

AI and Ecological Humanities: Linking Sustainability, Environment, and AI-Enhanced Learning

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ABSTRACT

This paper offers a theoretical and conceptual examination of the emerging convergence between artificial intelligence (AI), the environmental humanities, and sustainability-oriented pedagogy. Positioned at the intersection of ecopedagogy, environmental intelligence theory, and the United Nations Sustainable Development Goals' education agenda, the paper argues that AI-enhanced learning can either deepen or diminish the ecological and ethical sensibilities that the humanities are uniquely positioned to cultivate, depending on how it is pedagogically framed. Drawing on Freirean and ecopedagogical theory, Leonelli's concept of environmental intelligence, UNESCO's cross-cutting sustainability competencies, and recent empirical case-study evidence on AI in sustainability education, the paper develops an original five-stage conceptual model, the Encounter–Interrogate–Reconnect–Reconstruct–Act (EIRRA) framework, for integrating AI into ecological humanities teaching in ways that preserve critical, place-based, and narrative modes of ecological understanding. The paper also foregrounds a central paradox largely absent from mainstream AI-in-education discourse: that the computational infrastructure underlying generative AI carries a measurable carbon and resource cost, meaning that AI-enhanced sustainability education risks reproducing the very extractive logics it seeks to critique unless this tension is made an explicit object of study. The paper concludes that ecological humanities education in the AI era must move beyond treating AI as a neutral productivity tool and instead treat it as a contested socio-technical and socio-ecological artefact worthy of sustained humanistic scrutiny.

Keywords: artificial intelligence, ecological humanities, environmental humanities, sustainability education, ecopedagogy, green AI, environmental intelligence, higher education

INTRODUCTION

The twenty-first century has been marked by the simultaneous acceleration of two seemingly unrelated global forces: the deepening ecological crisis, evidenced by biodiversity loss, climate destabilisation, and resource depletion, and the rapid diffusion of artificial intelligence (AI) across nearly every domain of social and educational life. That these two forces should now be considered together is not incidental. Scholars increasingly argue that the tools society builds to think with, including AI, are never ecologically neutral; they are entangled with energy systems, data infrastructures, and cultural narratives about humanity's relationship to the natural world (Leonelli, 2025). At the same time, the humanities, and specifically the environmental humanities, have long insisted that ecological crises are not merely technical or scientific problems but crises of meaning, value, and narrative that require sustained humanistic inquiry (Schmidt et al., 2020).

This paper takes up the question of how these two developments, AI-enhanced learning and the environmental humanities, might be productively and critically linked within higher education. Rather than treating AI as a simple productivity tool to be added to existing sustainability curricula, the paper approaches AI as a socio-technical and socio-ecological artefact that carries its own assumptions, costs, and narratives, ones that ecological humanities pedagogy is well positioned to interrogate. In doing so, the paper responds to a growing, though still fragmented, body of scholarship that examines AI's role in environmental education (Leal Filho et

al., 2025), ecopedagogical theory (Misiaszek, 2020), and the philosophical reframing of AI itself around ecological rather than purely computational values (Leonelli, 2025).

The paper is deliberately theoretical and conceptual in orientation. Rather than reporting new empirical data, it synthesises existing theoretical traditions, namely ecopedagogy, environmental humanities, sustainability competency frameworks, and emerging Green AI scholarship, into a coherent conceptual model that can subsequently inform curriculum design, further empirical inquiry, and institutional policy. This approach follows a long tradition in educational and humanities scholarship of using conceptual synthesis to open new lines of empirical and pedagogical investigation, a method also adopted in recent theoretical work on AI and ecopedagogy in higher education.

Purpose of the Study

The purpose of this paper is to theoretically examine how artificial intelligence, sustainability, and the environmental humanities might be conceptually and pedagogically linked in higher education. Specifically, the paper sets out to:

1. clarify the conceptual relationship between ecological/environmental humanities, sustainability education, and AI-enhanced learning;
2. examine the theoretical and philosophical foundations, namely ecopedagogy, environmental intelligence theory, and UNESCO's sustainability competency framework, that can ground AI-enhanced ecological humanities pedagogy;
3. critically interrogate the ecological paradox posed by AI's own environmental footprint within sustainability-oriented education;
4. propose an original conceptual model for integrating AI into ecological humanities teaching and learning; and
5. discuss the curricular, institutional, and policy implications of this model, with particular attention to the Nigerian and African higher education context.

LITERATURE REVIEW

Conceptual Review

Ecological and Environmental Humanities

The environmental humanities, sometimes used interchangeably with ecological humanities, constitute an interdisciplinary field that draws on environmental literature, environmental philosophy, environmental history, science and technology studies, and environmental anthropology to examine the complex relationships between human culture and the natural world. The field emerged in response to a growing recognition that ecological crises cannot be adequately understood, still less resolved, through scientific and technical approaches alone, since they are equally crises of narrative, value, and historically embedded human practice (Schmidt et al., 2020). Central to the field is the conviction that humanistic tools, storytelling, ethical reasoning, historical analysis, and cultural critique, are indispensable to understanding how societies have arrived at the present ecological moment and to imagining just and liveable futures.

Sustainability Education

Sustainability education, closely aligned with the United Nations' Sustainable Development Goal Target 4.7, is concerned with equipping learners with the knowledge, skills, and values needed to promote sustainable development, sustainable lifestyles, and global citizenship. UNESCO has identified eight cross-cutting sustainability competencies, including systems thinking, anticipatory competency, critical thinking, and integrated problem-solving, that are considered essential across disciplines and educational levels for

achieving the Sustainable Development Goals (UNESCO, 2017). These competencies were themselves developed in response to the UN's 2030 Agenda for Sustainable Development, which explicitly frames education as a lever for achieving broader sustainability transformation (United Nations, 2015).

AI-Enhanced Learning

AI-enhanced learning refers to the use of artificial intelligence technologies, including generative language models, adaptive learning systems, and intelligent tutoring platforms, to support, personalise, or extend teaching and learning processes. Within sustainability education specifically, AI has been documented to enhance personalised instruction, facilitate interactive simulations of complex environmental systems, and increase student engagement through real-time feedback and adaptive learning pathways (Leal Filho et al., 2025). However, the same body of literature cautions that AI's integration into sustainability teaching raises unresolved questions about equity, access, and the ethical implications of relying on data-intensive technologies to teach about ecological limits (Leal Filho et al., 2025).

Locating the Convergence

Bringing these three concepts together, this paper argues that the convergence of AI, sustainability, and the environmental humanities is not merely additive, that is, simply using AI tools to deliver existing sustainability content, but potentially transformative, in that AI itself becomes an object of humanistic and ecological inquiry. This reframing is consistent with recent scholarship proposing that generative AI in higher education be treated as a contested socio-technical system whose narratives, data sources, and environmental impacts warrant the same critical scrutiny that environmental humanities scholars have long applied to other cultural technologies and institutions.

Theoretical Review

Ecopedagogy and Freirean Critical Pedagogy

The paper's primary theoretical foundation is ecopedagogy, a critical educational tradition rooted in Paulo Freire's insistence that education should help learners critically read the world in order to transform it. Ecopedagogy extends this insight by confronting the intertwined ecological and social dimensions of oppression, and by fostering what has been termed world–Earth de-distancing, the process of understanding humans as embedded within, rather than positioned above, ecological systems (Misiaszek, 2020). Recent scholarship applies this ecopedagogical lens explicitly to climate justice and just-transition education, arguing that conventional environmental teaching often falls short of cultivating the critical awareness and collective agency needed to address the systemic roots of ecological degradation, and that ecopedagogy offers a more emancipatory alternative rooted in grassroots and dialogical practice (Iyengar et al., 2025).

Environmental Intelligence as a Philosophical Reframing of AI

A second, more recent theoretical contribution is particularly generative for this paper's argument. Leonelli (2025) proposes the concept of environmental intelligence (EI) as an alternative to the dominant historical framing of artificial intelligence as an attempt to rationalise, mechanise, and ultimately transcend human cognitive limits and the constraints of nature. Instead, EI reframes AI as an effort to develop digital and data-intensive systems explicitly oriented toward sustaining and enhancing life on the planet, including its non-human members and habitats. This reframing is philosophically significant for ecological humanities pedagogy because it suggests that the ecological value of AI in education depends not on the sophistication of the technology itself, but on whether its design and use are oriented toward planetary flourishing or toward narrow computational efficiency. Applied pedagogically, environmental intelligence theory invites learners to ask not only what AI can do, but what kind of relationship with the natural world a given AI application enacts or forecloses.

UNESCO's Sustainability Competency Framework

The paper's third theoretical anchor is UNESCO's (2017) framework of cross-cutting sustainability competencies, developed to operationalise SDG Target 4.7. These eight competencies, systems thinking, anticipatory competency, normative competency, strategic competency, collaboration, critical thinking, self-awareness, and integrated problem-solving, provide a widely recognised vocabulary for describing the outcomes sustainability education should cultivate across disciplines. Systems thinking, in particular, which concerns the ability to recognise relationships, analyse complex systems, and deal with uncertainty across different scales, offers a natural bridge between environmental humanities' attention to interconnected human–ecological narratives and AI's capacity to model and visualise complex systems (UNESCO, 2017).

Technology–Pedagogy Integration Frameworks

Finally, the paper draws more lightly on technology-integration theory, specifically the Technological Pedagogical Content Knowledge (TPACK) framework, which conceptualises effective technology-integrated teaching as arising from the dynamic interaction between technological, pedagogical, and content knowledge (Mishra & Koehler, 2006). While TPACK was not developed with ecological or sustainability content in mind, it usefully reminds curriculum designers that the pedagogical and disciplinary (in this case, ecological-humanistic) dimensions of AI integration must be as carefully attended to as the technological dimension itself, a caution echoed in systematic reviews noting that AI's growing presence in higher education has often outpaced educators' capacity to critically evaluate its pedagogical implications (Zawacki-Richter et al., 2019).

The Green AI Paradox: A Central Tension

A theme that receives insufficient attention in much of the AI-in-education literature, but which this paper treats as central, is the material and ecological cost of the AI systems being proposed as tools for sustainability education. Recent technical scholarship demonstrates that training large-scale AI models carries a substantial and measurable carbon footprint, with some estimates suggesting that training a single large language model can generate emissions comparable to the lifetime output of several passenger vehicles (Liu & Yin, 2024). This concern has given rise to a distinct research field, Green AI, which explicitly calls for AI development to prioritise energy efficiency and reduced computational demand alongside model performance, rather than treating environmental cost as an externality (Liu & Yin, 2024).

This creates what may be termed the Green AI paradox for ecological humanities pedagogy: the very technologies increasingly proposed to enhance sustainability education are themselves implicated in the resource extraction, energy consumption, and carbon emissions that sustainability education seeks to critique. An ecological humanities pedagogy that uncritically adopts AI tools without addressing this paradox risks reproducing the extractive and solutionist logics that environmental humanities scholarship has long contested. Addressing this tension does not require rejecting AI outright; rather, consistent with the environmental intelligence framing proposed by Leonelli (2025), it requires treating the environmental cost of AI itself as legitimate curricular content, a subject of critical inquiry rather than a background condition to be ignored.

Practically, this means that AI-enhanced ecological humanities courses might productively ask students to investigate the energy and carbon implications of the very AI tools they use in class, drawing on emerging carbon-accounting methodologies developed within Green AI scholarship, thereby transforming a potential pedagogical blind spot into a rich site of critical, reflexive learning (Liu & Yin, 2024).

Toward a Conceptual Model: The EIRRA Framework

Building on the theoretical foundations and thematic analysis above, this paper proposes an original conceptual model for integrating AI into ecological humanities teaching and learning, termed the Encounter–Interrogate–Reconnect–Reconstruct–Act (EIRRA) framework. The model synthesises Freirean and ecopedagogical dialogical method (Misiaszek, 2020), the critical AI literacy emphasis found in recent postdigital and ecopedagogical scholarship, and UNESCO's sustainability competencies (UNESCO, 2017) into a five-stage pedagogical cycle. Unlike models that treat AI as a neutral instructional aid, EIRRA positions AI as a

contested cultural and ecological artefact to be critically examined at every stage of the learning process, consistent with Leonelli's (2025) call to redefine AI's philosophical premises around planetary flourishing rather than computational efficiency alone.

Stage	Guiding Question	AI-Enabled Humanities Practice
1. Encounter	What story is being told about human–nature relations, and by whom?	Students use AI tools to surface and compare narratives, images, or translations of ecological texts across cultures and eras.
2. Interrogate	Whose knowledge, data, and assumptions shape this AI output?	Students audit AI-generated content for bias, omission, and the environmental cost of the system producing it.
3. Reconnect	How does this text or theme relate to lived, local, ecological experience?	Students ground AI-assisted analysis in place-based knowledge, oral history, and indigenous ecological perspectives.
4. Reconstruct	What more just, sustainable, and humanistic account can we compose?	Students co-author, with AI as scaffold, revised narratives, arguments, or creative works that foreground ecological responsibility.
5. Act	What does this understanding demand of us as citizens and learners?	Students translate humanistic insight into communicative or civic action, using AI tools reflectively rather than automatically.

The EIRRA framework is deliberately cyclical rather than linear: the Act stage is intended to generate new material, questions, or ecological encounters that feed back into a subsequent Encounter stage, mirroring ecopedagogy's understanding of praxis as an ongoing dialogue between reflection and action rather than a terminal outcome (Misiaszek, 2020). The framework also deliberately embeds the Green AI paradox within the Interrogate stage, ensuring that critical reflection on AI's own environmental cost is not treated as a peripheral ethical add-on but as a structural component of the pedagogical cycle.

Thematic Discussion: The Convergence of AI, Sustainability, and Ecological Humanities

AI as Scaffold for Ecological Storytelling and Narrative Analysis

One of the most promising convergences lies in AI's capacity to support the environmental humanities' longstanding interest in ecological narrative, that is, the stories societies tell about their relationship to nature. AI-assisted text and translation tools can help learners access, compare, and analyse environmental narratives across languages, cultures, and historical periods, extending the reach of comparative ecocritical analysis beyond what is feasible through unaided human reading. Case-study evidence from a 45-country survey of sustainability education practice found that AI integration enhanced learners' engagement with complex environmental issues by supporting personalised instruction and interactive simulation of ecological systems, outcomes with clear relevance for humanities courses built around ecological texts and case narratives (Leal Filho et al., 2025). At the same time, this scaffolding function must be pedagogically bounded: the same body of literature identifies a persistent digital divide, with many regions lacking the infrastructure required to benefit equitably from AI-enhanced instruction, a concern with direct relevance for humanities departments in resource-constrained contexts (Leal Filho et al., 2025).

Systems Thinking and Interdisciplinary Bridges

A second convergence concerns systems thinking, one of UNESCO's core sustainability competencies. Environmental humanities scholarship has traditionally approached ecological systems through narrative, historical, and ethical modes of analysis, while environmental science approaches the same systems

computationally and quantitatively. AI-enabled visualisation and simulation tools offer a potential bridge between these modes, allowing humanities students to move fluidly between qualitative ecological narrative and quantitative systems modelling without requiring extensive technical training. Teacher-education research on AI and sustainability similarly emphasises that professional development for educators must cultivate this interdisciplinary fluency, since the competent use of AI in sustainability-oriented teaching depends as much on pedagogical judgement as on technical familiarity (Isidori et al., 2024).

Place-Based, Indigenous, and Local Ecological Knowledge

A third theme concerns the risk that AI-enhanced learning, if uncritically adopted, may privilege globally dominant, English-language, and data-rich ecological narratives at the expense of place-based, indigenous, and locally situated ecological knowledge. This concern is especially salient in African and Nigerian contexts, where recent scholarship on AI integration in green chemistry and sustainability-oriented higher education has identified a global AI divide, characterised by unequal infrastructure, algorithmic bias, and the risk of over-reliance on AI outputs that may not reflect local ecological realities (Alli, 2026). Addressing this risk requires that AI-enhanced ecological humanities pedagogy be deliberately designed to foreground, rather than displace, local ecological knowledge systems, oral histories, and community-based environmental narratives, using AI as a tool for amplifying and cross-referencing such knowledge rather than substituting for it.

Ethical and Critical AI Literacy

A fourth theme concerns the cultivation of critical AI literacy as itself an ecological humanities competency. Scholars argue that students and educators must be equipped to question how AI models work, where their training data originates, who's ecological and cultural perspectives are represented or absent, and what environmental costs are embedded in a given AI application, framing such critical literacy as both defensive and transformative when combined with ecopedagogical aims. This positions the environmental humanities classroom not merely as a consumer of AI tools but as a site for the critical interrogation of AI itself, consistent with ecopedagogy's broader commitment to reading the world critically in order to transform it (Misiaszek, 2020).

Implications for Curriculum, Practice, and Policy

Curriculum Design

For curriculum designers, the EIRRA framework suggests that ecological humanities courses incorporating AI should be structured around recurring cycles of encounter and critical interrogation rather than one-off technology demonstrations. Assessment tasks might productively require students to trace the provenance and environmental cost of AI-generated content alongside its substantive analysis, integrating critical AI literacy directly into humanities assessment rather than treating it as a separate digital-literacy module.

Educator Development

For educator development, the findings reinforce the argument that effective AI integration in sustainability-oriented teaching depends less on technical AI proficiency than on pedagogical and ethical judgement, a conclusion consistent with teacher-training research emphasising exploratory, reflective approaches to AI adoption for sustainability educators (Isidori et al., 2024). Professional development programmes should therefore cultivate educators' capacity to model critical, rather than uncritical, AI use for students, including modelling the kind of provenance-and-impact interrogation embedded in the EIRRA framework's second stage.

Institutional and Policy Considerations

At the institutional level, the persistent digital divide documented in AI-and-sustainability-education scholarship (Leal Filho et al., 2025) and the global AI divide noted specifically in African higher education contexts (Alli, 2026) suggest that policies promoting AI-enhanced ecological humanities teaching must be

accompanied by parallel investment in equitable infrastructure, lest such pedagogy inadvertently privilege already well-resourced institutions and learners. For Nigerian and other African universities specifically, this implies that AI-enhanced ecological humanities initiatives should be designed to strengthen, rather than bypass, engagement with local ecological knowledge systems, oral traditions, and community-based environmental narratives, consistent with the place-based emphasis identified earlier in this paper.

Research Agenda

Because this paper is conceptual rather than empirical, its central contribution, the EIRRA framework, requires empirical testing. Future research might productively pilot the framework within specific humanities courses (for example, environmental literature, ecological history, or cultural anthropology of climate change) and evaluate its effects on students' critical AI literacy, ecological systems thinking, and sustainability competencies using instruments aligned with UNESCO's (2017) competency domains.

Limitations

As a theoretical and conceptual paper, this work is necessarily limited by its reliance on synthesis rather than original empirical investigation; the EIRRA framework proposed here represents a theoretically grounded hypothesis about effective practice rather than a validated instructional model. The literature synthesised is also unevenly distributed across contexts, with a substantial proportion of AI-and-sustainability-education scholarship originating from well-resourced institutions in the Global North, meaning that the paper's African and Nigerian contextual claims, while grounded in available scholarship (Alli, 2026), would benefit from further region-specific theoretical and empirical development. Finally, because Green AI research is a rapidly evolving field, the specific carbon-footprint figures cited in this paper should be treated as illustrative of a broader trend rather than as fixed benchmarks, given the pace of change in AI model architectures and energy-efficiency practices.

CONCLUSION

This paper has argued that the convergence of artificial intelligence, sustainability, and the environmental humanities offers rich but underexplored pedagogical possibilities, provided that AI is treated not as a neutral instructional tool but as a contested ecological and cultural artefact worthy of the same critical scrutiny the environmental humanities have long directed at other technologies and institutions. Drawing on ecopedagogy, environmental intelligence theory, UNESCO's sustainability competencies, and emerging Green AI scholarship, the paper has proposed the EIRRA framework as a conceptual starting point for integrating AI into ecological humanities teaching in ways that cultivate, rather than erode, critical, place-based, and narrative modes of ecological understanding. Central to this argument is the recognition of the Green AI paradox: that AI's own environmental cost must become an explicit object of humanistic and pedagogical inquiry rather than a background condition of its use. As higher education institutions, including those across Nigeria and the wider African continent, continue to navigate the rapid diffusion of AI, ecological humanities pedagogy is well positioned to insist that questions of narrative, value, justice, and planetary responsibility remain at the centre of that navigation, rather than being displaced by narrower concerns of technical efficiency alone.

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