

Full Length Research

Revitalizing Education Through Environmental Science Education: A Conceptual Framework for Transformative Learning

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Accepted 17 June 2025

This conceptual study explores the transformative potential of Environmental Science Education (ESE) as a catalyst for revitalizing contemporary education systems. Drawing on theoretical frameworks and empirical evidence, the paper argues that ESE's interdisciplinary nature, emphasis on real-world problem-solving and focus on sustainability competencies position it uniquely to revitalize educational practices, policies and outcomes. The analysis reveals that ESE fosters deeper cognitive engagement, enhances scientific literacy, cultivates environmental agency and promotes action competence. By integrating insights from educational theory, sustainability frameworks and exemplary practices, this paper proposes a comprehensive conceptual framework for repositioning ESE from a peripheral subject to a central organizing principle for educational renewal. Recommendations include curriculum integration strategies, pedagogical innovations, teacher professional development and policy alignment to realize ESE's revitalizing potential across diverse educational contexts.

Keywords: Environmental Science Education, educational revitalization, transformative learning, conceptual framework.

Cite This Article As: Mshelbwala, RB (2025). Revitalizing Education Through Environmental Science Education: A Conceptual Framework for Transformative Learning. *Inter. J. Acad. Res. Educ. Rev.* 13(2): 49-53

Introduction

Contemporary education systems worldwide face mounting criticism for their perceived inability to equip students with the necessary knowledge, skills and dispositions to navigate and address complex 21st-century challenges. As noted by Blumstein and Saylan (2021), despite decades of reform initiatives, many educational institutions remain characterized by disciplinary fragmentation, theoretical abstraction and pedagogical approaches that prioritize content acquisition over meaning-making and application. This has resulted in widespread student disengagement, inadequate development of higher-order thinking skills and limited cultivation of civic responsibility and environmental stewardship.

The revitalization of education represents an urgent imperative rather than a mere aspiration. Environmental Science Education (ESE), with its inherent interdisciplinary nature, focus on real-world problems and explicit emphasis on sustainability and civic engagement, offers a promising pathway for such educational renewal. As Wals, Brody, Dillon and Stevenson (2014) convincingly argue, ESE integrates scientific knowledge with ecological understanding, ethical reasoning and socio-political analysis to foster comprehensive environmental literacy.

The recent OECD PISA 2025 Science Framework significantly expands the scope of science education to prepare students for decision-making and action-taking regarding contemporary socio-ecological challenges. This shift reflects growing recognition that science education must evolve beyond introducing conceptual products and practices to encompass developing agency and engaging with complex systems. Similarly, research published in *Nature* (2025) demonstrates that educational science is increasingly recognized as crucial in environmental management and green technology adoption, particularly in rural revitalization contexts.

Statement of the Problem

Education systems globally face several interconnected problems that limit their effectiveness and relevance, particularly in addressing contemporary environmental and sustainability challenges. First, there exists a significant relevance gap between curricular content and students' lived experiences and future realities. As Stevenson, Peterson and Bondell (2019) found, traditional science education often emphasizes abstract concepts disconnected from pressing socioecological issues, leading to diminished student engagement and perceived relevance.

Second, prevailing educational approaches demonstrate inadequate preparation for complexity. The multidimensional nature of contemporary challenges like climate change, biodiversity loss and environmental justice requires systems thinking, interdisciplinary understanding and adaptive problem-solving capabilities that conventional education struggles to foster. Third, there is a persistent action-awareness disconnect in environmental education. While environmental awareness has increased substantially in recent decades, Monroe, Plate, Oxarart, Bowers and Chaves (2019) highlight that this has rarely translated into meaningful action or behavior change.

Furthermore, significant educational inequities exacerbate environmental challenges and limit educational effectiveness. Disparities in educational resources, quality and access persist across geographic, socioeconomic and cultural contexts. As research in *Nature* (2025) indicates, these inequities are particularly evident in environmental education, where resource constraints and inadequate teacher preparation hinder effective implementation, especially in rural areas where educational materials often fail to align with local economic, social and environmental contexts.

Objectives of the Study

This conceptual paper aims to develop a comprehensive framework for understanding how Environmental Science Education can serve as a catalyst for educational revitalization. The specific objectives are:

1. To analyze the theoretical foundations and conceptual premises underpinning environmental science education as a transformative educational approach, drawing on constructivist learning theories, critical pedagogy and place-based education frameworks.
2. To examine how ESE develops crucial competencies including systems thinking, critical evaluation, decision-making and action-taking that are essential for both academic engagement and civic responsibility, as reflected in the OECD PISA 2025 Framework.
3. To propose innovative pedagogical approaches and curriculum design principles that realize ESE's revitalizing potential across diverse educational contexts, particularly addressing the relevance gap in current educational practices.
4. To identify how ESE can address educational inequities through inclusive, culturally responsive approaches that honor diverse cultural perspectives on environment and sustainability.
5. To establish a comprehensive conceptual framework that guides the implementation of ESE for educational revitalization at multiple levels: classroom practice, institutional policy and system-wide reform.

Significance of the study

This paper will make significant contributions to educational theory, policy and practice by articulating the revitalizing potential of Environmental Science Education. Theoretically, this research advances conceptual understanding of how environmental science education can transform educational paradigms. As Zelinski and Riseman (2021) note, by positioning ESE as an integrative force rather than a specialized domain, the paper addresses the "epistemological divides between Environmental Education and Science Education" and proposes a reconciled theoretical foundation.

Practically, for educators, curriculum developers and school leaders, this paper provides evidence-informed guidance for designing and implementing revitalizing educational experiences. It offers practical insights into pedagogical approaches that foster environmental agency and action competence, directly addressing what Krasny and DuBois (2019) identify as the essential need for "climate adaptation education" that engages with community and ecosystem resilience.

From a policy perspective, this research provides policymakers with a robust rationale and strategic direction for

prioritizing and supporting Environmental Science Education within broader educational reform agendas. By demonstrating ESE's role in addressing multiple educational challenges, the paper offers compelling arguments for policy alignment and resource allocation, particularly important in contexts where, as Nature (2025) reports, educational materials often "don't align with local economic and social needs."

Societally, this paper contributes to broader capacity for environmental stewardship and sustainable development. As Chawla (2020) emphasizes, by articulating how ESE develops citizens capable of addressing complex sustainability challenges, the paper highlights education's crucial role in achieving sustainability transitions and climate action.

Literature Review

Conceptual Framework

Evolution and Theoretical Foundations

Environmental Science Education has evolved significantly from its origins as nature study and conservation education to become an interdisciplinary field integrating scientific knowledge with sustainability principles and civic engagement. Contemporary ESE represents a convergence of multiple educational traditions, including science education, environmental education, education for sustainable development and place-based education (Gough, Lee, & Tsang, 2020).

The field has been profoundly influenced by global policy frameworks, particularly the United Nations Sustainable Development Goals. More recently, the OECD PISA 2025 Science Framework has substantially expanded the conception of science education to include competencies necessary for addressing what Springer (2025) terms "socio-ecological challenges of the Anthropocene." This framework incorporates three key competencies: explaining phenomena scientifically; constructing and evaluating scientific enquiry and "research, evaluate and use scientific information for decision making and action."

Conceptualizing Educational Revitalization through ESE

Educational revitalization through Environmental Science Education involves a fundamental reorientation of educational purposes, practices and structures to enhance relevance, efficacy and transformative potential. Our conceptual framework identifies three interconnected dimensions of this revitalization:

Epistemological Dimension: This dimension shifts from disciplinary knowledge silos and theoretical abstraction toward interdisciplinary integration and knowledge contextualization within real-world issues. As Wals et al. (2014) argue, this convergence between science and environmental education represents a crucial advancement in educational theory and practice.

Pedagogical Dimension: This transformation moves from teacher-centered transmission and classroom confinement toward experiential, inquiry-based learning, community engagement and action-oriented approaches. Ballard, Dixon and Harris (2017) demonstrate how youth-focused citizen science effectively develops both scientific learning and environmental agency.

Teleological Dimension: This reorientation expands educational goals from primarily academic achievement toward the development of agency, action competence and ecological citizenship. As the PISA 2025 Framework explicitly notes, this includes demonstrating "hope and respect for diverse perspectives in seeking solutions to socio-ecological crises."

Core Principles of Revitalizing ESE

Based on analysis of theoretical literature and exemplary practices, we identify five core principles that characterize Environmental Science Education as a revitalizing force:

Contextual Relevance: ESE connects learning to local environmental, cultural and socioeconomic contexts, enhancing relevance and meaning. Research in rural contexts demonstrates that education aligned with local realities significantly enhances engagement and effectiveness (Nature, 2025).

Interdisciplinary Integration: ESE bridges natural sciences, social sciences and humanities to address complex environmental issues holistically. This integration is essential for developing the systems thinking required to understand human interactions with Earth's systems (Springer, 2025).

Action Orientation: ESE develops capacity for informed action through experiential learning, community engagement and civic participation. The PISA 2025 Framework's emphasis on "informed decisions to act" reflects this action orientation.

Critical Engagement: ESE fosters critical evaluation of information, ethical reasoning and consideration of diverse

perspectives on environmental issues. Ernst and Theimer (2011) highlight how this critical engagement enhance environmental connectedness and reasoning.

Hope and Agency: ESE cultivates constructive hope and self-efficacy through solution-focused learning and positive visioning. As Chawla (2020) notes, maintaining hope while addressing environmental challenges is essential for sustained engagement and action.

Methodology

This research adopts a conceptual paper methodology, focusing on theory building, conceptual analysis and framework development rather than empirical data collection. The approach involves systematic analysis and synthesis of existing literature, theories and practices to develop a comprehensive framework for understanding how Environmental Science Education can revitalize education systems.

The methodology incorporates several specific approaches as outlined by Ardoin, Bowers and Gaillard (2020) in their systematic review of environmental education outcomes. These include conceptual analysis of key terms, theoretical synthesis across multiple disciplines, framework analysis of existing conceptual models and document analysis of policy frameworks and curriculum documents.

The methodological approach is qualitative and interpretive, aiming to develop new understandings and conceptual frameworks through rigorous analysis of existing knowledge. The process involves iterative cycles of reading, analysis, synthesis and framework refinement to develop a robust conceptualization of how ESE can serve as a catalyst for educational revitalization, following established protocols for conceptual research in education (Zelinski & Riseman, 2021).

Discussion

Environmental Science Education prompts fundamental reconsideration of educational purposes in the Anthropocene era. Traditional education has often privileged knowledge acquisition for its own sake, with success measured primarily through academic achievement on standardized assessments. ESE expands these purposes to include developing agency, action competence and ecological citizenship. As Springer (2025) notes, the OECD PISA 2025 Framework reflects this expanded purpose by including competencies related to "decision making and action" and emphasizing the development of "hope and respect for diverse perspectives in seeking solutions to socio-ecological crises."

This reorientation addresses the relevance gap in contemporary education by connecting learning to pressing real-world issues. When students engage with authentic environmental challenges in their communities, they perceive education as meaningful and consequential. Research in rural contexts demonstrates that education connected to local environmental realities significantly enhances engagement and perceived relevance (Nature, 2025). This suggests that ESE's revitalizing potential lies partly in its capacity to make education matter in immediate and tangible ways.

Environmental Science Education necessitates and enables transformative pedagogical approaches that engage students more deeply than traditional transmission models. As Ballard et al. (2017) demonstrate through their research on citizen science, these approaches include experiential learning that emphasizes direct engagement with local environments, inquiry-based learning where students investigate authentic environmental questions using scientific practices and community-connected learning that bridges classroom and community through partnerships with local organizations.

Most significantly, action-oriented learning enables students to identify, implement and evaluate actions addressing environmental issues, developing agency and practical impact. This pedagogical approach directly develops the capacity to make what the PISA 2025 Framework describes as "informed decisions to act based on evaluation of diverse sources of evidence." These pedagogical approaches revitalize education by increasing student engagement, developing higher-order thinking skills and creating meaningful opportunities for application and impact.

Environmental Science Education has significant potential to address educational inequities through inclusive, culturally responsive approaches. However, realizing this potential requires careful attention to issues of access, representation and multiple knowledges. As Nature (2025) emphasizes, this includes culturally sustaining pedagogy that honors and incorporates diverse cultural perspectives on environment and sustainability, contextual adaptation with approaches tailored to local environmental, cultural and socioeconomic contexts and recognition and inclusion of Indigenous knowledge, local knowledge and community wisdom alongside scientific understandings.

When implemented with explicit attention to equity, ESE can help address achievement gaps by engaging diverse learners through relevant, meaningful content. The emphasis on "respect for diverse perspectives" in the PISA 2025 Framework supports this inclusive approach. As Chawla (2020) argues, conversely, when ESE fails to address equity concerns, it risks reinforcing existing educational disparities.

Recommendations

Based on the conceptual analysis and framework developed in this study, the following recommendations for realizing the revitalizing potential of Environmental Science Education were made:

First, integrate ESE as a cross-curricular priority rather than treating it as a separate subject. Second, implement action-oriented pedagogies that shift from awareness-focused approaches to those developing action competences through community projects and citizen science. Third, develop place-based curriculum resources that support teachers in connecting learning to local environmental contexts, addressing what Nature (2025) identifies as the need for materials aligned with "rural realities." Fourth, incorporate systems thinking explicitly through learning experiences that develop understanding of human-environment interactions.

Establish professional learning communities focused on ESE implementation and create structures for interdisciplinary teacher collaboration. As Monroe et al. (2019) suggest, align educational standards with environmental literacy and sustainability competencies, reflecting the expanded vision of frameworks like PISA 2025. Dedicate specific funding for ESE implementation and develop assessment approaches that capture ESE learning outcomes, including action competence and environmental agency.

Conclusion

Environmental Science Education (ESE) serves as a pivotal force for revitalizing contemporary education systems. It directly addresses persistent shortcomings, including irrelevant curricula, disciplinary silos and the gap between awareness and action. Through its integration of scientific knowledge, sustainability principles and civic engagement, ESE fosters crucial action competence in students. The proposed conceptual framework encompassing epistemological, pedagogical and teleological dimensions enables a more engaging and effective educational experience. By connecting learning to real-world issues, ESE develops essential sustainability competencies and promotes student agency and equity. Realizing this transformative potential requires concerted effort in curriculum redesign, teacher development and supportive policy. Ultimately, repositioning ESE as a central organizing principle, rather than a peripheral subject, is fundamental to creating education systems that are relevant, impactful and capable of preparing students to build a sustainable future.

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