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Forging ecological innovators: An integrated model for innovation-entrepreneurship education and ecological civilization education in Chinese higher education

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ABSTRACT

China's sustainable development strategy urgently requires talent capable of harmonizing economic ambition with ecological responsibility. However, despite parallel promotion in higher education, Innovation and Entrepreneurship (IE) education and Ecological Civilization (EC) education often remain fragmented in practice, with no empirically tested integrative model available. Addressing this gap, this study aims to construct an integrated framework through an in-depth qualitative case study of the desert soilization project at Chongqing Jiaotong University. Employing document analysis, artifact examination, and outcome data for triangulation, the research delineates a replicable model comprising a three-tiered curriculum system (faculty empowerment, curricular infusion, specialized programs) and a dual-platform experiential ecosystem (on-campus research center, off-campus desert bases). Through a virtuous cycle of mission-driven motivation, interdisciplinary integration, and practice-informed feedback, this model systematically fosters students' interdisciplinary knowledge, problem-solving capabilities, and green entrepreneurship competencies. Empirical findings demonstrate that the model not only enabled students to win a national innovation competition gold award and establish large-scale ecological restoration bases, but also significantly enhanced students' project engagement and systemic ecological thinking. The study concludes that mission-oriented, project-based integration offers an effective pathway for universities to contribute to national sustainable development goals. It also discusses the model's theoretical contributions to green entrepreneurship education, acknowledges single-case design limitations, and proposes future research directions.

Keywords: ecological civilization, innovation and entrepreneurship education, educational integration, case study methodology, desert soilization, higher education reform

INTRODUCTION

China's economic development trajectory has reached a critical juncture, catalyzing a national consensus on reconciling rapid growth with ecological constraints (Pan, 2016; Xue et al., 2023; Zhou, 2021; Zuo et al. 2021). This paradigm shift, emblematic of a broader global reckoning with sustainability challenges, is institutionally embedded within China's higher education system through the parallel promotion of Innovation and Entrepreneurship (IE) education and Ecological Civilization (EC) education. The former aims to cultivate a dynamic, competency-based skill set of creativity, critical thinking, and venture creation, while the latter seeks to instill a deep-seated ethos of environmental stewardship and systems thinking, drawing from both ancient Chinese philosophical traditions and contemporary sustainability science (Xu, 2021; Yang, 2024).

Despite robust policy endorsement and conceptual alignment at the strategic level, a significant implementation gap persists in practice. IE and EC education frequently operate within institutional silos, characterized by disjointed curricula, competing pedagogical priorities, and disparate evaluation mechanisms (Li et al., 2016; Zhou & Xu, 2012). This functional disconnect undermines the development of a holistic talent profile capable of devising innovations that are simultaneously technologically viable, economically sound, and ecologically restorative. Consequently, this study seeks to investigate the following research question: How can higher education institutions effectively integrate IE and EC education to systematically cultivate "ecological innovators"?

Despite the recognized need for integration, existing literature offers no empirically tested, replicable model that

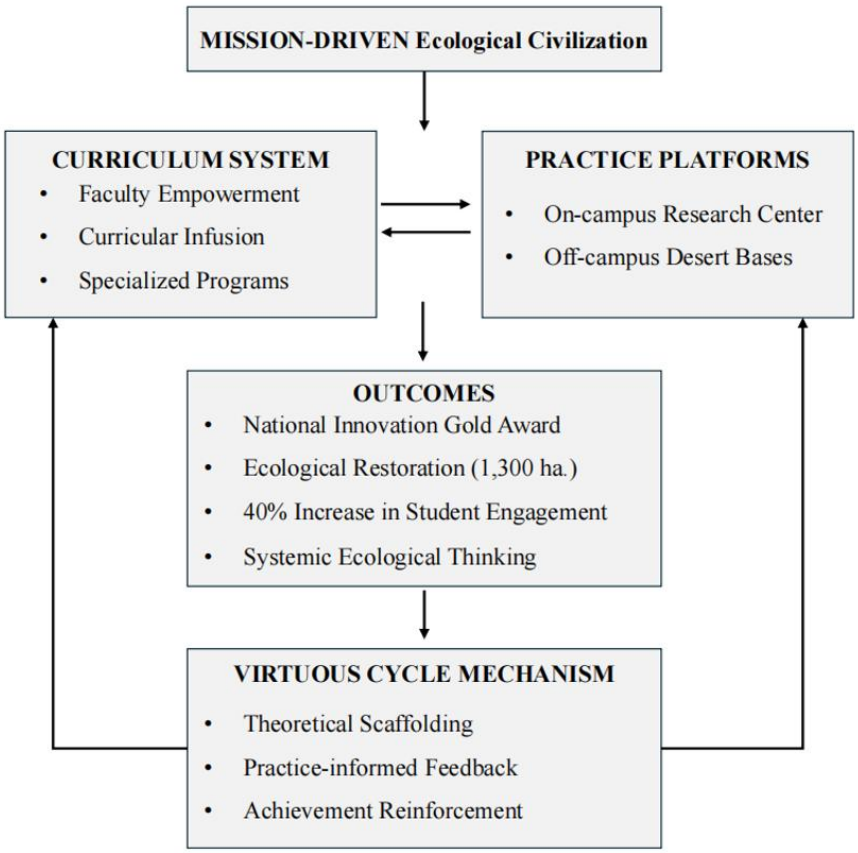

Figure 1. The integrated education model: A virtuous cycle framework (Source: Author's own elaboration)

demonstrates how IE and EC education can be systematically merged in practice. Most studies remain conceptual or focus on isolated interventions, leaving a clear gap in actionable frameworks. The novelty of this study lies in providing a mission-oriented, project-anchored integration model that is empirically grounded in a real-world ecological restoration project. Unlike prior work, the proposed model operationalizes integration through a three-tiered curriculum system and a dual-platform experiential ecosystem, generating a self-reinforcing virtuous cycle (See **Figure 1**). This represents a distinct departure from classroom-based green entrepreneurship education approaches.

This paper posits that the strategic integration of these two educational domains is not merely an additive process but a fundamental reorientation of pedagogical philosophy and practice. It responds to this imperative by constructing a coherent, integrated model, empirically grounded and theoretically informed. Through a meticulous examination of a paradigmatic case study, this research elucidates the core architectural components and dynamic mechanisms of such integration. The findings contribute to the nascent literature on Green Entrepreneurship Education (Ansar et al., 2024; Miroshnyk et al., 2022; Soomro et al., 2020) by presenting a distinct, mission-oriented Chinese approach, thereby offering a replicable framework for educational innovation that aligns human capital development with the urgent imperatives of planetary health.

This study contributes to the nascent literature on Green Entrepreneurship Education by proposing a mission-oriented, project-anchored integration model that is distinctly contextualized within China's Ecological Civilization discourse. Unlike conventional GEE approaches that often prioritize classroom-based opportunity recognition, this model embeds learning within large-scale, real-world ecological restoration projects, thereby creating a virtuous cycle of motivation, interdisciplinary synthesis, and entrepreneurial action. This represents a novel pathway for aligning higher education with national sustainability agendas.

Divergent yet Parallel Evolution of IE and EC Education in China

A historical analysis reveals the distinct yet increasingly convergent pathways of IE and EC education in China, each evolving from marginal concepts to central educational pillars, driven by national strategic needs.

IE education has undergone a remarkable metamorphosis. Its emergent phase (Late 1990s - Early 2000s) was characterized by extracurricular activities and pilot programs, responding to the demands of the global knowledge economy (Cao & Zhou, 2018; Zou & Zhao, 2014). The institutionalization phase (Mid-2000s - 2010s) witnessed its rapid incorporation into the core curriculum, propelled by top-down policy directives that framed mass entrepreneurship and innovation as engines of economic transformation (Mok & Kan, 2013). The current ecosystem development phase (2010s - Present) marks a strategic pivot from quantitative expansion to qualitative enhancement, focusing on building comprehensive innovation ecosystems that integrate university-industry collaboration, incubators, and sophisticated evaluation models (Niu et al., 2019; Zhang & Xi,

2020; Zhu et al., 2017). Despite this evolution, enduring challenges such as curricular fragmentation, superficial implementation, and assessment methods under-suited to capturing complex innovation capabilities remain prevalent (Ji & Ziyi, 2024; Tu, 1985).

EC education boasts a profound intellectual lineage. Its philosophical foundations are deeply rooted in classical Chinese thought, where Confucianism, Daoism, and other traditions articulated a holistic cosmology of human-nature harmony (Hansen et al., 2018; Li, 2023; Mok, 2020; Tu, 1998; Tucker, 2020). The conceptual formalization phase (Late 1990s - 2010s) saw "ecological civilization" evolve from an academic concept into a cornerstone of national policy (Goron, 2020). The ongoing strategic integration phase (2010s - Present) involves its systematic incorporation into the education system, driven by its elevation to a national strategic imperative and its alignment with global frameworks like the UN Sustainable Development Goals (Hughes & Wang, 2023; Lu & Chen, 2021). Scholarly work in this phase documents advancements in curriculum development and practical activities, empirically validates the positive impact of educational interventions on student awareness and behavior and notes a paradigm shift from education for sustainable development to ecological civilization (Shen & Chen, 2023; Sun & Nan, 2023; Zhou et al. 2023).

Theoretical Imperative for Integration: Bridging to Green Entrepreneurship Education

The rationale for integrating IE and EC education extends beyond pragmatic policy alignment and engages with the global academic discourse on Green Entrepreneurship Education (GEE). GEE is defined as a pedagogical approach that equips students with the knowledge, skills, and values to identify and exploit opportunities for launching ventures that generate economic value while solving environmental problems (Ansar et al., 2024; Miroshnyk et al., 2022; Soomro et al., 2020).

While the proposed integration model shares GEE's core objective of fostering sustainable venturing, it introduces several distinctive characteristics. Primarily, it is enveloped by the powerful, overarching national narrative of "Ecological Civilization." This mission-oriented framework provides a compelling, morally charged purpose that transcends individual opportunity recognition, fostering a deeper sense of collective responsibility and long-term commitment. Furthermore, the model's design, as explored in the case study, emphasizes deep immersion in large-scale, real-world ecological restoration projects as the central pedagogical platform. This moves beyond classroom-based case studies, offering an authentic context for interdisciplinary application and systems thinking.

Therefore, this study contends that the integrated model represents a significant and distinct variant within the broader GEE landscape—one that is characterized by its mission-driven ethos, project-anchored pedagogy, and synergistic coupling of national strategy with grassroots educational innovation. The model serves as a test case for how GEE principles can be operationalized within a specific, high-stakes national context.

METHODOLOGY

This study employs a qualitative single-case study research design, guided by the methodological principles outlined by Yin (2018) and Stake (1995). This approach is expressly chosen for its suitability in investigating a complex, contemporary phenomenon within its real-life context, particularly when the boundaries between the phenomenon and its context are not clearly evident. The case study method facilitates an in-depth, holistic exploration of the intricate processes and structures underlying the integration of IE and EC education.

The desert soilization project was selected as a critical and revelatory case (Yin, 2018) for several reasons. First, it represents one of the most mature and systematically implemented models of integration in China, with documented outcomes spanning educational, ecological, and entrepreneurial domains. Second, its longitudinal development (over a decade) allows for the observation of sustained integration mechanisms. Third, the project's national recognition and scalability make it an ideal exemplar from which transferable principles can be extracted. While single-case design limits statistical generalizability, it enables deep analytical generalization regarding the structural and processual elements of integration. As the progenitor of the groundbreaking desert soilization technology and a pioneer in building a comprehensive educational model around it, this case represents a "revelatory" instance (Yin, 2018) where the core processes of integration are most visible and mature. Its demonstrated success in yielding tangible educational and ecological outcomes makes it an ideal context for extracting insights that are logically, if not statistically, generalizable to other settings seeking similar transformative goals.

To ensure construct validity and methodological rigor, data were collected from multiple sources, enabling data triangulation (Yin, 2018). Triangulation was achieved by integrating evidence from three complementary strands: document analysis of university strategic plans, syllabi from the "Eco-Mechanics" major, project reports, and policy documents; artifact analysis of photographs, exhibition materials, and competition submissions; and publicly available outcome data including competition results, published project metrics, and media reports.

Data Collection and Sources

Data were collected between January 2022 and December 2024 from three complementary sources. First, document analysis included university strategic plans (n=8), syllabi from the "Eco-Mechanics" major (n=12), project progress reports (n=24), and national policy documents related to IE and EC education (n=15). Second, artifact analysis examined photographs of student field activities (n=86), exhibition materials from the China Higher Education Expo (n=5 displays), and competition submissions (n=3). Third, publicly available outcome data comprised competition results, media reports (n=12), and published project metrics from university and government sources.

No interviews were conducted with students, faculty, or project managers. This is a limitation of the study, as direct participant perspectives could have provided richer insights

into the lived experience of the integrated model. However, the triangulation of documentary, artifactual, and quantitative outcome data ensures construct validity and reduces reliance on self-reported or retrospective accounts.

Research Procedures

The research proceeded through the following steps. Step 1 is case selection. The desert soilization project was selected as a critical and revelatory case (Yin, 2018) based on its maturity, longitudinal development (>10 years), national recognition, and documented multidimensional outcomes. Step 2 is data collection. All materials were retrieved from publicly accessible sources or provided by the university's research office with permission for academic use. Documents were organized chronologically; artifacts were categorized by type and activity. Step 3 is data screening and organization. Duplicate or irrelevant materials were excluded. A case study database was created to store all evidence, enabling auditability. Step 4 is thematic analysis. Following the approach of Braun and Clarke (2006), the author performed initial open coding on 20% of the materials, generating 56 codes. Codes were grouped into conceptual categories (e.g., "curriculum design," "platform function," "student engagement"). Categories were then synthesized into overarching themes, resulting in the final themes: "three-tiered curriculum system," "dual-platform experiential ecosystem," and "virtuous cycle mechanism." Step 5 is validation. Patterns and interpretations were cross-checked across data sources (triangulation). Negative case analysis was performed by searching for evidence that contradicted emerging themes—none were found. A draft of the case study analysis was reviewed by a senior researcher not involved in the study to assess plausibility.

Case Study Analysis: Deconstructing the Integrated Model

Developed by a research team at Chongqing Jiaotong University, the desert soilization technology—an original innovation based on granular material constraint theory—mechanically transforms sandy desert into soil with hydrological and mechanical properties suitable for cultivation. Its successful application across diverse ecologies, encompassing over 3,300 hectares domestically and internationally, transforms it from a mere technical solution into a powerful, authentic platform for education. Its inherent interdisciplinarity—spanning mechanics, materials science, soil ecology, agronomy, and water resource management—makes it an ideal nucleus for an integrated curriculum, compelling students to synthesize knowledge from disparate domains to address a complex, real-world challenge.

The analysis reveals that the model's success is underpinned by two mutually reinforcing architectural pillars: a structured curriculum and a layered practical ecosystem.

One structural tier is the three-tiered integrative curriculum system, which represents the formal, structured dimension of the integration, designed to systematically scaffold student competence.

The first tier is foundational faculty empowerment. Acknowledging that pedagogical transformation is contingent upon educator capacity, the model prioritizes immersive faculty development. Through structured visits to desert soilization bases, educators transition from being passive knowledge transmitters to authentic, experience-informed facilitators of integrated learning.

The second tier is pervasive curricular infusion. The desert soilization technology and its associated challenges are embedded as cross-cutting case studies across a wide spectrum of existing courses, from mechanical engineering and environmental science to business strategy and public policy. This strategy ensures that sustainability and innovation principles are not ghettoized but are presented as fundamental considerations in all fields.

The last tier is specialized programmatic crystallization. The establishment of an "Eco-Mechanics" undergraduate major represents the fullest expression of integration. This program institutionalizes the interdisciplinary fusion, requiring students to engage in capstone projects and team-based ventures that navigate the entire innovation lifecycle, from fundamental R&D and prototype development to business model formulation and market analysis.

The other pillar is the dual-platform experiential learning ecosystem characterized by on-campus and off-campus platforms. This pillar operationalizes the curriculum through a progressive, spatially distributed set of practical environments.

The on-campus platform is a university-based desert soilization research center which serves as an accessible, low-stakes environment for initial experimentation, concept validation, and skill acquisition. It democratizes access to the technology, fostering broad-based curiosity and foundational competency.

The off-campus platform is composed of dedicated field bases in major deserts which function as the ultimate "living laboratories." Here, students confront unscripted, real-world complexities, testing theoretical models against unpredictable environmental and logistical challenges. These sites directly fuel advanced capstone projects and serve as incubators for nascent startup ventures, with the most promising teams progressing to international deployment, thereby executing the critical leap from academic project to global enterprise.

The efficacy of this integrated model is substantiated by a portfolio of tangible outcomes, as summarized in **Table 1**. These achievements span competitive accolades, technological industrialization, and public engagement, collectively demonstrating the model's multifaceted impact.

Critically, the three-tiered curriculum system and the dual-platform experiential ecosystem are not parallel structures but deeply interdependent. The curriculum provides the theoretical scaffolding that enables students to meaningfully engage with the practical platforms, while the field experiences generate authentic problems and questions that feed back into curricular refinement. This recursive relationship—wherein classroom learning informs field practice and field challenges drive curricular innovation—constitutes the operational engine of the virtuous cycle mechanism discussed below.

Table 1. Documented outcomes of the integrated education model

Category of Achievement	Core Initiatives & Projects	Key Outcomes (Quantified / Specific)
Awards in Innovation & Entrepreneurship Competitions	Student project "Transforming Sand into Soil, Turning Weeds into Grain" participated in the China International College Students' Innovation Competition (2024).	Won the National Gold Award, (the university's first gold award at this top-tier competition).
Technological Industrialization & Ecological Restoration	Established a research and industrialization base in the Kubuqi Desert in 2022	1,300 hectares of desert soilization completed, making it the largest demonstration base for this technology; pioneered an industrialization model integrating "Mechanics + Ecology + Agriculture".
Intelligent Systems & Technological Innovation	Constructed an AI data center and solar-panel greenhouse at the Kubuqi Desert soilization site, applying technologies like big data, AI, and the Internet of Things (IoT).	Real-time environmental monitoring and precision irrigation control achieved, reducing water usage by over 30%.
Integrated EC and IE training	Conducted lectures on scientific spirit and desert soilization technology, along with field practice sessions.	Reached over 800 students; student engagement in related projects increased by 40%.
Achievement Exhibition & Science Popularization	Exhibited physical outcomes (e.g. potatoes, peanuts) grown using desert soilization technology at the 62nd China Higher Education Expo.	Attracted more than 5,000 visitors; enhanced public awareness of ecological restoration and sustainable technology.

DISCUSSION

The preceding case analysis has delineated the architectural components of the integrated model. **Figure 1** visually synthesizes these components and illustrates their dynamic interrelationships, which together constitute the proposed "virtuous cycle" mechanism.

This study aimed to construct and empirically validate an integrated framework for combining Innovation and Entrepreneurship (IE) education with Ecological Civilization (EC) education in Chinese higher education. Based on the research results—namely the identification of a three-tiered curriculum system, a dual-platform experiential learning ecosystem, and a virtuous cycle mechanism—the purpose of this research is fulfilled: to delineate a replicable, mission-oriented pedagogical model that systematically cultivates "ecological innovators" capable of addressing complex sustainability challenges.

The findings of this study hold both theoretical and practical significance. Theoretically, the proposed "virtuous cycle" mechanism—comprising mission-driven motivation, interdisciplinary integration, practice-informed feedback, and achievement reinforcement—offers a novel conceptualization of how deep educational integration can be sustained over time. This moves beyond static curriculum design approaches prevalent in existing literature, highlighting the dynamic, self-reinforcing nature of effective integration. Practically, the model provides higher education institutions with a concrete, transferable template for restructuring curricula and experiential learning platforms. The documented outcomes—including enhanced student engagement (40% increase), improved systemic ecological thinking, and tangible entrepreneurial achievements—demonstrate the model's capacity to generate measurable educational and societal impact, thereby contributing directly to national sustainable development goals.

Compared with prior studies on Green Entrepreneurship Education (GEE), which predominantly emphasize classroom-based opportunity recognition and individual entrepreneurial intention (Ansar et al., 2024; Soomro et al., 2020), the integrated model presents distinct characteristics. First, while conventional GEE approaches focus on identifying green business opportunities within existing market structures, this model embeds learning within large-scale, real-world ecological restoration projects, thereby fostering a deeper sense of collective ecological responsibility. Second, whereas previous research has highlighted curricular fragmentation between IE and EC education as a persistent challenge (Li et al., 2016; Zhou & Xu, 2012), this study provides an empirically grounded solution through its three-tiered curriculum architecture that systematically bridges disciplinary silos. Third, unlike studies that treat IE and EC as parallel but separate educational tracks (Lu & Chen, 2021; Sun & Nan, 2023), this research demonstrates their synergistic integration through a shared mission nucleus—desert soilization—that structurally necessitates interdisciplinary collaboration. These comparisons underscore the model's contribution as a distinct, context-rich variant within the broader GEE discourse, one that is characterized by its mission-driven ethos, project-anchored pedagogy, and synergistic coupling of national strategy with grassroots educational innovation.

While the model demonstrates success, the integration of entrepreneurial and ecological logics is not without inherent tensions. Entrepreneurial ventures often emphasize speed to market and profitability, whereas ecological restoration requires long-term resilience, precaution, and adaptive management. In the desert soilization project, these tensions are navigated through: 1) Interdisciplinary mentorship teams comprising engineers, ecologists, and business advisors who collectively guide student projects; 2) Stage-gated project development, where ecological impact assessments are embedded at each phase to ensure environmental integrity; 3) Long-term performance metrics that balance economic viability with ecological restoration indicators such as soil health, biodiversity recovery, and water resource conservation. This balanced approach ensures that student ventures remain both innovatively agile and ecologically responsible.

Despite its contributions, this study has several limitations that warrant acknowledgment. First, the single-case research design, while enabling deep analytical generalization, limits the statistical generalizability of findings to other institutional contexts. The desert soilization project, as a nationally recognized exemplar, may possess unique characteristics—such as sustained funding, high-level policy support, and

media visibility—that are not readily replicable in ordinary university settings. Second, the study's reliance on publicly available outcome data and retrospective document analysis may introduce selection bias, as predominantly positive outcomes are documented while challenges, failures, or less successful implementations may be underreported. Third, the temporal scope of the study captures the model's development and early outcomes but does not systematically follow long-term impacts on graduate career trajectories or sustained ecological engagement. Fourth, the study focuses on a single technological intervention (desert soilization), leaving unanswered questions about the model's applicability to other types of ecological challenges, such as urban pollution, biodiversity conservation, or circular economy initiatives. Fifth, the absence of primary interview data from students, faculty, and project managers limits the study's ability to capture subjective experiences and nuanced challenges of the integrated model. Future research should incorporate semi-structured interviews to complement document-based findings.

Based on these limitations, several directions for future research are proposed. First, comparative multi-case studies should be conducted across diverse university types (e.g., research universities, teaching-focused institutions, vocational colleges) and different ecological project domains (e.g., wetland restoration, renewable energy, sustainable agriculture) to test the model's transferability and refine its contextual adaptations. Second, longitudinal research designs employing mixed methods are needed to track graduate outcomes over extended periods, examining whether the competencies cultivated through the integrated model translate into sustained entrepreneurial activity and ecological stewardship in professional careers. Third, future studies should actively seek and analyze cases of partial success or failure to identify boundary conditions and potential pitfalls in integration, thereby providing a more balanced evidence base. Fourth, comparative international research could explore how similar integration challenges are addressed in different national policy contexts, facilitating cross-cultural learning and theoretical refinement. Finally, developing and validating quantitative instruments to measure integrated competencies—such as systemic ecological thinking, green entrepreneurial self-efficacy, and interdisciplinary problem-solving—would enable larger-scale empirical testing and contribute to assessment methodology in green entrepreneurship education.

Beyond the inherent tensions between entrepreneurial and ecological logics, the replication of this integrated model across diverse institutional contexts may face significant structural barriers. These include the challenge of securing sustained funding for large-scale field bases, potential resistance from faculty accustomed to disciplinary silos, and the need for institutional policies that incentivize cross-departmental collaboration and reward the kind of mission-oriented, time-intensive pedagogy described here. Addressing these institutional prerequisites is crucial for successful model transfer.

CONCLUSIONS

This study presents a comprehensive analysis of an integrated education model, empirically grounded in the pioneering desert soilization project at Chongqing Jiaotong University. The research delineates a coherent framework composed of a three-tiered curriculum system and a dual-platform experiential learning ecosystem, which together engender a "virtuous cycle" of mission-driven learning, interdisciplinary application, and entrepreneurial action. While the single-case design limits statistical generalizability, the model's underlying principles—such as the virtuous cycle mechanism, the dual-platform structure, and the three-tiered curriculum—offer analytical generalizability for other institutions seeking similar integration. Future research should pursue comparative multi-case studies across diverse university types and ecological projects to further validate and refine this framework. By situating its findings within the global discourse on green entrepreneurship education, this study offers a distinct, context-rich variant that emphasizes the power of mission-oriented, project-anchored pedagogy.

The findings of this study carry implications for higher education policy both within China and internationally. For Chinese higher education, the model demonstrates how national strategic priorities—ecological civilization and innovation-driven development—can be operationalized at the institutional level through coherent curriculum design and experiential learning platforms. Policymakers should consider: 1) Incentivizing cross-disciplinary program development that bridges IE and EC education; 2) Supporting faculty development initiatives that prepare educators for mission-oriented, project-based pedagogy; 3) Establishing funding mechanisms for university-led ecological restoration projects that serve as educational platforms; 4) Revising evaluation frameworks to recognize integrated educational outcomes beyond conventional metrics. For international audiences, the model offers a distinctive example of how higher education can align with the UN Sustainable Development Goals through mission-anchored, context-responsive pedagogical innovation. The virtuous cycle mechanism—grounded in authentic challenges, interdisciplinary collaboration, and recursive learning—holds potential for adaptation in diverse cultural and policy contexts addressing sustainability challenges.

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AI statement: The author stated that no generative artificial intelligence or AI-based tools were used in the design, data collection, analysis, interpretation, or writing of this manuscript.

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