**Impact Factor (QJIF): 8.47** **E-ISSN: 2583-1615, P-ISSN: 3049-3498**

International Journal of Research in Academic World

**Received:** 10/November/2025 **IJRAW:** 2026; 5(SP1):166-169 **Accepted:** 12/December/2025

# Eco-Technologies and Digital Divides: Re-Envisioning Environmental Justice through Sustainable Infrastructure and Green Pedagogies

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**Abstract**

Higher education in the digital era exists at the crossroads of technology, sustainability and justice. However, the twin phenomena of eco-technologies adoption and persistence of digital divides threaten to reinforce environmental injustice rather than mitigate it. The paper aims to present a Digital Eco-Justice Framework that interlinks three domains: sustainable digital infrastructure, such as energy-efficient computing and smart campuses; justice-oriented pedagogy, including green literacy and participatory learning; and equity in digital access that ensures traditionally marginalised students are not excluded. The framework builds on the recognition that digital equity forms the foundation necessary for sustainability in higher education and that bridging digital divides is fundamental for social justice in climate and environmental action. Furthermore, this model integrates studies on the digital transformation of higher education in the service of sustainable development, providing pathways for universities to transition from technologically intensive but unequal "digital futures" to inclusively climate-responsive education. The following key implications are outlined for institutional leadership, policy and educators: conducting digital-infrastructure audits through a green justice lens; designing curriculum that involves students in the process of learning, both in ecological literacy and digital fluency; and embedding participatory frameworks so that the contributions of marginalised communities underpin sustainable digital strategies. By reframing digital learning environments as sites of ecological and social transformation, the paper argues that higher education can play a critical role in re-envisioning environmental justice for the digital age. The paper considers how sustainable infrastructure, digital pedagogy and equity must co-exist if institutions are to achieve their potential as agents of transformative and inclusive digital futures.

**Keywords:** Eco-Technologies, Digital Divides, Re-Envisioning, Environmental Justice, Sustainable Infrastructure, Green Pedagogies.

## Introduction

The twenty-first century has seen the intersection of two paradigmatic forces in the transformation of higher education worldwide: digitalization and sustainability. Digital technologies such as AI, IoT, and smart learning environments are core to both an institution's operations and its pedagogy. Simultaneously, universities are being called to promote environmental sustainability and social justice agendas in congruence with the UN's SDGs-SDGs 4, 10, and 13 (UNESCO, 2021). These parallel movements, however, are divergent at most times: the rapid use of eco-technologies threatens to deepen existing digital divides through further exclusion of students and institutions not positioned for equitable access to technological resources (Golden et al., 2023).

Environmental justice, understood here as the fair distribution of environmental benefits and burdens (Schlosberg, 2013), occurs well beyond physical ecology and within the digital. In higher education, environmental injustice occurs when digital infrastructures are energy-intensive, pedagogical technologies marginalize under-resourced learners, or sustainability initiatives privilege elite institutions. Thus, Digital Eco-Justice necessitates a harmonious balance across three domains:

- Sustainable digital infrastructure,
- Justice-oriented pedagogies, and
- Equitable technology access.

The paper presents a Digital Eco-Justice Framework that reimagines environmental justice through sustainable infrastructure and green pedagogies. It thus calls on higher education institutions to shift from technology-driven yet inequitable "digital futures" toward inclusive, climate-responsive education. The analysis integrates empirical and conceptual insights from sustainability science, educational technology, and social justice theory, offering a roadmap for policy and practice that positions universities as catalysts for environmentally just digital transformation.

## Background and Rationale

The transformation of higher education through digitalization has been rapid and deep: cloud services, data centers, AI-

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driven platforms, and Internet of Things (IoT) infrastructures are now integral to institutional teaching, research, and administration (Lin et al., 2024). While these technologies offer opportunities for pedagogical innovation and operational efficiency, they also introduce significant environmental consequences: energy consumption of computational infrastructure and lifecycle impacts of devices are increasingly recognized components of universities' carbon footprints (Paredes-Canencio et al., 2024; Hölbling, 2025). Consequently, the environmental impacts of digital technologies in higher education can no longer be treated as a peripheral IT issue but must be integrated into institutional sustainability planning (Lin et al., 2024; Paredes-Canencio et al., 2024).

Running parallel to these environmental concerns is the perpetual issue of the digital divide. The COVID-19 pandemic dramatically revealed and extended inequalities in access to reliable devices, broadband connectivity, and digitally capable learning environments (Golden et al. 2023). Empirical research indicates that students who experienced inadequate access to either the internet or devices suffered decreased learning, lower engagement, and higher dropout rates; the effect was to widen existing socioeconomic and geographic inequalities (Golden et al. 2023; Pierce et al. 2024). When digital technologies are used for delivering sustainability education or climate-related curricula, unequal access risks creating asymmetrical capacities for learners to engage with, act on, or benefit from environmental knowledge-a dynamic that turns technological deficits into environmental injustice (Golden et al. 2023; Pierce et al. 2024).

The concept of environmental justice traditionally foregrounds the equitable distribution of environmental benefits and burdens and the meaningful participation of affected communities in environmental decision making (Schlosberg, 2013). Within higher education, environmental justice must therefore consider not only physical exposures or campus siting but also the distributive and procedural implications of digital transitions — who gains access to green learning technologies, whose knowledge counts in sustainability curricula, and who bears the environmental costs of digital infrastructure (Misiaszek, 2023). Justice-based environmental sustainability (JBES) research calls for pedagogy that centers marginalized voices, cultivates critical reflexivity, and links ecological concerns to social inequalities — an orientation highly pertinent when digital tools mediate environmental learning (Misiaszek, 2023).

Policy frameworks and international initiatives further underscore the urgency of integrating sustainability, equity, and digitalization. UNESCO's Greening Education Partnership and its guidance for higher education encourage whole-system approaches that unite curricular reform, institutional greening, and community engagement to support climate-ready education (UNESCO, 2023). National policies, such as India's National Education Policy (NEP 2020), similarly emphasize digital learning and equity as strategic priorities, with an emphasis on sustainability and skill development, thereby creating an enabling policy context for Digital Eco-Justice interventions in Higher Education Institutions (Ministry of Education, 2020). Yet, policy pronouncements are not enough: evidence indicates uneven institutional uptake and a frequent disconnection between digital investments and equity-focused sustainability outcomes (OECD, 2024). This gap between policy intent and institutional practice is another motivating factor for research bridging technology, pedagogy, and justice.

A growing body of technical literature also offers actionable approaches to reducing the environmental footprint of digital infrastructures. Advances in green computing, energy-efficient data centers, renewable-powered campus networks, and circular economy approaches to e-waste management provide practical pathways for universities to lower Information and Communication Technology-related emissions (Gupta & Bhandari, 2023; Atadoga, 2024). Yet, merely technical solutions risk reproducing inequities if they are decoupled from pedagogical design and access strategies. Rooftop solar powering campus data centers will not address remote rural students' lack of devices or internet access, just as Open Educational Resources promote access but require connectivity and digital literacy. The interplay between infrastructure mitigation and socio-educational inclusion thus forms a core rationale for a combined framework.

Therefore, the proposed study — which develops and refines a Digital Eco-Justice Framework for higher education — is timely and necessary. The framework will aim to integrate:

a) Sustainable digital infrastructure (green computing, renewable energy, lifecycle management),
b) Justice-oriented pedagogy (participatory, community-engaged, critical sustainability education), and
c) Equitable access strategies (connectivity programs, device provisioning, inclusive design).

This integration responds to three interlinked gaps in the literature and practice, namely:

i). Separating the sustainability and digital equity agendas;
ii). The hitherto limited translation of technical green-Information and Communication Technology solutions into pedagogically meaningful practices; and
iii). A lack of empirical evidence regarding how institutional policies can simultaneously reduce carbon impacts while advancing social inclusion.

Conceptually and operationally, the Digital Eco-Justice Framework developed through this study will provide Higher Educational Institutions with practically relevant, evidence-informed pathways toward ensuring that digitalization supports rather than undermines environmental justice.

Finally, the study's outcomes will have policy and practical relevance: they can inform institutional sustainability plans, national education policy implementation, such as NEP 2020, and international education-for-sustainability initiatives, such as UNESCO GEP. The framework would be subjected to empirical testing through case studies and pilot audits that would yield transferable metrics and governance templates, thus enabling Higher Educational Institutions to measure both digital carbon costs and equity impacts with a view to aligning digital futures with just and sustainable educational missions.

## Literature Review

Scholarly work into higher education, sustainability, and digitalization has grown rapidly, yielding both opportunities and tensions where digital futures intersect with environmental justice. Research that quantifies campus emissions demonstrates that significant sources of institutional carbon footprints include electrical energy consumption, data-centre usage, and digital infrastructures. This now calls for low-carbon campus planning and green computing strategies (Paredes-Canencio et al., 2024; Lin et al., 2024). Such studies provide an empirical basis for treating

the approach to digital infrastructure as not only educational but also an environmental one rather than merely an IT issue (Paredes-Canencio et al., 2024; Lin et al., 2024).

These literatures foreground the social, suggesting that the COVID-19 pandemic has revealed and then extended the digital divide, with a pre-existing gap now transformed into a chasm, something starkly inequitable, which has impacted marginal learners and deeply extended educational and social inequities (Golden et al., 2023; Matsieli et al., 2024). Synthesis research on digital transformation in higher education reflects that, without intentional equity interventions, technological adoption reproduces or deepens socio-economic and spatial inequalities (Golden et al., 2023; Matsieli et al., 2024). This places digital equity at the fore of what it means for justice-oriented sustainability in higher education.

Conceptual advances in environmental justice and pedagogy argue for Justice-Based Environmental Sustainability (JBES) approaches that centre marginalized voices and foreground care, participation, and critical reflection within curricula (Misiaszek, 2023; Cuenca-Soto, 2023). Justice-Based Environmental Sustainability research in higher education proposes pedagogical practices—service-learning, participatory curriculum design, and community-engaged research—that explicitly link ecological concerns to social justice outcomes (Misiaszek, 2023; Cuenca-Soto, 2023). Such pedagogies are particularly relevant where digital tools mediate learning because they can either support or subvert emancipatory goals depending on design and access.

Policy and governance literature underlines institutional variability in embedding sustainability: Whereas some universities pursue systematic carbon audits and sustainability reporting, other practices are far from standardized, and technology adoption is conflated with sustainability without equity impact appraisals. International norms, such as UNESCO's Recommendation on the Ethics of Artificial Intelligence, meanwhile, provide governance frameworks that require fairness, transparency, and human rights protections in deploying digital technologies, thereby underscoring the need to consider ethical and distributive dimensions in digitizing education (UNESCO, 2021).

Considering the above research works, these literatures highlight a critical gap: research often frames environmental sustainability (carbon reduction, energy efficiency) and digital equity (connectivity, device access) apart from one another, with less research integrating justice-centred pedagogy, infrastructure greening, and equity policy into a single operational framework for higher education. This gap sets the motivation for the Digital Eco-Justice Framework proposed in the paper, as an effort to synthesize technological, pedagogical, and governance strands toward ensuring that digital transitions in higher education are both low-carbon and socially inclusive.

## Theoretical and Conceptual Framework: The Digital Eco-Justice Model

Building on the intersections identified in the literature, the Digital Eco-Justice Framework integrates three mutually reinforcing domains—sustainable digital infrastructure, justice-oriented pedagogy, and equitable digital access—within the broader mission of higher education sustainability.

- ***Sustainable Digital Infrastructure:*** It is important that universities design and maintain information-technology systems that minimize environmental impact while maximizing accessibility. The infrastructure core of green computing includes energy-efficient hardware, renewable-powered data centers, e-waste reduction, and lifecycle management (Gupta & Bhandari, 2023; Lin et al., 2024). These infrastructures enable institutional carbon neutrality goals and allow for inclusive participation in digital learning environments.
- ***Justice-Oriented Pedagogy:*** Drawing from justice-based environmental sustainability (Misiaszek, 2023) and critical pedagogy, Digital Eco-Justice Framework places educators as facilitators of participatory, problem-based learning where students investigate environmental injustices through digital tools. Pedagogies centered on virtual fieldwork, simulation-based sustainability scenarios, and community mapping strengthen both ecological literacy and digital competence (Cuenca-Soto, 2023).
- ***Equitable Digital Access:*** Digital equity is an important enabling condition of eco-justice. This means investment in infrastructure for the rural and marginalized, open access to digital resources, and proper funding for devices and connectivity (Golden et al. 2023; OECD, 2024).

Theoretically, the Digital Eco-Justice Framework draws from ecological modernization theory-in which technological innovation is seen to reconcile economic and environmental imperatives (Mol & Sonnenfeld, 2000)-and capability theory, wherein equitable opportunities to function and flourish are a prime focus of development and justice (Sen, 1999). The framework brings these two views together by considering technology as both means and medium of environmental justice.

Visually, it could look like a tri-circle Venn: each of the domains-Infrastructure, Pedagogy, and Access-overlap at their core, representing Digital Eco-Justice where sustainable technology use, ethical pedagogy, and equity come together to create just digital futures.

## Discussion and Implications

Digital Eco-Justice Framework supports the idea that Higher Education Institutions have a transformational role in the operationalization of environmental justice through their digital transition. This must occur across various levels: at the level of institutional policy, curriculum reform, and community partnership.

- ***Institutional Policy and Governance:*** Sustainability needs to be a governance imperative rather than an auxiliary initiative. To this end, universities can adopt green Information and Communication Technology policies requiring lifecycle analyses for all digital equipment, carbon audits of cloud storage, and preferencing of renewable-energy suppliers (Paredes-Canencio et al., 2024). Accordingly, UNESCO's Greening Education Partnership calls on the Higher Education Institutions to integrate environmental and social dimensions into all digital-transformation plans (UNESCO, 2023). Transparency mechanisms, represented in public dashboards of digital energy use and metrics of e-waste arising, enhance accountability.
- ***Curriculum and Pedagogy:*** Embedding eco-justice into the curriculum requires more than just awareness-raising modules; it entails transformative learning experiences. Blended learning models can be used for immersive simulations in climate adaptation planning or digital storytelling platforms in environmental advocacy

(Matsieli et al., 2024). Equally important is faculty development: the educator himself/herself must be competent in sustainability science and digital ethics to model responsible technological citizenship. Interdisciplinary collaboration between computer science, education, and environmental studies could result in new course offerings such as Green EdTech and Digital Ethics for Sustainability.

- ***Addressing the Digital Divide:*** Bridging the technological divide is at the heart of justice. Government initiatives like India's Digital India initiative and the National Education Policy 2020 emphasize universal connectivity and open educational resources (Ministry of Education, 2020). Yet, there are disparities across regions and socio-economic groups. Partnerships with telecom service providers to create subsidized educational broadband and institutional loan programs for devices are needed. Community digital hubs on or near campuses can extend resources to first-generation learners and local residents.
- ***Ethical and Cultural Dimensions:*** Technological adoption also gives rise to ethical issues. Guided by UNESCO's Recommendation on the Ethics of Artificial Intelligence (2021), Higher Education Institutions must ensure that AI-assisted learning tools protect the values of fairness, transparency, and human dignity. Embedding cultural diversity within sustainability pedagogy prevents Western-centric models from dominating global narratives of digital sustainability (Ramírez-Correa et al., 2025).

  Taken together, these strategies operationalize the Digital Eco-Justice Framework to bring policy, pedagogy, and participation into alignment for sustainable and inclusive ends. Where coherently implemented, universities not only reduce their ecological footprint but also democratize access to the benefits of digital learning, embodying environmental justice in practice.

## Conclusion and Future Directions

The rapid digitalization of higher education is at once a challenge and an opportunity. If driven solely by imperatives of efficiency or prestige, technology will likely exacerbate inequalities and environmental degradation. If anchored, however, in sustainability and justice, digital innovation can democratize learning while also fostering ecological stewardship. Drawing from environmental justice theory, green computing, and critical pedagogy, the Digital Eco-Justice Framework which is mentioned provides a coherent means for institutions to design inclusive, low-carbon digital ecosystems.

It is expected that future research will empirically validate this framework through case studies of universities implementing green Information and Communication Technology strategies, participatory digital pedagogy, or carbon-neutral e-learning systems. Quantitative analysis of the relationship between digital inclusion indicators and campus sustainability metrics could inform evidence-based policy. Longitudinal evaluation of students' environmental literacy and digital-ethics competencies would also detail long-term educational impacts.

Ultimately, reenvisioning environmental justice through eco-technologies and green pedagogies requires an ethical reorientation of higher education-from consumers of technology to custodians of planetary and digital commons. By integrating sustainability, justice, and innovation, Higher Education Institutions can lead the transition toward equitable digital futures that sustain both people and the planet.

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