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# Teaching Eco-Innovation: A Key Challenge for Sustainable Development

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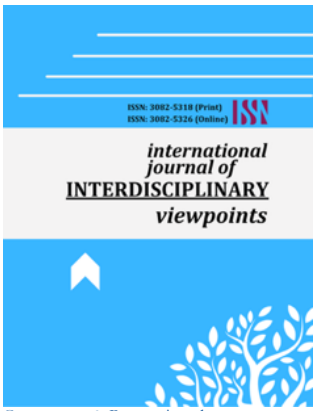
**Research Article**

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**ABSTRACT**

The integration of eco-innovation into educational programs is examined in this study, with a focus on how important it is for student training and the promotion of sustainable development. Applying organizational and technology solutions to lessen environmental effect is known as eco-innovation, and it is viewed as a strategic tool for increasing students' knowledge of today's ecological issues. The study presents a pedagogical revolution based on an interdisciplinary approach that integrates science, technology, economics, and social sciences, proving via a literature analysis and case studies that eco-innovation goes beyond simple awareness-raising. Additionally stressed is the use of active educational techniques like experiential pedagogy and project-based learning. Depending on national circumstances, the use of eco-innovation varies, according to research on environmental and educational policy. Countries in Europe, North America, and Asia seem to be more developed than underdeveloped nations, where systemic obstacles such inadequate financing and training for teachers still exist. This study offers a number of best practices that have been drawn from global experiences, such as the significance of a collaborative approach that involves all parties involved and the use of adaptable curriculum that integrate ideas of social responsibility and ecological transition. *Keywords: education, innovation, educational policies*

## INTRODUCTION

In a world where climate change is an emergency, natural resources are running out, and economies must evolve toward sustainability, innovation becomes a vital tool for balancing growth with environmental responsibility. Eco-innovation stands out as a promising approach to address these intertwined challenges. It encompasses technical, organizational, and social innovations that reduce environmental harm while generating economic and social value (Carrillo-Hermosilla et al., 2010; Bocken et al., 2014). Examples include clean technologies, energy-efficient industrial processes, and circular economy business models that prioritize resource conservation (Le et al., 2024; Espuny et al., 2025).

Over time, eco-innovation has evolved to include environmental, economic, and social dimensions. Scholars have defined it through various lenses—reducing ecological impact, enhancing competitiveness, and transforming production and consumption systems (del Río González, 2009; Geels, 2011). The integration of market knowledge and open innovation practices has also been shown to improve eco-innovation performance (Sanchez-Henriquez & Pavez, 2021), while governance plays a moderating role in its effectiveness, especially in developing regions (Naz & Aslam, 2023).

Eco-innovation is not only essential for transforming industries and public policy—it must also be embedded in education. Teaching future generations to develop eco-friendly solutions and adopt sustainable habits is crucial for transitioning to a greener development model (Charina et al., 2022; Jirapong et al., 2021). Schools and universities must adapt by integrating environmental challenges into curricula and equipping students with the

skills to innovate responsibly. This requires experiential learning approaches that foster collaboration, experimentation, and problem-solving (Peralta, 2022; Speckemeier & Tsivrikos, 2022).

Integrating eco-innovation into education involves embedding ecological ideas, methods, and practices into academic environments. The goal is to cultivate awareness of environmental challenges and empower students to design solutions that mitigate human impact (Alamandi, 2025; Audretsch et al., 2025; Audretsch & Fiedler, 2024; Sun et al., 2025).This interdisciplinary approach combines environmental science, economics, technology, and social sciences to prepare learners for green entrepreneurship and sustainable design. Implementation can include curriculum reforms (e.g., circular economy, waste management), active pedagogies (e.g., innovation labs, industry partnerships), and institutional strategies (e.g., carbon reduction policies, eco-responsible infrastructure).

The ultimate aim of this integration is to prepare future generations to address environmental crises and lead the shift toward sustainable development. By fostering civic responsibility and innovation, education can produce individuals capable of designing and implementing eco-solutions (Yang, Liao, & Li, 2021; Ebzeeva & Smirnova, 2023). In the context of climate urgency and resource depletion, education becomes a transformative force—raising awareness and nurturing changemakers who can reimagine production, consumption, and resource management (Lee et al., 2016; Citaristi, 2022).

**Literature Review**

This review synthesizes studies examining green business, eco-innovation, sustainable development policies, and the roles of higher education, government, and innovation communities in facilitating the transition to sustainability. The review examines policy analyses, empirical investigations, theoretical frameworks, and practical case studies to identify common themes that emerge across them, as well as methodological gaps that need to be addressed in future research.

**International groups and global policy frameworks**

Global policy models, such as the UN's 2030 Agenda and the Sustainable Development Goals (SDGs), are crucial for guiding national and sectoral activities toward sustainability, according to research. Lee et al. (2016) discuss how SDG indicators make the 2030 Agenda workable and provide methods for measuring progress toward public health and intersectoral policy goals. An international study by groups shows that inventories from multilateral bodies (such as the UNDP) and intergovernmental organizations help organize actions for sustainability across different areas of responsibility (Citaristi, 2022). According to Ebzeeva and Smirnova (2023), UNESCO and higher education roadmaps are important means of teaching people about sustainability and helping them develop the skills, beliefs, and knowledge necessary for sustainability. This supports SDG 4 (quality education) as a key part of long-term systemic change.

**Different ways of thinking about creativity and sustainability**

The multi-level perspective (MLP) and innovation-diffusion theories can still help us understand how societies and technologies change to become more sustainable. Many people have said negative things about MLP, but Geels (2011) supports it by highlighting the connections between niche innovations, sociotechnical regimes, and regions. Del Río González (2009) says that market signs, government rewards, and the sharing of information within organizations and sectors all have an impact on eco-innovation. Knowledge spillover theory says that entrepreneurship turns public and private research and development into business-level innovation. This helps the growth of regions and links research results to long-lasting solutions that can be sold (Audretsch & Fiedler, 2024; Audretsch et al., 2025).

**Eco-friendly business models and tactics for creativity**

Researchers have developed various types of sustainable business models to help individuals in business and government identify ways to make their operations more circular, while minimizing their environmental impact (Bocken et al., 2014). (Carrillo-Hermosilla et al., 2010) Eco-innovation studies examine how companies utilize new technologies and adapt their structures to balance growth with environmental protection. Some examples include redesigning products, improving processes, and initiating service-oriented projects. Taxes, grants, and permits that can be bought and sold are examples of market and government benefits that influence how businesses utilize green technologies. Researchers say that the effectiveness of green innovation in reducing emissions is affected by the quality of government and the structure of incentives (Le et al., 2024; Naz & Aslam, 2023).

**The triple helix, the link between businesses and colleges, and higher education**

Higher education schools help the economy in many ways, such as by creating new knowledge, training new workers, and directly promoting creativity through spin-offs and partnerships. UNESCO's goals for higher education and changes to national education make it even more crucial for schools to teach students about sustainability (Ebzeeva & Smirnova, 2023). The Triple Helix method links the government, businesses, and schools. According to Espuny et al. (2025), coordinated policies accelerate the adoption of the circular economy and the establishment of new businesses. This is especially true when governments assume roles that encourage teamwork and streamline processes. Case studies of collaboration between universities and startups have demonstrated that it can facilitate the development of sustainable products and promote the adoption of green technologies (Jirapong et al., 2021).

**Ecosystem dependency, green business, and new ways of doing business**

Researchers who study green entrepreneurship examine the strategies that companies employ, the changes in people's behavior over time, and the rules that facilitate the growth and sustainability of eco-ventures. Evolutionary game models demonstrate how government actions and reward policies influence business behavior and strategy in green markets (Yang et al., 2021). Audretsch and Fiedler (2024) study business communities and find that knowledge sharing, easy access to money, and clear rules are all important for the growth of circular economy projects. Policy discussions examine how lawmakers should allocate funds to sustainable hubs and startups that lower barriers to entry and encourage the growth of green businesses, despite mixed evidence on the best way to establish these facilities and how to finance them (Speckemeier & Tsivrikos, 2022).

**Open innovation, sources of knowledge, and how markets work**

When it comes to eco-innovation, businesses perform better when they are open to new ideas and learn from diverse sources. This gives them better access to information about the business, partners, and technologies that work well with their own. Research suggests that utilizing information sources focused on the market and collaborating on research and development (R&D) could lead to better results in eco-innovation. This is especially true when companies utilize customer feedback and supply chain insights to enhance their products (Sanchez-Henriquez & Pavez, 2021). A post-COVID study focuses on open innovation and sustainable education as means to help small businesses rebound and become more resilient through skill development and teamwork (Charina et al., 2022; Peralta, 2022).

**The Circular Economy, Government, and Putting Systems Together**

Governance, industrial strategy, and collaboration across sectors are all discussed in writings on the circular economy. Research indicates that circular models must integrate with existing processes for policy, finance, and creativity. Espuny et al. (2025) suggest that triple helix coordination is a practical approach to integrate study, regulation, and market application. Theoretical and empirical studies on sustainable innovation management show that long-term environmental stewardship and short-term growth goals are often at odds with each other. Alamandi (2025) states that this implies management systems must consider external factors and stress resilience.

**Geography, sectoral application, and actual data as proof**

Different results were found in different places in a recent scientific study. Researchers using Chinese data have found a link between higher education, technological innovation, and the green economy. They found that research and development led by universities improves the performance of eco-innovation in the region and supports green growth in general (Sun et al., 2025). Studies conducted in South Asia indicate that the impact of green innovations and industrialization on pollution is contingent upon the government's effectiveness (Naz & Aslam, 2023). This illustrates the importance of institutions in transforming new ideas into tangible environmental benefits. Firms and case studies demonstrate that lean startup, open innovation, and customer growth can enhance the effectiveness of long-term business model innovation for goods and markets (Peralta, 2022).

**There are methods, limits, and suggestions for further study**

The field employs a combination of theoretical models (such as evolutionary games), case studies, econometric analysis of panel data, and a synthesis of the literature. There are still some tasks that need to be completed, such as conducting a longitudinal study on the transition of technologies from university labs to the market, comparative analyses of various governance frameworks, and comprehensive reviews of policy instrument combinations. New areas of study include: (1) how entrepreneurs' values and cultural backgrounds affect their drive for sustainability; (2) ways for universities, businesses, and governments to share knowledge when resources

are limited; and (3) ways to figure out how much social and environmental good eco-innovation does. Adding quantified measures, such as SDG indicators, to qualitative story synthesis can enhance policy effectiveness (Lee et al., 2016; del Río González, 2009).

## MATERIALS AND METHODS

### Design

This study employs a qualitative approach to explore the multidimensional nature of eco-innovation and its integration into education. The objective is to understand the conceptual foundations of eco-innovation, identify global practices, and analyze the challenges and opportunities for embedding it into curricula. To achieve this, the methodology combines a comprehensive literature review, comparative analysis of academic experiences, and an examination of educational and environmental policy frameworks (Carrillo-Hermosilla, Del Río, & Könnölä, 2010; Geels, 2011; Sun, Wu, & Shi, 2025).

### Research Approach

The study adopts both exploratory and analytical approaches. The exploratory dimension allows for the identification of diverse definitions and theoretical underpinnings of eco-innovation, including its role in sustainable development and its evolution across sectors (del Río González, 2009; Bocken, Short, Rana, & Evans, 2014). The analytical dimension focuses on evaluating pedagogical practices and determining effective strategies for integrating eco-innovation into educational systems (Peralta, 2022; Espuny et al., 2025).

### Data Collection and Processing

Data collection is structured around three key components:

Literature Review: The conceptual framework draws on seminal works such as Kemp and Pearson (2007), Horbach (2008), and Jaffe et al. (2002), alongside more recent contributions by Carrillo-Hermosilla et al. (2010), Geels (2011), and Sanchez-Henriquez and Pavez (2021). These sources provide insights into the environmental, economic, and social dimensions of eco-innovation and its relevance to education.

Comparative Analysis: The study compares global initiatives for integrating eco-innovation into education, identifying best practices and contextual adaptations. This includes examining interdisciplinary models, partnerships with industry, and curriculum reforms (Charina et al., 2022; Jirapong et al., 2021).

Policy Examination: Educational and environmental policies are analyzed to assess how institutions and governments promote or hinder eco-innovation integration. This includes national strategies, funding mechanisms, and regulatory frameworks (Lee et al., 2016; Ebzeeva & Smirnova, 2023; Alamandi, 2025).

### Ethical Considerations

This study depends solely on secondary sources, such as literature reviews, comparative studies, and policy assessments. As a result, the ethical considerations concern more with ensuring that knowledge management is honest, fair, and courteous than with protecting the persons involved. Because the study examines programs in a range of nations and cultures, broad generalizations should be avoided. Being precise about how sources are selected, reviewed, and merged ensures that the results are credible and do not reflect prejudice or selective reporting. The program will also disseminate its findings in a way that teachers, lawmakers, and academics can understand and use, so that the information gathered may assist advance conversations about eco-innovation in education. The work's moral foundation is based on honesty, respect for other cultures, and a commitment to promoting sustainable development through ethical research techniques.

## RESULTS AND DISCUSSION

The study emphasizes the importance of having clear rules and effective leadership to support eco-innovation and implement lasting changes. The work done by Lee et al. in 2016 demonstrates how SDG metrics influence the goals of review and how tactics are applied consistently across different contexts. Many businesses choose green technology because it is easy to understand, comes with tax benefits, and can help them reduce their environmental impact (del Río González, 2009; Le, Nguyen, & Le, 2024; Naz & Aslam, 2023). Working together remains challenging, as international goals, state laws, and local institutions often conflict with one another. In other words, good ideas that lack significant backing often fail to gain traction (Geels, 2011). The second major

trend is the collaboration of these groups to create new things and share information. Schools and study halls are places where new information is made. How they change society depends on how effectively they can transform their findings into rules and laws. The government, colleges, and businesses are all interconnected through the "triple helix" concept. This is often done to accelerate the circular economy and make green studies more effective. This is beneficial for training, group projects, and planning to bring the government together (Audretsch & Fiedler, 2024; Espuny et al., 2025; Jirapong et al., 2021). Sun et al. (2025) suggest that green growth is more effective when schools and businesses collaborate closely. Studies from China and other places have shown this to be true. Third, we need to stop going around in circles and start doing business in eco-friendly new ways. Sustainable business models, such as platform methods, resource loops, and brand-service systems (Bocken et al., 2014; Carrillo-Hermosilla, Del Río, & Könnölä, 2010), help companies separate progress from material complexity. It has been looked at how circle design and lean startup methods can work together. They are more likely to work in business if you can keep the same people on board and make products that make good use of resources. To facilitate eco-innovation, many people utilize open innovation and draw knowledge from external sources. If a business wants to develop eco-friendly ideas, it should examine the market, gather feedback from customers, and consult with experts. Additionally, research conducted after COVID-19 has also shown that long-term education and open innovation can help small companies improve and learn new things (521; Charina et al., 2022). Price cuts in trade are made possible by information tools and intermediaries. These things also help various groups of people work together to complete their tasks. They pass these tests to demonstrate their importance. Research on green startups reveals that businesses can adapt their methods to benefit the climate, the government, and their own operations. People who run businesses are less likely to adopt eco-friendly practices when the government intervenes and provides them with financial incentives, subsidies, and clear regulations. The way eco-ventures generate revenue, their platforms, and their hubs evolve as they start up and grow (Yang, Liao, & Li, 2021; Speckemeier & Tsivrikos, 2022). Policy discussions primarily focus on how to help green startups meet performance goals, implement market measures, and establish risk-sharing arrangements, enabling them to succeed in the long run. Both Ebzeeva and Smirnova (2023) and Cariaga and El Halaissi (2024) say that all classes should teach skills for survival. It would be easier for college students to understand other cultures, and they would learn more about business and cycle planning, which would make it more useful in various settings. In the country, some programs help children secure jobs and start their own businesses. It has been demonstrated that these apps aid in learning technology and mathematics. These themes always have the same problems: short-term political or managerial incentives do not always match up with long-term systemic resilience; policy instruments do not always work the same way in different cultural and governmental settings; and it is not always clear how knowledge moves from academic research and development to visible social and environmental outcomes (Geels, 2011; Lee et al., 2016; Audretsch et al., 2025; Naz & Aslam, 2022). We need robust, long-term research that examines various areas and aligns with the SDGs. We also require in-depth qualitative research to address these issues. Many of the articles agree on a few things: policy mixes should include rules, money, and skill-building (del Río González, 2009; Le et al., 2024); to improve triple helix translation, funded translational units, incubators, and joint programs should be used (Espuny et al., 2025); and companies should be aware of other cultures (Peralta, 2022). Business plans that are based on processes and market attention should be designed to last (Peralta, 2022). New ideas are more likely to spread when people work together. This can help make changes that are fair and sustainable, continuing to happen.

**Changes in teaching that were made possible by collaboration between different fields**

The research indicated that the integration of eco-innovation in educational institutions significantly transforms students' learning across all subjects. Students could view environmental problems from different perspectives when they learned science, technology, business, and social studies all within the same school. That helped them learn more about ecology and systems thinking, which is a significant approach to addressing challenging environmental problems. Students in Finland and Japan know that mixed courses help them connect what they learn in school to how they can use it in real life. They didn't teach eco-innovation as a separate subject in these places; instead, they mixed it with other subjects, which made it more useful in real life and for future jobs. Students were more interested and felt like they had more control over their lives after hearing about this plan. It was more likely that they would help the environment, find new ways to solve problems, and seek jobs that are environmentally friendly. This demonstrates that learning from diverse fields not only enhances individuals' abilities but also provides them with motivation and a sense of purpose. The school played a significant role in facilitating this change in how teachers approached their jobs, and the program was highly flexible. When

schools allow students from different fields to collaborate on projects, it becomes easier for them to apply eco-innovation in real-life situations. These results demonstrate the importance of reforming the way schools operate.

**What are the benefits and drawbacks of learning through projects and experiences?**

Doing things is now an essential part of teaching eco-innovation. Living labs, green centers, and project-based learning made students more engaged and creative in their school experiences. These methods helped students work together and be creative by giving them real-life problems to solve. Students who worked on real-world projects learned how to utilize green energy, create products that last, and handle materials in an environmentally responsible manner. These activities helped students connect what they learned in school with what they saw and did in nature. This helped them prepare for careers in public service and the green business sector. Experiential learning was more effective when integrated with collaboration among local businesses and environmental organizations. Students learned about the company's rules and what to expect by working on problems in their own towns. It was easier for them to learn and remember things when they could see how they fit into the real world. Additionally, hands-on learning prompted students to reflect on their actions. Students not only solved problems, but they also considered how those solutions would impact people and the world around them. This vital part made students more responsible and taught them to think about the long term, which are skills that future leaders in sustainability will need.

**Different places have different rules and places to stay.**

The comparison revealed that eco-innovation is employed in significantly different ways across various fields. Countries in North America, Europe, and Asia performed better. Changes to their national education policies, smart funds, and better connections between institutions made this possible. Policy processes that worked well together, along with long-term efforts to educate people about sustainability, helped these places. Finland's interdisciplinary curriculum and Japan's Society 5.0 model are two examples of how to incorporate eco-innovation into different aspects of education. The majority of the funds allocated by these nations for education are directed towards recruiting educators and enhancing educational institutions. This ensures that teachers have the necessary supplies to teach subjects that cover a wide range of topics and incorporate hands-on activities. Developing countries, on the other hand, often face fundamental challenges. We can't teach more about eco-innovation because we lack sufficient funding, our teachers are not adequately trained, and our policies are not consistently supported. Many programs rely on test projects or work done by NGOs, which often require government assistance to make a meaningful difference. Even with these problems, there is still some hope in some growing places. The "Green Skills for Youth" program in South Africa and the "Circular Economy" units in Brazil demonstrate how targeted approaches can facilitate eco-innovation even in resource-constrained environments. These examples illustrate the importance of employing the right strategies for each situation.

**The best ways to blend in**

The study identified several effective ways to integrate eco-innovation into the learning process. First, classes that were flexible and incorporated sustainability into all subjects performed better than classes that focused solely on sustainability. It was straightforward to adapt these lessons to suit the business and the region. Second, the shared government played a big part in the success. Lessons were more effective and had a greater impact when teachers, lawmakers, businesses, and members of civil society collaborated to plan and deliver them. Many people were involved in this method, ensuring that eco-innovation was accessible to everyone. Third, teaching kids about social responsibility made them more aware of right and wrong and more motivated. When students understood the impact of their work on others, they were more likely to choose long-term careers and community projects. It was also crucial for teachers to continually improve their skills. Teachers who learned about eco-innovation were more effective in helping their students learn about various subjects and address complex environmental problems. The money spent on people is essential for improving schools in the long run.

**Conclusion and Recommendations**

Integrating eco-innovation into formal education is no longer a pedagogical luxury but a realistic need. When schools and universities stop using tokenistic environmental modules and start using interdisciplinary, practice-based methods, students learn how to identify complex socio-ecological problems, devise solutions that fit the situation, and work across technical and social boundaries. This study demonstrates that experiential learning, project-based inquiry, and a curriculum that deliberately integrates science, technology, economics, and the social

sciences cultivate learners who engage in systemic thinking, entrepreneurial action, and ethical decision-making about technological choices. Eco-innovation in education is essential because it empowers students to make informed decisions. Instead of just passively receiving "green" knowledge, they become active participants in attempts to change their communities. Well-resourced areas have begun to incorporate curriculum changes, partnerships with businesses, and incubator routes into their educational systems as a permanent part of their educational systems. These changes enable student initiatives to grow into local pilots or enterprises. In low-resource settings, on the other hand, some problems are easy to see and fix, such as a lack of funding, inadequate teacher training, and insufficient coordination of policies, which prevent good practices from spreading beyond individual classrooms. These disparities are not predetermined; they signify decisions about the allocation of resources and the formulation of policies that are attuned to local limitations and ambitions.

Investing in teacher capacity must be the cornerstone of any serious effort to scale eco-innovation in education: sustained, hands-on professional development that weaves subject knowledge in sustainability with practical skills for facilitating project-based learning, community partnerships, and reflective assessment empowers teachers to become catalysts rather than mere implementers. Curricula should be competency-driven and modular, allowing schools to focus on systems thinking, circular design, and applied problem-solving without having to overhaul everything at once. Project-based evaluations should give more weight to students' ability to frame real problems, iterate prototypes, and critically weigh social and ecological trade-offs. By incorporating multi-stakeholder partnerships into the system through regional hubs, incubators, or formal agreements, classrooms can connect with mentors, material resources, and opportunities for promising student projects to evolve into community pilots or social enterprises. Sustainable funding and a consistent policy across education and environmental portfolios are both significant. Dedicated budget lines, seed grants for student projects, and small investments in shared makerspaces all help make sure that innovation can continue. Scaling must be fair and take into account the local situation. It should utilize low-cost, high-impact teaching methods, open educational resources, remote mentoring, and phased rollouts that adapt to and learn from the regional situation. Finally, integrated mixed-method monitoring and evaluation systems that connect learning outcomes to community and environmental impact—and are designed to be formative—will keep projects flexible and continually improve. When you put all of these interlocking moves together, they create a virtuous cycle in which better-prepared teachers lead to stronger curricula, which attract partnerships and justify continued funding, resulting in measurable social and ecological benefits that help improve the system and make it more sustainable.

**Conflict of Interest**
The author declared no conflict of interest in the preparation and publication of this research.

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