despite these advances, the intersection of CCE, deep learning, and indigenous knowledge within ELT remains insufficiently explored. Existing studies rarely examine how culturally grounded, multimodal scientific texts can support not only reading comprehension but also the development of ecoliteracy and eco-identity among EFL learners. Moreover, there is a lack of

research adopting iterative and design-oriented approaches to systematically develop and refine such pedagogical interventions in classroom settings (Saiful & Shein, 2025). This gap underscores the need for studies that conceptualize ELT as a site for integrated ecological, cognitive, and identity development, supported by contextually relevant materials and sustained instructional design.

Taken together, the literature suggests that while CCE, ecoliteracy, deep learning, and multimodal text-based instruction are individually well-established, their systematic integration in junior high school EFL—particularly through indigenous knowledge and iterative pedagogical design—remains limited. Addressing this gap requires a framework that connects multimodal input, deep learning processes, and multidimensional literacy outcomes, including ecological awareness and identity formation.

Methodology

Research Design

This study employed a design-based research (DBR) approach to systematically design, implement, and refine an instructional intervention integrating climate change education into English Language Teaching (ELT). DBR is particularly suitable for investigating complex educational innovations in authentic classroom settings while simultaneously generating theoretical and pedagogical insights (Anderson & Shattuck, 2012).

Unlike linear experimental designs, DBR is characterized by iterative cycles of design, enactment, analysis, and refinement. Data from this article is part of the larger project on designing model of integrated climate change education curriculum in English language learning. The overall design is described in Table 1.

Table 1

Overall Design-Based Research Project

Phase	Research Activities	Data Sources	Key Design Features	Theoretical Contributions
Phase 1: Problem Identification & Analysis	- Literature review on CCE-ELT integration - Needs analysis at research site	- Policy documents - FGD with EFL teachers in the region	- Alignment with national education framework - Contextualization to rural	Refined understanding of barriers to CCE integration in under-

	● Identification of indigenous knowledge resources ● Collaborations between university researchers & teacher	● Curriculum analysis	● Indonesian setting ● Integration of local ecological knowledge	● resourced ELT contexts ● Conceptualization of indigenous knowledge as pedagogical resource
Phase 2: Intervention Design & Development	● Development of CSRLA instrument ● Design of 10-week teaching procedures ● Selection and design of multimodal scientific texts ● Integration of indigenous knowledge ● Expert validation of the materials	● Design team meeting records ● Expert validation feedback ● Instrument reliability testing ($\alpha = 0.835$) ● Pilot materials	● Four CCE themes: cause, impact, adaptation, mitigation ● Multimodal text integration ● Indigenous knowledge focus ● Scaffolded cognitive demand (C1–C5)	● implementation of ecoliteracy dimensions (Head, Heart, Hand, Eco-Identity) ● Framework for sequencing scientific reading in ELT
Phase 3: Implementation	● Pre-test administration ● Weekly instructional procedures ● During-intervention test ● Weekly reflective journal collection ● Classroom observation	● CSRLA pre-test scores ● 340 reflective journal entries ● During-intervention test scores ● Field notes ● Student work samples	● Progressive text complexity ● Guided reading and discussion ● Cause–effect analysis focus ● Reflective writing integration ● Connection to local contexts	● Empirical documentation of implementation processes in authentic classroom conditions ● Identification of pedagogical scaffolds supporting scientific reading

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Phase 4: Evaluation and analysis	● Post-test administration (Week 11) ● Quantitative analysis (ANOVA, Tukey's HSD) ● Thematic analysis of journals ● Intercoder reliability check ($\kappa = 0.913$) ● Pattern identification	● CSRLA post-test scores ● Comparative test data (3 time points) ● Coded journal themes ● Coder meeting records	● Triangulation of quantitative and qualitative data ● Multidimensional ecoliteracy framework ● Tracking of development	● Evidence of CCE-ELT integration effects on scientific reading comprehension ● Thematic mapping of eco-identity formation processes
Phase 5: Refinement & Theoretical Articulation	● Interpretation of patterns of differences ● Identification of design principles ● Articulation of indigenous knowledge contribution ● Development of pedagogical model	● Cross-analysis of all data sources ● Researcher memos ● Draft design principles ● Theoretical synthesis	● Iterative reflection on design effectiveness ● Contextualization of findings within broader CCE literature	● Design principles for integrating CCE in ELT ● Model of indigenous knowledge integration for eco-identity development

In this article, the research focused on the implementation phase while still adhering to core DBR principles, including ecological validity, theory-informed design, and iterative responsiveness to classroom dynamics. The intervention was theoretically grounded in three interrelated frameworks:

1. **ecoliteracy**, emphasizing cognitive, affective, and behavioral environmental understanding;
2. **deep learning**, focusing on higher-order thinking, meaning-making, and knowledge transfer; and
3. **scientific reading within multimodal texts**, which supports comprehension of complex informational content in ELT contexts.

The instructional design applied these frameworks through scientific multimodal texts organized around four key climate change themes: causes,

impacts, adaptation, and mitigation. The DBR approach enabled the examination of how these design principles functioned in practice, particularly in fostering students' scientific reading comprehension, ecoliteracy development, and emerging eco-identity.

Research Site and Participants

The study was conducted in a public junior high school located in a deforested area dominated by palm oil plantations and mining activities in a rural Musi Banyuasin regency, South Sumatra, Indonesia, a context characterized by limited access to interdisciplinary instructional resources, particularly those integrating environmental education into ELT.

A total of 34 eighth-grade students (aged 13–17) from one intact class participated in the study. The class was selected through purposive sampling, ensuring the feasibility of implementing the intervention within an authentic instructional setting. The use of an intact class aligns with DBR's emphasis on naturalistic inquiry, where learning processes are examined within real classroom constraints rather than controlled experimental conditions.

All participants engaged in the intervention as part of their regular English lessons. Ethical considerations were conducted in accordance with Indonesia's National Research and Innovation Agency (BRIN) ethical clearance for social sciences and humanities and was approved by the Institute for Research and Community Service of Sriwijaya University.

Table 2

Participants' profile

Gender	Age Range (years)	Number of Students
Female	13–14	14
Female	15–17	4
Male	13–14	12
Male	15–17	4
Total (N)		34

Intervention Design and Teaching Procedures

The intervention consisted of a 10-week instructional program, designed as a theory-driven pedagogical prototype within the DBR framework. Each week focused on specific learning objectives that progressively integrated ecoliteracy, scientific reading, and climate change content. The instructional sequence followed a progressive learning trajectory:

Indigenous knowledge integration → Scientific reading comprehension → Ecoliteracy awareness → Climate action → Eco-identity formation

Students engaged with scientific multimodal texts (e.g., visuals, infographics, short expository texts) through structured activities, including guided reading, collaborative discussion, critical analysis, and reflective writing.

Table 3

Teaching procedures

Week	Learning Focus	Main Activities	Skill Development
1	Introduction to Climate Change and Ecoliteracy	Students explored basic concepts of climate change and environmental issues through short scientific texts and visuals, focusing on key vocabulary and general comprehension.	Vocabulary building, general comprehension of environmental issues
2	Causes of Environmental Problems	Students read texts related to waste management and burning trash, identified causes and effects, and discussed alternative environmentally friendly practices.	Cause and effect analysis, discussion of local practices Interpretation of environmental visuals and disaster narratives
3	Climate Change Impacts	Students engaged with texts and visuals illustrating climate-related disasters, analyzed impacts on nature and daily life, and shared reflections through guided discussion.	Interpretation of environmental visuals and disaster narratives
4	Reading for Cause and Effect Relationships	Students analyzed scientific explanations of climate processes, focusing on cause and effect expressions and comprehension of environmental phenomena.	Analysis of scientific explanations
5	Local Ecosystems and Environmental Issues	Students read a narrative-based environmental text, identified ecological problems, and summarized key ideas using mind maps.	Narrative reading and mind mapping
6	Indigenous Ecological Practices	Students examined texts describing traditional ecological tools and practices, discussed	Exploration of traditional sustainability practices

		their environmental value, and connected them to sustainability concepts.	
7	Climate Change and Biodiversity	Students read scientific texts about pollinators and biodiversity loss, identified key information, and discussed human roles in environmental protection.	Scientific reading on pollinators and ecosystem balance
8	Adaptation Strategies	Students analyzed texts describing climate adaptation strategies at individual and community levels and reflected on practical actions through guided tasks.	Evaluation of real-life adaptation practices
9	Mitigation and Climate Action	Students read texts focusing on mitigation efforts, evaluated proposed solutions, and expressed opinions through short written and oral responses.	Argumentation and opinion-based responses
10	Synthesis and Reflection	Students synthesized information from previous weeks through integrative reading activities, reflective discussion, and short written responses related to ecoliteracy.	Integrative reading and eco-reflective writing

From a DBR perspective, these procedures functioned as a designed intervention prototype, allowing examination of how instructional elements influenced learning processes and outcomes.

Data Collection

This study adopted a convergent mixed-methods approach to capture both learning outcomes and developmental processes.

Quantitative Data

Quantitative data were collected through three assessment points:

- Pre-test (baseline)
- Mid-intervention test
- Post-test (outcome)

The instrument used was the Climate Science Reading Literacy Assessment (CSRLA) (Purwandani et al., 2025), consisting of 40 items measuring

students' scientific reading comprehension and ecoliteracy. It demonstrated strong psychometric properties:

- Item validity: All items met acceptable correlation thresholds
- Reliability: Cronbach's alpha = 0.835, indicating high internal consistency

(Item-level statistics are presented in the Appendix.)

Qualitative Data

Qualitative data were obtained through students' reflective journals (n = 34), written weekly throughout the intervention. These journals captured students':

- cognitive understanding of environmental issues;
- emotional engagement and values;
- behavioral intentions and actions; and
- emerging ecological identity

Within DBR, these qualitative data are critical for understanding how and why the intervention works, beyond measurable outcomes.

Data Analysis

Quantitative Analysis

Quantitative data were analyzed using inferential statistics to examine learning progression across the three phases:

1. Individual scores (0–40) were calculated for each student
2. A one-way repeated measures ANOVA was conducted to identify significant differences across pre-, mid-, and post-tests
3. When significant differences were detected ($p < 0.05$), Tukey's HSD post hoc test was applied to determine pairwise differences
4. Score patterns were interpreted to identify trajectories of learning improvement

Qualitative Analysis

Qualitative data were analyzed using thematic analysis, guided by an ecoliteracy framework consisting of four dimensions:

- head (knowledge and awareness);
- heart (values and empathy);
- hand (action and behavior); and
- eco-identity (self-concept and environmental positioning)

The analysis followed these steps: initial coding of reflective journals, categorization into ecoliteracy dimensions, and theme generation across student responses

1. Cross-validation between coders

To ensure reliability, inter-rater agreement was calculated using Cohen's Kappa, yielding a value of 0.913, indicating substantial agreement between the two coders. This analysis enabled the researchers to identify recurring themes and representative behaviors that illustrated how students internalized ecological awareness and eco-identity formation.

Results

Development of Students' Scientific Reading Comprehension

Students' scientific reading comprehension was examined across three measurement points: pre-test (T1), mid-intervention (T2), and post-test (T3). As presented in Table 4, mean scores increased substantially from 43.82 (SD = 19.20) at T1 to 67.37 (SD = 13.23) at T2, and further to 81.36 (SD = 13.13) at T3, indicating a continuous upward trajectory in performance.

A one-way ANOVA revealed a **statistically significant effect of instructional stage**, $F(2, 99) = 51.269, p < .001$, with a **large effect size** ($\eta^2 = 0.51$). This suggests that over half of the variance in students' scores can be attributed to the instructional intervention, indicating strong pedagogical impact.

Table 4

Grand mean scores before, during and after training

Summary of Data								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Pre-test (T1)	34	43.82	19.200	3.293	37.12	50.52	8	75
During Intervention (T2)	34	67.37	13.230	2.269	62.75	71.98	28	83
Post-test (T2)	34	81.36	13.130	2.252	76.78	85.95	35	95
Total	102	64.19	21.824	2.161	59.90	68.47	8	95
ANOVA								

Source	Sum of Squares	df	Mean Square	F	Sig.		
Between Groups	24475.275	2	12237.637	51.269	0.000		
Within Groups	23630.793	99	238.695				
Total	48106.068	101					
Post Hoc Tukey HSD (beta)							
Source	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval		Interpretation	
				Lower Bound	Upper Bound		
Tukey HSD	T1: T2	-23.544*	3.747	0.000	-32.46	-14.63	Significant
	T1:T3	-37.541*	3.747	0.000	-46.46	-28.63	Significant
	T2:T1	23.544*	3.747	0.000	14.63	32.46	Significant
	T2:T3	-13.997*	3.747	0.001	-22.91	-5.08	Significant
	T3: T1	37.541*	3.747	0.000	28.63	46.46	Significant
	T3:T2	13.997*	3.747	0.001	5.08	22.91	Significant

A Tukey HSD post hoc test was performed to determine the specific group differences. The results demonstrated that all pairwise comparisons were statistically significant. Specifically, the mean score during the intervention stage (T2) was significantly higher than that of the pre-test (T1) [Mean Difference = -23.544, $p < 0.001$]. This indicates a substantial improvement in students' scores during the intervention. Similarly, the post-test (T3) showed a significantly higher mean score compared to the pre-test (T1) [Mean Difference = -37.541, $p < .001$], suggesting a considerable improvement after completion of the instructional process. Furthermore, a significant difference was also observed between the intervention stage (T2) and the post-test (T3) [Mean Difference = -13.997, $p = .001$].

Notably, the significant difference between T2 and T3 indicates that learning gains were sustained and further developed beyond the initial intervention phase, suggesting cumulative learning effects. Taken together, these findings indicate that the integration of climate change content through scientific multimodal texts substantially enhanced students' ability to comprehend complex informational texts, supporting both immediate and progressive learning gains.

Development of Ecoliteracy and Eco-Identity

Students' perceptions of their learning experiences were analyzed based on classroom observations and reflective journals written after each instructional session. The thematic analysis identified four major dimensions that capture students' ecoliteracy development: head (knowledge and awareness), heart (values and empathy), hand (action and behavior), and eco-identity (integration of knowledge, values, and action). Each dimension represents a

distinct yet interconnected aspect of students' growth in ecological awareness and eco-identity formation. A summary of the themes and representative codes derived from 34 students' reflective journals is presented in Table 5 below.

Table 5

Result of thematic analysis

Ecoliteracy Dimension	Theme	Code	Description	Example Statements	Frequency (n)
Head	Understanding environmental causes and effects	K1	Students demonstrate awareness of the relationship between human activities and environmental problems such as floods, pollution, and climate change.	"Burning waste can cause floods and environmental damage." (S); "Floods happen when people throw garbage into rivers." (E).	18
	Recognizing biodiversity and ecological balance	K2	Students recognize the importance of biodiversity and the need to protect ecosystems and living organisms.	"Bees and fish must be protected." (HN); "Pesticides harm bees." (RA)	6
	Learning from local context and indigenous ecology	K3	Students show understanding of environmental knowledge rooted in local ecological practices and indigenous wisdom.	"Peatlands must not be burned." (MA)	1
Heart	Developing care and empathy for living beings	K4	Students express emotional concern and empathy toward animals, plants,	"I will plant flowers so bees can survive." (D); "Animals and plants must be	6

	Building moral awareness and environmental ethics	K5	and other living beings. Students express ethical considerations and moral responsibility related to environmental protection.	protected.” (BO); “I will not cut protected forests or pollute water.” (D); “I will stop playing with fire because it causes forest fires.” (SO)	2
	Feeling personal responsibility and connection to nature	K6	Students demonstrate personal attachment and responsibility toward protecting nature.	“I stopped throwing waste into rivers.” (VR); “Trees make the soil fertile and prevent dryness.” (AM)	3
Hand	Practicing eco-friendly habits	K7	Students indicate behavioral changes and daily practices that support environmental sustainability.	“I started sorting waste for recycling.” (IA); “I will recycle waste.” (Y); “I will keep the environment clean.” (SI)	27
	Initiating family and community participation	K8	Students encourage environmental awareness and action within their family or community.	“I will remind my parents to fertilize oil palm trees properly.” (VR); “I will educate my parents about pesticide use.” (IA); “I will tell my family to reduce pesticide use.” (RA)	4
	Engaging in environmental regeneration	K9	Students propose restorative environmental actions such as planting trees, conserving	“I will plant useful plants and trees.” (AM); “I will protect fish habitats.” (RO)	15

			habitats, or protecting species.		
Eco- Identity	Internalizing sustainable habits as a way of life	K11	Students express long- term commitment to maintaining environmentally responsible lifestyles.	“I will always keep my environment clean.” (E)	1

The thematic analysis based on the ecoliteracy framework of head, heart, and hand reveals multidimensional development in students’ environmental understanding and eco-identity. The findings indicate that the learning intervention not only facilitated cognitive awareness but also encouraged emotional engagement and environmentally responsible behavior.

In the head dimension, the most frequent theme was understanding environmental causes and effects (K1) with 18 occurrences. This indicates that many students understood the relationship between human activities and environmental problems. For example, one student stated, *“Burning waste can cause floods and environmental damage”* (S). These statements show that students started to understand the cause and effect of environmental problems. Some students also recognized the importance of biodiversity (K2), as shown in the statements *“Bees and fish must be protected”* (HN) and *“Pesticides harm bees”* (RA). This indicates some students understood the importance of protecting living organisms and ecosystems. However, learning from local context and indigenous ecology (K3) appeared only once. One student stated, *“Peatlands must not be burned”* (MA). This suggests that while students mentioned local ecological knowledge, it appeared less frequently in their reflections.

In the heart dimension, students showed emotional awareness and concern for the environment. For example, *“I will plant flowers so bees can survive”* (D) and *“Animals and plants must be protected”* (BO). This indicates that the students expressed concern for animals and plants. Some students also felt responsible for protecting the environment, as reflected in the statement *“I stopped throwing waste into rivers”* (VR). Meanwhile, students showed ethical awareness by expressing that they would avoid harmful actions, such as cutting protected forests or playing with fire (K5=2).

In the hand dimension, the theme practicing eco-friendly habits (K7) was most dominant with 27 occurrences. This result shows that many students expressed intentions to practice environmentally friendly behaviors in their daily lives. For example, students stated, *“I started sorting waste for*

recycling” (IA) and *“I will recycle waste”* (Y). Students also expressed willingness to restore the environment through actions such as planting trees or protecting habitats (K9), for example, *“I will plant useful plants and trees”* (AM). Some students also encouraged environmental actions within their families (K8), such as *“I will educate my parents about pesticide use”* (IA). Finally, the emergence of eco-identity (K11) showed the beginning of a long-term commitment to sustainable behavior, as reflected in the statement *“I will always keep my environment clean”* (E).

Discussion

This study investigated the integration of CCE into ELT through a DBR approach, examining its influence on students’ scientific reading comprehension and ecoliteracy development. The findings provide robust empirical evidence that such interdisciplinary instruction can yield significant cognitive, affective, and behavioral gains. By positioning climate change content as both the medium and context for language learning, the study demonstrates how ELT can be reconceptualized as a strategic site for fostering disciplinary literacy and ecological identity essential for addressing complex global challenges (Maijala et al., 2024).

Effects on Scientific Reading Comprehension

The first research question addressed the influence of the intervention on students’ scientific reading comprehension. The quantitative results revealed a statistically significant and sustained improvement in students’ scientific reading comprehension across the three assessment stages. The progression from pre-test to post-test, accompanied by a large effect size ($\eta^2 = 0.51$), indicates that the intervention exerted a strong pedagogical impact. This finding is further nuanced by individual learning trajectories: 64.71% of learners demonstrated significant gains, whereas 35.29% showed no statistically significant change. Such variation reflects the inherent heterogeneity of classroom learning, where students respond differently to instructional innovations. Consistent with prior research (Masitoh et al., 2025; Muhaimin et al., 2026), these differences suggest that while the instructional design was effective for the majority, some learners may require additional scaffolding, differentiated support, or extended exposure to achieve comparable outcomes.

Importantly, the significant differences across all measurement points—including continued improvement from mid-intervention (T2) to post-test (T3)—indicate cumulative and sustained learning rather than short-term gains. This pattern supports the effectiveness of the structured

instructional progression, which gradually developed students' ability to interpret scientific multimodal texts, analyze cause and effect relationships, and synthesize complex information. In line with previous studies (Brown, 2024; Firinci Orman, 2024; Léger-Goodes et al., 2022), the findings confirm that integrating content-based instruction within language learning enhances comprehension outcomes. However, the present study extends this body of work by demonstrating how climate change content, when embedded within a systematic reading-oriented pedagogy, functions as meaningful cognitive scaffolding. Specifically, positioning climate change as both content and context enabled learners to engage more deeply with complex informational texts than is typically observed in conventional ELT practices.

From a theoretical perspective, these results align with a deep learning framework, where learning involves not only information acquisition but also higher-order meaning-making and knowledge transfer. The use of multimodal scientific texts appeared to facilitate this process by providing multiple entry points for comprehension, thereby supporting students in constructing integrated and transferable understanding. The sustained improvement across stages further suggests that students internalized disciplinary reading practices, reinforcing the role of ELT as a site for developing academic literacy rather than solely general language skills.

Development of Ecoliteracy Across Head, Heart, and Hand

The second research question explored how engagement with climate change mitigation texts, including those grounded in indigenous knowledge, contributed to students' ecological awareness and eco-identity. The qualitative thematic analysis of reflective journals and classroom observations revealed a rich, multidimensional development across four interconnected dimensions—head (knowledge), heart (affect/values), hand (action), and eco-identity—capturing the holistic nature of ecoliteracy (Silvhiany et al., 2026).

Qualitative analysis reveals that students' ecoliteracy developed across four interconnected dimensions: head (cognitive), heart (affective), hand (behavioral), and eco-identity. In the cognitive domain, students showed increased understanding of environmental causes and effects, biodiversity, and local ecological issues. The prominence of cause and effect reasoning indicates that scientific texts were particularly effective in supporting conceptual learning. This finding is consistent with previous research suggesting that contextualized environmental content enhances comprehension of complex scientific ideas, especially when linked to learners' immediate environments (Rafiee Moghadam et al., 2022). Nevertheless, the relatively limited references to biodiversity and indigenous ecological knowledge suggest that deeper ecological interdependencies and locally

grounded knowledge systems require more explicit pedagogical emphasis (McLean Davies et al., 2024).

The behavioral domain emerged as the most dominant dimension, with many students reporting concrete actions such as recycling, waste management, and environmental advocacy within their families and communities. This aligns with research emphasizing the importance of action-oriented learning in translating awareness into practice (Ha et al., 2022). The instructional design—particularly reflective writing and collaborative discussion—appears to have played a critical role in bridging the gap between knowledge and action. These findings underscore the potential of ELT classrooms to move beyond knowledge transmission toward fostering environmentally responsible behavior (Arslan & Curle, 2021).

Eco-Identity Formation and the Role of Indigenous Knowledge

A key contribution of this study lies in its examination of eco-identity as an emergent outcome of integrated ELT instruction. The findings indicate that the interaction of cognitive understanding (head), emotional engagement (heart), and behavioral practice (hand) contributed to the initial formation of eco-identity. The integration of head, heart, and hand contributed to the development of students' eco-identity (Young et al., 2020). Students began to position themselves as environmental stewards and expressed commitments to sustainable living, reflecting early stages of identity transformation.

However, the relatively limited frequency of explicit eco-identity expressions suggests that identity development is gradual and may extend beyond the duration of the intervention. This is consistent with theoretical perspectives that conceptualize identity as socially constructed and longitudinal through repeated engagement and reflection. Despite this limitation, the emergence of eco-identity within a 10-week intervention highlights the transformative potential of interdisciplinary ELT.

The nascent emergence of this theme (K11) signifies the beginning of a profound internalization process, where learners increasingly identified themselves as environmental stewards and expressed long-term commitments to sustainable living. Importantly, the use of climate change mitigation texts grounded in indigenous knowledge played a contributing role in this identity development. Local and culturally familiar environmental practices enabled learners to connect abstract climate concepts with their lived experiences. By engaging with indigenous perspectives on sustainability, learners perceived environmental protection not merely as scientific knowledge but as a shared cultural value, which reinforced their identification as environmental stewards (Léger-Goodes et al., 2022). This finding

highlights the potential of culturally grounded pedagogy to foster a deeper, more integrated sense of self in relation to the environment.

Conclusions, Implications, and Limitations

This study confirms and extends existing research on CCE, scientific reading, and ecoliteracy within ELT. Theoretically, it advances an integrated framework that brings together ecoliteracy, deep learning, and scientific reading within a DBR paradigm. The findings demonstrate how these constructs interact to produce not only cognitive gains but also affective engagement, behavioral change, and identity formation. Pedagogically, the study provides an empirically grounded model for integrating CCE into ELT. By embedding interdisciplinary content into language instruction, the study illustrates how ELT can function as a meaningful space for promoting deep learning, ecological awareness, and responsible action. Importantly, the findings highlight the need for differentiated support to address learner variability, as well as more explicit integration of indigenous knowledge to strengthen contextual relevance.

Despite its contributions, this study has several limitations. The use of a single intact class and a single DBR cycle constraints the generalizability and iterative refinement of the findings to similar contexts. Additionally, the relatively short duration of the intervention constrains the extent to which long-term eco-identity development can be observed.

Future research should consider longitudinal designs, multiple DBR cycles, and diverse educational contexts to examine the scalability and sustainability of the proposed model. Further investigation into strategies for integrating indigenous knowledge more effectively and supporting lower-performing learners would also enhance the robustness of this pedagogical approach.

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Appendix

Validity of the Climate Science Reading Literacy Assessment (CSRLA)

Item	Cognitive Level	Mean	Std. Deviation	r value	Discrimination index	Difficulty Index	Level of Difficulty
Q01	C3	0.6730	0.46968	0.743	0.80	0.71	Easy
Q02	C4	0.5711	0.49551	0.583	0.68	0.57	Moderate
Q03	C4	0.6825	0.46607	0.611	0.66	0.68	Moderate
Q04	C4	0.7986	0.40154	0.418	0.34	0.80	Easy
Q05	C4	0.6327	0.48264	0.34	0.39	0.63	Moderate
Q06	C2	0.6896	0.46322	0.45	0.48	0.69	Moderate
Q07	C5	0.7725	0.41971	0.485	0.45	0.77	Easy
Q08	C5	0.7891	0.40843	0.507	0.48	0.79	Easy
Q09	C1	0.6730	0.46968	0.743	0.80	0.67	Moderate

Q10	C1	0.5711	0.49551	0.583	0.68	0.57	Moderate
Q11	C2	0.7962	0.40329	0.395	0.36	0.80	Easy
Q12	C4	0.6256	0.48454	0.6	0.68	0.63	Moderate
Q13	C2	0.6919	0.46224	0.626	0.67	0.69	Moderate
Q14	C2	0.8223	0.38273	0.492	0.37	0.82	Easy
Q15	C5	0.6114	0.48802	0.443	0.50	0.61	Moderate
Q16	C2	0.7204	0.44935	0.532	0.53	0.72	Easy
Q17	C3	0.7701	0.42124	0.513	0.49	0.77	Easy
Q18	C5	0.7251	0.44698	0.423	0.44	0.73	Easy
Q19	C4	0.6730	0.46968	0.743	0.80	0.67	Moderate
Q20	C4	0.5711	0.49551	0.583	0.68	0.57	Moderate
Q21	C2	0.4336	0.49617	0.585	0.68	0.43	Moderate
Q22	C3	0.5569	0.49734	0.562	0.65	0.56	Moderate
Q23	C5	0.7796	0.41499	0.532	0.48	0.78	Easy
Q24	C5	0.7583	0.42863	0.501	0.48	0.76	Easy
Q25	C2	0.6185	0.48634	0.303	0.32	0.62	Moderate
Q26	C1	0.6256	0.48454	0.392	0.46	0.63	Moderate
Q27	C1	0.6801	0.46699	0.447	0.44	0.68	Moderate
Q28	C1	0.6730	0.46968	0.743	0.80	0.67	Moderate
Q29	C2	0.5711	0.49551	0.583	0.68	0.57	Moderate
Q30	C5	0.4336	0.49617	0.585	0.68	0.43	Moderate
Q31	C2	0.5427	0.49877	0.696	0.80	0.54	Moderate
Q32	C4	0.5711	0.49551	0.633	0.71	0.57	Moderate
Q33	C2	0.6682	0.47140	0.649	0.68	0.67	Moderate
Q34	C2	0.7796	0.41499	0.508	0.48	0.78	Easy
Q35	C2	0.5616	0.49678	0.438	0.48	0.56	Moderate
Q36	C5	0.7370	0.44080	0.484	0.48	0.74	Easy
Q37	C4	0.7346	0.44207	0.452	0.44	0.73	Easy
Q38	C4	0.7796	0.41499	0.532	0.48	0.78	Easy
Q39	C2	0.7583	0.42863	0.501	0.48	0.76	Easy
Q40	C3	0.6185	0.48634	0.303	0.322345	0.62	Moderate