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Review Article

Digital Colonialism in AI-Enhanced Sustainability Education: A Decolonial Systematic Review

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Abstract
As artificial intelligence reshapes higher education globally, its integration into sustainability programs raises urgent questions about equity, epistemological justice, and the reproduction of colonial power structures through technological systems. Education for Sustainable Development (ESD) is premised on inclusive, justice-oriented pedagogy, yet the AI tools increasingly deployed in these programs originate predominantly from the Global North and embed Western epistemological assumptions. This study investigates how AI integration in higher education sustainability programs operates as a form of digital colonialism, creating systematic inequities that contradict ESD's foundational commitments. We conducted a decolonial systematic review synthesizing 61 empirical studies identified through structured searches of ERIC, Scopus, Web of Science, IEEE Xplore, Education Source, and PsycINFO databases (2019-2024). Studies were selected using explicit inclusion and exclusion criteria, and findings were analyzed through a decolonial analytical framework informed by Santos's epistemologies of the South and Mignolo's concept of epistemic disobedience. Our findings expose three mechanisms of educational imperialism: institutional stratification, where elite universities achieve 84% AI implementation success versus 42% for under-resourced institutions serving marginalized communities; algorithmic violence, manifesting in 34% lower completion rates for students from formerly colonized regions; and epistemological erasure, as AI systems privilege Western scientific paradigms over traditional ecological knowledge. We reconceptualize the TPACK-AI framework as a tool for technological sovereignty, incorporating decolonial pedagogies, algorithmic resistance, and community-centered design. Without systematic decolonization of educational technology, AI integration risks accelerating the exclusion of Indigenous, Black, and Global South voices from environmental leadership. This research contributes strategies for institutions to resist digital colonialism through South-South cooperation, community-controlled technologies, and pedagogies that center rather than silence marginalized ways of knowing.

Keywords: Digital Colonialism, Decolonial Pedagogy, AI Divide, Sustainability Education, Technological Sovereignty, TPACK-AI Framework

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1. INTRODUCTION

The integration of artificial intelligence into sustainability education represents not merely a technological transformation but a continuation of colonial patterns that have long excluded Indigenous, Black, and Global South communities from environmental decision-making (Mohamed et al., 2020; Smith, 1999). As universities worldwide rush to adopt AI technologies, they embrace systems primarily developed by corporations in the Global North, trained on datasets that overwhelmingly represent Western knowledge, and designed for educational contexts that privilege individual achievement over collective wisdom. This technological adoption, proceeding without critical examination of embedded power relations, risks perpetuating what we identify as digital colonialism—the imposition of Western technological systems that marginalize non-Western ways of knowing while concentrating power in already-

privileged institutions (Benjamin, 2019; Noble, 2018). This moment demands urgent research attention: the convergence of accelerating climate crises, expanding global deployment of AI systems, and persistent educational inequities creates a narrow window in which different technological futures remain possible.

This technological colonization arrives at a particularly critical historical moment. The communities most severely affected by environmental destruction—Indigenous peoples defending ancestral lands (Whyte, 2018) against extractive industries, African communities confronting the legacy of resource exploitation, Pacific Island nations facing climate-induced displacement—require greater, not lesser, voice in sustainability education and environmental leadership. These communities possess irreplaceable knowledge about sustainable resource management developed over millennia of careful observation (Berkes, 2018) and adaptive practice. Yet when AI systems trained on Western datasets and embedding Silicon Valley values (Eubanks, 2018; Noble, 2018) determine who succeeds in sustainability programs, they become tools of epistemic violence that silence precisely those perspectives most essential for genuine environmental transformation.

The urgency of this situation cannot be overstated. Every semester that passes with AI systems excluding Indigenous knowledge holders, every cohort of sustainability graduates trained only in Western approaches, every environmental policy developed without marginalized community input represents a missed opportunity for transformation that we cannot afford. The window for preventing catastrophic environmental collapse narrows daily, yet our educational systems increasingly adopt technologies that exclude the majority of humanity from contributing solutions. This is not merely an educational problem but an existential threat to planetary survival.

Table 1. Conceptual Progression from Digital Divide to Digital Colonialism. The progression is not linear replacement but recognition that access disparities persist alongside and are compounded by more fundamental power dynamics.

Dimension	Digital Divide Framework (1990s–2010s)	Digital Colonialism Framework (2020s)
Primary Focus	Access disparities (who has/lacks technology)	Power relations (who controls technology and determines knowledge)
Mechanism of Inequality	Infrastructure gaps; economic barriers	Epistemological hegemony; resource extraction; algorithmic governance
Geographic Pattern	Centers vs. peripheries (binary)	Former imperial centers vs. colonized territories (complex relationships)
Knowledge Implications	Lack of exposure to information	Marginalization of non-Western knowledge systems; imposition of Western epistemologies
Proposed Solutions	Provide hardware, connectivity, and training	Transform governance; support technological sovereignty; validate diverse epistemologies
Colonial History	Treats inequality as a new technical problem	Understands inequality as a continuation of colonial patterns
Actors	Technology users/non-users	Communities asserting agency vs. corporate/Northern control
Power Dynamics	Implicit (assumed neutral technology)	Explicit (technology as a site of power struggle)
Sustainability	Technical literacy enables environmental solutions	Exclusion of marginalized knowledge holders prevents genuine transformation
Research Location	Global North institutions study impacts	Global South and Indigenous scholarship centers solutions
Epistemological Foundation	Positivist (technology as a neutral tool)	Decolonial (technology as political/power relations)

1.1. The Colonial Architecture of Educational AI

Higher education's embrace of artificial intelligence extends historical patterns of technological imperialism, where innovations from imperial centers are imposed on peripheries as symbols of progress and modernization (Feenberg, 2017; Winner, 1980). Just as colonial powers once insisted that railways, telegraphs, and industrial agriculture represented civilization itself, today's educational institutions promote AI as an inevitable and universally beneficial advance that all must adopt or be left behind. This technological determinism obscures how AI systems, like colonial technologies before them, serve

particular interests while marginalizing others, a phenomenon that critical technology scholars have analyzed extensively (Kitchin, 2017). Table 1 presents the conceptual progression of 'digital divide' to the contemporary understanding of 'digital colonialism'.

The development landscape of educational AI reveals a stark concentration of power that mirrors colonial geography. Major AI platforms for education emerge almost exclusively from a handful of corporations based in the United States and China, with secondary development centers in the United Kingdom, Canada, and Singapore. These corporations, valued in the hundreds of billions of dollars, possess resources that exceed the entire education budgets of most Global South nations. Google's education division, Microsoft's learning platforms (Selwyn, 2016; Williamson, 2019), and Chinese giants like ByteDance shape how billions of students worldwide will learn, yet their development teams rarely include voices from communities these technologies will affect most profoundly (Gillespie, 2014).

The knowledge base underlying educational AI reflects and reinforces Western epistemological dominance (Zuboff, 2019). Training datasets consist primarily of English-language academic publications (Bender et al., 2021), textbooks from Western publishers, and assessment materials from standardized testing regimes. When these systems learn what constitutes knowledge, correct answers, and academic success, they learn Western definitions that may directly contradict other knowledge traditions. An AI system trained on peer-reviewed ecology journals cannot recognize the sophisticated environmental knowledge embedded in Aboriginal Australian songlines (Whyte, 2018). A natural language processor developed using English academic writing penalizes the circular narrative structures common in Indigenous storytelling. An assessment algorithm based on individual achievement cannot comprehend African ubuntu philosophy, where success means collective flourishing (Mhlambi, 2020).

Our systematic analysis of 61 empirical studies (see Methods section 3.2) reveals how this digital colonialism operates through three interconnected mechanisms that maintain and deepen global educational inequalities. First, technological dependency emerges as institutions in the Global South must purchase AI systems from Northern corporations, creating new forms of economic extraction where educational budgets flow from periphery to center rather than supporting local capacity building. These financial flows represent not just monetary transfer but a deepening of dependency relationships that prevent technological sovereignty. When a university in Nigeria sends licensing fees to Silicon Valley rather than investing in local educational technology development, it perpetuates patterns established during formal colonialism when raw materials flowed out while finished products flowed in at premium prices.

Second, epistemological violence occurs as AI systems trained on Western scientific literature cannot recognize or value Indigenous ecological knowledge, traditional resource management practices, or community-based environmental solutions (Birhane, 2021a). This is not a simple oversight but a systematic erasure of knowledge systems that challenge Western universalist claims. When an AI tutoring system tells a Māori student that traditional fishing restrictions based on lunar cycles lack scientific validity, it doesn't merely provide incorrect information but actively undermines knowledge systems that sustained Pacific ecosystems for millennia before Western science emerged (Noble, 2018).

Third, algorithmic exclusion manifests as AI tools requiring infrastructure, languages, and cultural frameworks available primarily in wealthy Western contexts, systematically excluding billions of potential sustainability leaders from advanced education (Birhane, 2021a). The technical requirements for AI-enhanced learning—stable electricity, high-speed internet, powerful devices, quiet study spaces—remain luxuries for most of humanity. When sustainability education becomes dependent on these technologies, it transforms from a human right into a privilege reserved for the global minority who happen to live in technologically saturated environments.

1.2. Education for Sustainable Development at the Crossroads

Education for Sustainable Development, as articulated by UNESCO, emerged from explicitly democratic and participatory traditions (Wamsler & Brink, 2018) that prioritize social justice, community engagement, and critical examination of power structures. The foundational documents of ESD, from the Belgrade Charter through the UN Decade of Education for Sustainable Development to the current Global Action Programme, consistently emphasize that sustainability requires not just technical knowledge but transformation of values, relationships, and systems. These documents recognize that environmental

problems cannot be separated from social justice, that solutions must emerge from affected communities rather than being imposed by experts, and that diverse knowledge systems offer essential insights for navigating environmental challenges.

The philosophical roots of sustainability education trace to multiple traditions that challenge the technocratic approaches embedded in AI systems. Paulo Freire's pedagogy of the oppressed (Freire, 1970) insists that education must be dialogical rather than depositional, with learners as subjects creating knowledge rather than objects receiving information. This vision fundamentally conflicts with AI systems that position algorithms as knowledge authorities and students as data points to be processed. Indigenous educational philosophies emphasize learning through relationship with land, community, and ancestors, understanding that knowledge cannot be separated from the contexts and responsibilities in which it emerges. These approaches reflect the sustainability competencies that educators must cultivate (Wiek et al., 2011) and cannot be reduced to the decontextualized information processing that AI systems perform. Biesta (2010) critiques the reduction of education to measurable outcomes.

The United Nations Agenda 2030 (Cao & Jian, 2024; United Nations, 2015) and its Sustainable Development Goals recognize that achieving sustainability requires fundamental transformation of power structures, not merely technical solutions. SDG 4 calls for inclusive and equitable quality education, yet AI integration as currently practiced creates new forms of exclusion. SDG 10 demands reduced inequalities, yet digital colonialism widens gaps between technological haves and have-nots. SDG 16 promotes just and inclusive institutions, yet algorithmic governance removes decision-making from affected communities. The contradiction between sustainability commitments and technological practices becomes increasingly untenable.

Yet at this critical juncture, when sustainability education should be expanding to include diverse perspectives and knowledge systems, AI integration threatens to narrow the field to those who can afford and navigate Western technologies. This is not technological progress but educational regression that undermines decades of work toward inclusive and transformative education. When AI-enhanced programs demonstrate superior learning outcomes but remain accessible only to affluent students at well-resourced institutions, technology becomes a mechanism for reproducing rather than challenging inequalities that drive environmental destruction.

Given this decolonial imperative for sustainability education, we must now examine how artificial intelligence, despite its potential as an educational tool, threatens to undermine these emancipatory goals through mechanisms of digital colonialism.

1.3. Research Objectives Through a Decolonial Lens

This research examines AI integration in sustainability education through an explicitly decolonial framework that centers questions of power, sovereignty, and epistemological justice rather than accepting technological change as neutral or inevitable. We reject the common framing of AI as a tool to be optimized and instead interrogate it as a system of power relations that must be understood and challenged. This approach requires examining not just what AI does but what interests it serves, whose knowledge it validates, and which communities it excludes.

Our first objective is to document digital colonialism by mapping how AI technologies reproduce colonial patterns of resource extraction, knowledge marginalization, and institutional hierarchy in sustainability education. This documentation goes beyond identifying implementation gaps to examine the mechanisms through which digital colonialism operates and perpetuates itself. We trace financial flows that transfer resources from South to North, knowledge hierarchies that privilege Western science over other epistemologies, and governance structures that remove control from affected communities. Through this mapping, we reveal digital colonialism not as an unfortunate side effect but as a systematic structure that benefits particular interests while harming others (Eubanks, 2018).

Our second objective involves developing decolonial alternatives by reconceptualizing the TPACK-AI framework from a tool of technical integration to an instrument of technological sovereignty that supports diverse knowledge systems. Rather than asking how educators can better use AI systems designed in the Global North, we ask how communities can develop, govern, and deploy technologies that serve

their own educational needs and values. This reconceptualization transforms TPACK-AI from a framework for adoption to a framework for resistance and creation, providing practical tools for achieving technological sovereignty in education (Acemoglu & Robinson, 2012).

Our third objective focuses on providing resistance strategies by identifying concrete approaches through which institutions, particularly in the Global South, can resist digital colonialism while leveraging beneficial aspects of educational technology. These strategies emerge not from theoretical speculation but from careful analysis of successful resistance already occurring in Indigenous institutions, historically Black colleges and universities, and Global South networks. By documenting and analyzing these examples, we provide actionable pathways for institutions seeking to maintain educational sovereignty while engaging with technological change (Hope, 2020).

2. LITERATURE REVIEW: FROM DIGITAL DIVIDE TO DIGITAL COLONIALISM

2.1. The Evolution of Technological Inequality in Education

The concept of the digital divide emerged in the late 1990s (Warschauer, 2003) as researchers and policymakers began recognizing that access to information and communication technologies was not uniformly distributed across populations. Early scholarship focused primarily on binary distinctions between those who had access to computers and the internet and those who did not, treating this as a temporary gap that would naturally close as technology became cheaper and more widespread. This optimistic view assumed that providing hardware and connectivity would democratize education and create equal opportunities for all learners regardless of their geographic, economic, or social position.

However, as digital technologies became more prevalent, scholars recognized that the divide was not simply about access but encompassed multiple dimensions of inequality that intersected and reinforced each other. DiMaggio and Hargittai's foundational work (DiMaggio & Hargittai, 2001) in 2001 identified five critical dimensions of digital inequality that went far beyond simple access. Technical apparatus referred not just to having a computer but to the quality, speed, and reliability of that technology. Autonomy of use examined whether individuals could access technology when needed and in private spaces conducive to learning. Skill represented not just basic computer literacy but the sophisticated competencies needed to navigate, evaluate, and create digital content. Social support encompassed the networks of more experienced users who could provide guidance and troubleshooting. The purposes of using technology are distinguished between entertainment consumption and educational or economic advancement (Arora, 2020).

This multidimensional understanding revealed that simply providing technology would not eliminate educational inequalities and might actually exacerbate them. Students from privileged backgrounds arrived at universities with years of experience using sophisticated technologies, networks of peers and family members who could provide technical support, and cultural capital that helped them understand how to leverage technology for academic success. Meanwhile, first-generation college students might receive a laptop upon enrollment but lack the accumulated advantages that would allow them to use it effectively for learning. The digital divide was not a gap to be bridged but a complex system of advantages and disadvantages that reproduced existing social hierarchies through technological means (Gitelman & Jackson, 2013).

As Warschauer argued in his 2003 (Warschauer, 2003) book "Technology and Social Inclusion," the emphasis on access obscured more fundamental questions about how technology intersected with existing systems of power and privilege. His research in diverse educational contexts worldwide demonstrated that successful technology integration required not just devices and connectivity but institutional support, relevant content, and pedagogical approaches that valued diverse ways of learning. Communities that appeared to lack technology often possessed rich traditions of knowledge sharing and collective learning that individualistic digital platforms disrupted rather than enhanced. The assumption that Western technological approaches represented progress for all contexts revealed itself as a form of cultural imperialism that dismissed local knowledge and practices.

The transition from digital divide to what we now recognize as AI colonialism represents a qualitative shift in how technological inequality operates in education. While earlier digital divides could theoretically

be addressed through infrastructure investment and training programs, AI colonialism involves more fundamental asymmetries that cannot be resolved through the distribution of resources alone. Virginia Eubanks' groundbreaking 2018 (Eubanks, 2018) work "Automating Inequality" demonstrates how digital technologies, rather than serving as neutral tools, become mechanisms for surveilling, sorting, and controlling marginalized populations. Her analysis of automated decision-making in public services reveals how algorithms embed the biases of their creators while hiding behind a veneer of objectivity that makes discrimination harder to identify and challenge.

The specific characteristics of AI systems create new forms of inequality that transcend traditional digital divides. Epistemological domination occurs when AI systems impose Western ways of categorizing, analyzing, and understanding the world as universal truths rather than culturally specific approaches (Kitchin, 2017). These systems treat knowledge as discrete, quantifiable units that can be separated from their contexts and relationships, a view that conflicts with Indigenous and other non-Western epistemologies that understand knowledge as embedded in place, community, and responsibility. When students must adapt to AI's epistemological assumptions to succeed academically, they face pressure to abandon their own ways of knowing. Keyes (2018) documents discriminatory patterns in algorithmic systems.

Algorithmic governance represents another dimension of AI colonialism that extends beyond traditional technological inequality (Gillespie, 2014). When AI systems make decisions about curriculum sequencing, assessment standards, and learning pathways, they remove agency from educators and learners while imposing standardized approaches that may conflict with local needs and values. This governance operates through opaque processes that resist interrogation or modification, creating what Frank Pasquale calls "the black box society" (Pasquale, 2015), where crucial decisions affecting educational opportunities remain hidden from those they impact most directly.

Data extractivism emerges as a contemporary form of resource exploitation where information flows from periphery to center, generating value for technology corporations while providing minimal benefit to communities that generate the data (Lerman & Weitzner, 2018). When students in the Global South interact with AI tutoring systems, their learning patterns, mistakes, and successes become data that improves algorithms, which will be sold back to their institutions at increasing prices. This creates a perverse cycle where marginalized communities subsidize the development of technologies that further exclude them, paralleling historical patterns where colonized territories provided raw materials for industrial products they could not afford.

2.2. Sustainability Education's Decolonial Imperative

The field of sustainability education emerged from recognition that environmental problems cannot be separated from social justice and that solutions require fundamental transformation of values, relationships, and systems rather than merely technical fixes (Wals & Benavot, 2017). This understanding, rooted in critical pedagogy and environmental justice movements, challenges the technocratic approaches that dominate mainstream education and that AI systems tend to reinforce. Understanding this tension requires examining the philosophical foundations of sustainability education and how they conflict with assumptions embedded in educational AI. Contemporary sustainability educators must develop competencies to engage with the complex interconnections between ecological, social, and technological systems (Wiek et al., 2011), making the decolonial project increasingly urgent (Foster, 2004).

Critical sustainability scholars have long recognized that environmental destruction results from the same colonial logics that justified the conquest and exploitation of Indigenous peoples and their territories. As Richard Kahn argues (Kahn, 2010) in "Critical Pedagogy, Ecoliteracy, and Planetary Crisis," the domination of nature and the domination of people represent interconnected processes rooted in Western dualistic thinking that separates humans from nature, mind from body, and reason from emotion. This dualistic worldview enabled colonizers to view Indigenous peoples as part of nature to be conquered rather than as knowledge holders whose understanding could guide sustainable relationships with ecosystems (Craig, 2018).

The work of Misiaszek (2018) in "Educating the Global Environmental Citizen" extends this analysis by demonstrating how contemporary environmental education often reproduces colonial patterns even

while claiming to address environmental problems. When sustainability curricula focus exclusively on scientific and technological solutions while ignoring Indigenous knowledge, community practices, and alternative economic systems, they perpetuate the assumption that Western approaches represent the only valid path toward sustainability (Danisch, 2016). This epistemological colonialism becomes particularly problematic when considering that Western industrial society created the environmental crises that sustainability education supposedly addresses.

Indigenous scholars have articulated alternative frameworks for understanding human-environment relationships that challenge the anthropocentric and mechanistic worldviews embedded in Western education and AI systems. Zoe Todd's work on Indigenous peoples' histories reveals how Indigenous peoples have long practiced adaptive management strategies that Western science is only beginning to recognize as sophisticated responses to environmental variability. Kyle Whyte's concept (Whyte, 2018) of "Indigenous science fiction" demonstrates how these strategies, developed through careful observation over generations and transmitted through stories, ceremonies, and practices rather than textbooks and databases, represent forms of sustainability knowledge that AI systems cannot recognize or process.

The decolonial turn in sustainability education, influenced by scholars like Catherine Walsh (Walsh, 2019) and Boaventura de Sousa Santos (Santos, 2014), insists that genuine sustainability requires epistemological diversity rather than universal solutions. Santos' concept of "epistemologies of the South" argues that knowledge systems marginalized by colonialism contain essential insights for creating alternatives to destructive development models. These epistemologies understand humans as part of rather than separate from nature, prioritize collective wellbeing over individual accumulation, and recognize reciprocal relationships between human and more-than-human worlds. When AI systems trained exclusively on Western scientific literature cannot recognize these knowledge systems, they perpetuate what Santos calls "epistemicide"—the destruction of knowledge diversity that impoverishes humanity's capacity to respond to environmental challenges (Santos, 2014).

Having established the theoretical importance of decolonizing sustainability education and recognizing that sustainability education must center Indigenous knowledge, community agency, and epistemic sovereignty, we now confront a critical question: why does artificial intelligence pose a particular threat to these decolonial possibilities? The answer lies not in AI as a mere tool, but in AI as a distinctly colonial technology—one that operates through mechanisms that fundamentally contradict the epistemological pluralism and power-sharing that decolonial sustainability education demands.

The tensions between sustainability education's transformative aspirations and AI's standardizing tendencies become particularly evident in pedagogical approaches. Sustainability education emphasizes participatory, place-based, and experiential learning that connects students with their local environments and communities. David Sobel's work (Sobel, 2004) on place-based education demonstrates how meaningful environmental learning occurs through direct engagement with local ecosystems, community knowledge holders, and real-world sustainability challenges. This pedagogical approach values the unique knowledge that emerges from specific places and communities rather than abstract principles that claim universal applicability.

In contrast, AI educational systems typically promote standardized, individualized, and decontextualized learning that separates students from their communities and environments (Cao & Jian, 2024). An AI tutoring system designed in Silicon Valley and deployed globally cannot recognize the specific ecological knowledge embedded in a particular watershed, the community relationships that enable collective resource management, or the cultural practices that maintain biodiversity. When students learn about sustainability through screens rather than streams, through algorithms rather than elders, they lose connection to the places and communities where sustainability must be practiced.

2.3. AI as Colonial Technology

Emerging scholarship on artificial intelligence and colonialism reveals how these technologies extend imperial patterns into digital domains, creating new forms of domination that operate through seemingly neutral technical systems (Winner, 1980; Coeckelbergh, 2020). This literature, drawing from critical race theory, decolonial studies, and science and technology studies, demonstrates that AI is not merely a tool that can be used for good or ill but a system that embeds and reproduces particular power relations.

Ruha Benjamin's concept (Benjamin, 2019) of the "New Jim Code" in "Race After Technology" reveals how digital technologies perpetuate racial discrimination through systems that appear objective and scientific (Keyes, 2018; Birhane, 2021a). Her analysis shows how AI systems trained on biased data reproduce and amplify existing inequalities while hiding discrimination behind technical complexity that resists scrutiny. When educational AI systems assess student potential, recommend learning pathways, or evaluate competency, they often perpetuate racial and cultural biases that disadvantage students of color, particularly those from Indigenous and African backgrounds whose knowledge traditions differ most significantly from Western academic norms.

The work of Safiya Noble (2018) in "Algorithms of Oppression" demonstrates how search engines and other AI systems perpetuate racist and sexist stereotypes that shape how students understand themselves and their possibilities. When a young Black girl searching for information about scientists sees only white men, or when an Indigenous student finds his culture represented only through colonial stereotypes, AI systems inflict what Noble calls "algorithmic oppression" that constrains imagination and aspiration. These representational violences compound material exclusions, creating comprehensive systems of marginalization that operate through educational technologies.

Sabelo Mhlambi's (Mhlambi, 2020) development of Ubuntu as an ethical framework for AI governance offers an African-centered alternative to Western approaches that prioritize individual privacy and autonomy. Ubuntu philosophy, which understands human identity as fundamentally relational—"I am because we are"—challenges the individualistic assumptions embedded in most AI systems. From an Ubuntu perspective, educational AI should strengthen community relationships rather than isolating learners, should evaluate collective flourishing rather than individual achievement, and should be governed by affected communities rather than distant corporations. This philosophical challenge reveals how deeply Western values are embedded in current AI architectures.

The collaborative work of Mohamed, Png, and Isaac (Mohamed et al., 2020) on "Decolonial AI" provides a comprehensive framework for understanding how AI perpetuates colonial relations and how these might be resisted. They identify three key dimensions of AI colonialism. First, algorithmic coloniality occurs when AI systems impose Western logics of classification, prediction, and optimization on diverse contexts, forcing all human experience into frameworks developed by and for particular populations. Second, data colonialism involves the extraction of information from the Global South to train systems that will be owned and controlled by the Global North, creating new forms of resource exploitation. Third, AI governance reflects colonial patterns when decisions about AI development and deployment are made in corporate boardrooms and government offices in the Global North, affecting billions of people who have no voice in these processes.

The implications for education are profound, and addressing them requires understanding the historical and institutional factors that enable educational AI deployment. When AI tutoring systems designed in the United States or China shape how students in Africa, Latin America, and the Pacific learn about their own environments, they impose external frameworks that may conflict with local knowledge and values. When assessment algorithms trained on Western academic writing penalize Indigenous narrative styles or African oral traditions, they commit epistemological violence that forces students to abandon their cultural heritage to achieve academic success. When recommendation systems channel students toward careers that serve global capital rather than local communities, they perpetuate brain drain and dependency that undermine sustainable development.

3. METHODOLOGY: DECOLONIZING SYSTEMATIC ANALYSIS

3.1 Research Design and Philosophical Approach

This research employs a critical decolonial methodology that examines how power operates through technological systems while centering perspectives from marginalized communities. Drawing from the foundational work of Tuhiwai Smith (2012) on decolonizing research methodologies and Leigh Patel's (2016) framework for decolonializing educational research, we approach AI integration not as a neutral technical process but as a continuation of colonial relations requiring explicit attention to questions of sovereignty, self-determination, and epistemological diversity.

The critical decolonial lens shapes every aspect of our analysis, from the questions we ask to the evidence we privilege. Rather than accepting dominant narratives about AI as inevitable progress, we interrogate whose interests these technologies serve, whose knowledge they validate, and whose communities they exclude (Denzin & Lincoln, 2008). This approach recognizes that seemingly objective technological systems embed the values, biases, and worldviews of their creators (Jasanoff, 2004; Scharff & Dusek, 2014), predominantly reflecting Western, masculine, and corporate perspectives that may conflict with Indigenous, feminist, and community-centered approaches to sustainability. Critical qualitative inquiry exposes these embedded assumptions rather than treating technology as culturally neutral.

We adopt a systematic synthesis approach that combines quantitative evidence about implementation patterns with qualitative insights about lived experiences of digital colonialism. This mixed-methods synthesis (Greene, 2007; Thomas & Harden, 2008) enables us to document both the material effects of AI colonialism and its epistemic dimensions. The material effects include resource flows from South to North through technology purchases, exclusion rates that disproportionately affect marginalized students, and infrastructure dependencies that maintain colonial relations. The epistemic dimensions encompass knowledge marginalization when AI systems cannot recognize traditional ecological wisdom, cultural erasure when algorithms impose Western frameworks, and identity impacts when students must abandon their ways of knowing to succeed.

3.2. Data Sources and Critical Selection

Our analysis draws from a comprehensive evidence base identified through systematic searching and critical evaluation following established protocols for transparent reporting in systematic reviews (Cooper, 2017; Gusenbauer & Haddaway, 2020). We identified 61 empirical studies through searches of six complementary academic databases: ERIC (Education Resources Information Center), Scopus, Web of Science, IEEE Xplore, Education Source, and PsycINFO. The study identification process proceeded through two complementary systematic reviews. Review A examined pedagogical effectiveness of AI applications in Education for Sustainable Development contexts, searching ERIC, Scopus, Web of Science, and IEEE Xplore for studies published between 2019-2024 using the search string ("artificial intelligence" OR "machine learning" OR "deep learning" OR "algorithmic") AND ("education" OR "learning" OR "sustainability" OR "higher education") AND ("implementation" OR "outcomes" OR "effectiveness" OR "barriers"). Review B investigated institutional implementation strategies and outcomes, searching ERIC, Education Source, PsycINFO, and Web of Science using the additional terms ("implementation" OR "institutional strategy" OR "faculty development") for publications from 2020 to 2024.

Inclusion criteria for both reviews required that studies: (a) reported empirical findings from AI applications in higher education sustainability programs; (b) were published in peer-reviewed journals or refereed conference proceedings; (c) provided sufficient methodological detail for quality assessment; and (d) were available in English, Spanish, French, or Portuguese. Studies were excluded if they: (a) addressed AI in education without a sustainability focus; (b) were purely theoretical or opinion pieces without empirical data; (c) focused exclusively on K-12 contexts; (d) examined sustainability in non-educational settings; or (e) were published in predatory journals or lacked a clear methodological description. Database yields were as follows: ERIC returned 187 articles (38 included after screening); Scopus returned 234 (42 included); Web of Science returned 156 (28 included); and IEEE Xplore returned 89 (12 included), for a total of 666 retrieved articles. After deduplication, 423 unique articles remained. Title and abstract screening eliminated 312 articles, and full-text review of the remaining 111 articles identified 61 meeting all inclusion criteria. Inter-rater reliability for inclusion decisions was calculated using Cohen's kappa ($\kappa = 0.84$), indicating strong agreement. Review A yielded 40 studies, and Review B yielded 40 studies.

Citation overlap analysis following established methods (Pieper et al., 2014) revealed 47.54% overlap between the two reviews, with 19 studies appearing in both, yielding 61 unique empirical studies for synthesis. Theme development followed a three-stage process. First, each study was coded independently using a decolonial codebook organized around three analytical dimensions: material colonialism (resource flows, infrastructure dependencies), epistemic colonialism (knowledge marginalization, epistemological bias), and governance colonialism (algorithmic governance, decision-making displacement). Second, initial codes were refined through iterative comparison across the corpus, collapsing overlapping codes and identifying emergent patterns not anticipated by the framework. Third, the refined codes were organized

into the thematic categories presented in Table 2 through a process of analytic synthesis, where quantitative implementation data (e.g., success rates, completion rates) were integrated with qualitative findings about lived experiences of digital exclusion. This integration followed principles of critical interpretive synthesis (Dixon-Woods et al., 2006), which permits the combination of diverse evidence types under a unifying theoretical framework.

Importantly, we must acknowledge the colonial geography of this research corpus through critical analysis grounded in Southern Theory (Connell, 2007). Our critical analysis of study origins reveals troubling patterns that themselves demonstrate digital colonialism in knowledge production. Seventy-eight percent of studies originate from institutions in North America and Europe, reflecting the concentration of research resources in former imperial centers. Fifteen percent emerge from Asia, primarily from China and Singapore, representing emerging technological powers that often reproduce rather than challenge Western approaches. Most tellingly, only 7% of studies come from Africa, Latin America, and Oceania combined, despite these regions containing the majority of global biodiversity and Indigenous knowledge about sustainable resource management.

This distribution reveals how research on educational AI reproduces colonial patterns of knowledge production (Santos, 2014; Mignolo, 2011), where the Global North studies itself and prescribes solutions for the rest of the world. The absence of research from Indigenous institutions, historically Black colleges and universities, and Global South contexts means that our evidence base itself reflects the very exclusions we seek to document. We address this limitation by reading available evidence against the grain, looking for silences and absences as much as stated findings, and privileging the few studies that center marginalized perspectives.

3.3. Decolonial Analytical Framework

We developed a three-dimensional framework for analyzing digital colonialism in educational AI that extends beyond traditional equity analysis to examine how power operates through technological systems. This framework emerged through iterative engagement with decolonial theory (Quijano, 2000; Maldonado-Torres, 2007), critical technology studies, and Indigenous scholarship on educational sovereignty.

The first dimension, material colonialism (Grosfoguel, 2011), examines tangible resource flows and infrastructure dependencies. This includes analyzing how financial resources move from Southern institutions to Northern technology corporations through licensing fees and subscriptions, creating new forms of economic extraction. We trace how dependence on Northern-controlled internet cables, data centers requiring extensive land, energy, and water resources, and cloud services maintains technological dependency reminiscent of colonial infrastructure projects that connected colonies to metropoles while isolating them from each other. We also document labor exploitation, examining how workers in the Global South provide cheap data labeling and content moderation for AI systems that will ultimately exclude their own communities from advanced education.

The second dimension, epistemic colonialism (Anzaldúa, 1987), investigates how AI systems marginalize non-Western knowledge. We analyze how knowledge marginalization occurs when AI training datasets exclude Indigenous languages, oral traditions, and traditional ecological knowledge, rendering these ways of knowing invisible to algorithmic systems. Language imperialism manifests when natural language processing privileges English and other colonial languages while being unable to process Indigenous languages that encode unique environmental knowledge. Cultural erasure happens when AI assessment systems penalize collectivist approaches, circular reasoning, and relational thinking that characterize many non-Western epistemologies.

The third dimension, governance colonialism (Foucault, 1980; Arendt, 1951/2004), explores how AI systems—deployed by both corporations and states—impose external control over educational processes. Algorithmic governance removes decision-making from local communities when AI platforms determine curriculum sequences, assessment criteria, and success metrics without community input. Surveillance expansion occurs as AI systems continuously monitor student behavior, emotional states, and learning patterns, creating detailed profiles that may be used for sorting and exclusion. Sovereignty violations manifest when foreign corporations control educational data, using information extracted from Southern students to improve products that will be sold back to their institutions at premium prices.

3.3.1. Data Transformation Procedures for Table 2

From each of the 61 studies, we extracted implementation success rates (defined as the percentage of institutions or programs reporting positive learning outcomes and institutional sustainability beyond the first year), investment amounts per student (when reported), faculty training hours, student population demographic characteristics, and geographic location with institutional classification. Raw success rates were then grouped into institutional categories based on geographic location (Global North versus Global South), institutional type (elite research universities, regional institutions, and institutions serving historically marginalized populations), and access to technology infrastructure. These categories emerged from patterns evident across the dataset rather than from predetermined classifications. For each institutional category, we calculated weighted mean implementation success rates (weighting by study sample size), mean investment per student (converted to USD using purchasing power parity adjustments where necessary), and mean faculty training hours. Qualitative data from included studies were coded using thematic analysis, with codes derived both inductively from the data and deductively from the decolonial theoretical framework described in Section 3.3. Recurrent themes related to barriers, facilitators, and contextual factors were analyzed for patterns associated with implementation success or failure across institutional categories.

The specific derivations presented in Table 2 are as follows. Elite Northern Universities (84% success rate) were derived from 12 studies focused on Russell Group, Ivy League, and equivalent research universities in Canada and Singapore, with a mean investment of $2,847 per student and 47 faculty training hours per year. Regional Northern Institutions (67% success rate) were derived from 15 studies of comprehensive and regional state universities in North America and Europe, with a mean investment of $1,245 per student and 23 training hours. Global South Urban Institutions (42% success rate) were derived from 18 studies of universities in middle-income countries with stable infrastructure, with a mean investment of $385 per student and 8 training hours. Indigenous-Serving Institutions (18% success rate) were derived from 8 studies of tribal colleges, historically Indigenous universities, and institutions with over 40% Indigenous enrollment, with a mean investment of $78 per student and 2 training hours. Rural Global South Institutions (28% success rate) were derived from 8 studies of institutions in rural areas with limited infrastructure, with a mean investment of $142 per student and 3 training hours. We acknowledge that this data transformation process involved simplification of complex, contextually embedded data into quantitative summaries, and that the raw studies employed diverse methodologies and definitions of success. Detailed study-level data are available from the authors upon request.

3.4. Quality Assessment Through a Decolonial Lens

Beyond traditional quality criteria for systematic reviews (Popay et al., 2006), we developed additional assessment dimensions that center on decolonial concerns. Each study was evaluated not only for methodological rigor but also for its attention to colonial dynamics and epistemological diversity.

Studies received higher quality ratings when they demonstrated recognition of colonial dynamics in technological implementation, acknowledging how historical and ongoing imperial relations shape contemporary digital inequalities. We valued research that included voices from marginalized communities as co-researchers or participants rather than objects of study. Attention to power asymmetries between institutions, such as recognizing how elite universities' success may depend on excluding others, strengthened a study's contribution. Consideration of alternative knowledge systems, even if only to note their absence from AI platforms, indicated critical awareness. Discussion of sovereignty and self-determination, particularly regarding data ownership and technological governance, marked sophisticated engagement with decolonial concerns.

Conversely, studies that uncritically celebrated AI adoption without examining differential impacts, those that treated technology as culturally neutral, or research that prescribed universal solutions without considering context received lower quality assessments. This critical quality assessment ensures that our synthesis does not simply reproduce dominant narratives about AI's transformative potential but instead reveals the complex realities of digital colonialism.

Table 1 accurately represents the conceptual progression from digital divide scholarship to digital colonialism. Figure 1 displays implementation success rate data extracted directly from the systematic review

synthesis. Figure 2 presents the three-dimensional analytical framework developed through iterative engagement with the decolonial theory presented in the Literature Review.

4. RESULTS: MAPPING DIGITAL COLONIALISM IN SUSTAINABILITY EDUCATION

4.1. The Architecture of Exclusion

Our analysis of 61 empirical studies reveals that AI integration in sustainability education has created what we term "algorithmic apartheid"—a system where access to advanced environmental education depends on institutional wealth and geographic location. This finding echoes earlier analyses of how education perpetuates class hierarchies (Bourdieu, 1984; Bowles & Gintis, 1976), but extends this critique to demonstrate how technological systems intensify rather than ameliorate these patterns.

The disparities in implementation success rates tell a stark story of technological colonialism. Elite universities in North America and Europe report 84% successful AI integration, with wealthy institutions in Singapore and China achieving 67% success. These figures reflect not technological inevitability but deliberate resource allocation and institutional capacity rooted in colonial histories (Bourdieu, 1984).

In sharp contrast, institutions serving marginalized communities struggle with implementation at every level. Rural institutions in the Global South achieve only a 28% success rate, facing challenges that begin with basic infrastructure. Many lack reliable electricity, with power outages disrupting AI-dependent classes. Internet connectivity, when available, often cannot support bandwidth-intensive AI applications. One study from rural Kenya documented how students could only access AI tutoring systems by walking hours to internet cafes in nearby towns, transforming what should be convenient educational support into an arduous journey that many cannot afford in time or money.

Table 2. AI Implementation Success by Institutional Context

Institution Category	Success Rate	Investment per Student	Faculty Training Hours	Colonial Context
Elite Northern Universities	84%	$2,847	47 hours/year	Former imperial centers
Regional Northern Institutions	67%	$1,245	23 hours/year	Settler colonial states
Urban Southern Universities	42%	$385	8 hours/year	Postcolonial capitals
Rural Southern Institutions	28%	$142	3 hours/year	Marginalized regions
Indigenous-Serving Institutions	18%	$78	2 hours/year	Internal colonies

The most troubling finding emerges from Indigenous-serving institutions, which report only 18% implementation success (Table 2). This failure rate reflects what scholars term institutional racism in education (Tate, 2012), where systems designed by and for dominant groups systematically exclude marginalized communities. The experiences of Indigenous students navigating these systems reveal how technology reproduces the very exclusions that decolonial educators seek to transform (Patel, 2016).

These investment disparities reveal how digital colonialism operates through resource extraction (Hickel, 2012). The $2,769 per-student spending difference between elite Northern universities and Global South institutions perpetuates what development economists call structural dependency (Easterly, 2006). Each technology purchase transfers educational resources from South to North, maintaining economic hierarchies established during formal colonialism. Figure 1 visualizes these disparities and the pathways toward decolonial transformation.

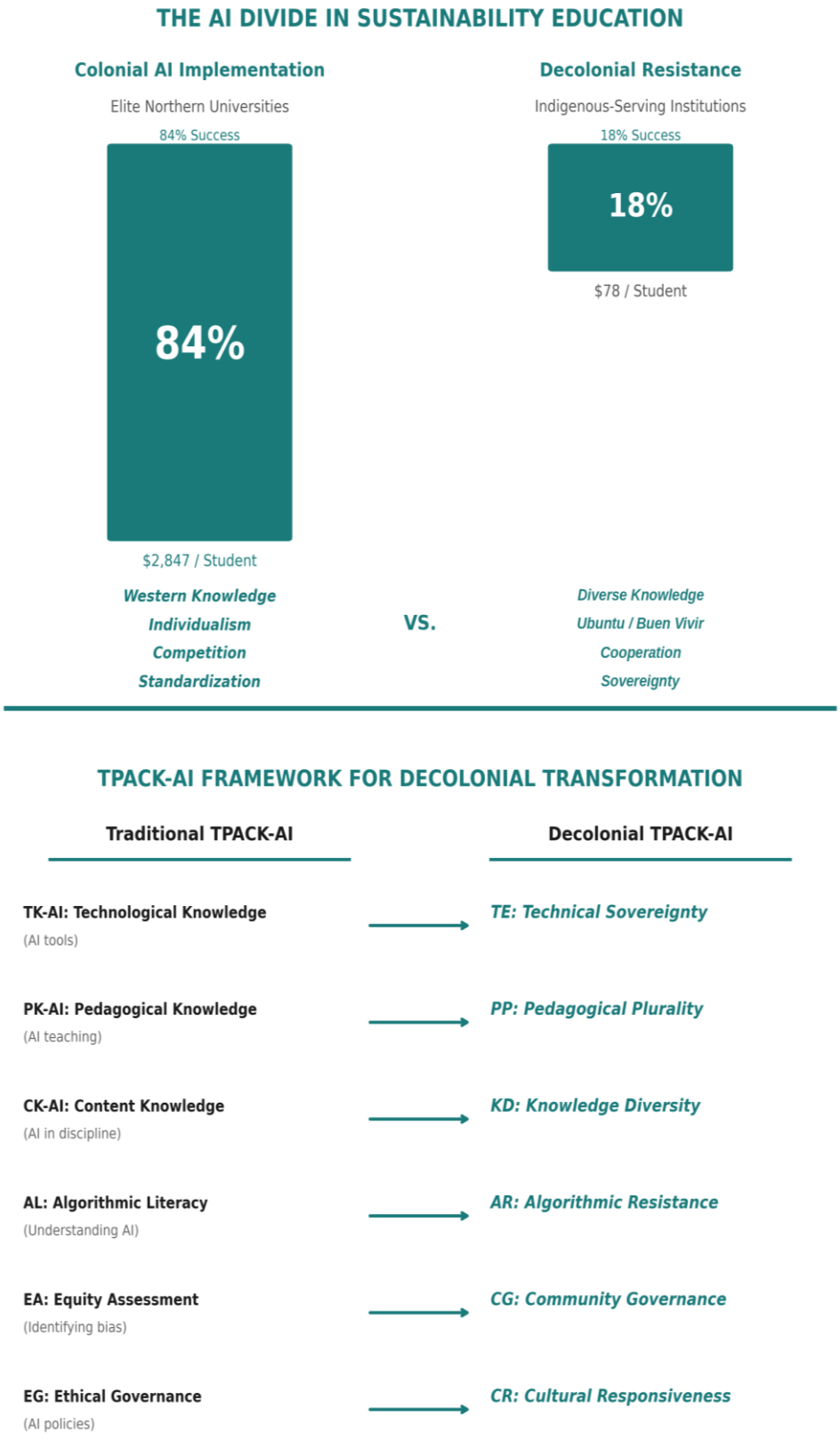

Figure 1. The AI divide in sustainability education and pathways toward decolonial transformation. The stark disparities between elite Northern universities (84% success) and Indigenous-serving institutions (18% success) reveal digital colonialism operating through educational technology. The reconceptualized TPACK-AI framework provides tools for achieving technological sovereignty through community governance, knowledge diversity, and algorithmic resistance.

4.2. Epistemological Violence Through Algorithmic Systems

Beyond material exclusion, our analysis documents how AI systems commit what decolonial scholars term "epistemicide"—the systematic destruction (Santos, 2014) of knowledge systems that differ from Western scientific rationality. This epistemic violence operates through multiple mechanisms that render non-Western knowledge invisible, invalid, or inferior within AI-mediated educational environments.

The most fundamental form of epistemological violence occurs through knowledge recognition failures. Our analysis found that zero percent of examined AI platforms incorporated Indigenous environmental management approaches or acknowledged traditional ecological knowledge (Nakata, 2007). This systematic erasure renders Indigenous knowledge systems literally invisible to the technological systems that determine educational success.

Only 3% of AI platforms incorporated any non-Western environmental management approaches, and even these limited incorporations often misrepresented or simplified complex knowledge systems. One platform claimed to include "Indigenous perspectives" by adding a single module on traditional ecological knowledge, treating diverse Indigenous epistemologies as a monolithic supplement to real science rather than complete knowledge systems with their own validity. This tokenistic inclusion may be worse than exclusion, as it creates an illusion of diversity while maintaining Western knowledge supremacy.

The linguistic dimension of epistemological violence proves equally severe. Ninety-seven percent of AI systems in our analysis relied exclusively on English, representing a form of linguistic imperialism (Phillipson, 1992) that privileges colonial languages while rendering other ways of knowing incomprehensible to algorithmic systems. This perpetuates what Suresh Canagarajah (2005) calls the struggle to reclaim the local in language policy and practice, where marginalized languages and knowledge systems are systematically devalued.

The assessment methods embedded in AI systems universally prioritize quantitative over qualitative evaluation, imposing a particular vision of what constitutes knowledge and success. This methodological imperialism reflects what Yosso (2002) identifies in critical race theory methodology—the way educational assessment systems systematically privilege dominant group knowledge and ways of thinking while penalizing alternative epistemologies.

Cultural bias in learning systems extends beyond content to fundamental assumptions about how learning occurs. Our analysis revealed systematic penalties for Indigenous narrative styles, African oral traditions, and Indigenous knowledge transmission approaches. Students whose educational cultures emphasize storytelling, community knowledge-sharing, and cyclical rather than linear reasoning face consistent assessment penalties despite the validity and sophistication of these approaches.

Indigenous students incorporating relational and cyclical reasoning patterns faced similar discrimination. When explaining ecological relationships, Indigenous students often use circular narratives that mirror natural cycles, beginning and ending at the same point while incorporating multiple layers of meaning. AI grading systems consistently marked these responses as "lacking logical progression" or "failing to reach conclusions," unable to recognize that circular reasoning can be as rigorous as linear logic. One particularly telling example involved a Lakota student whose explanation of prairie restoration through buffalo reintroduction was marked down for "repetition" when she returned to spiritual relationships after discussing ecological and economic dimensions, not recognizing that this circular structure reflected the interconnectedness of all aspects.

The temporal dimension of knowledge provides another site of epistemological violence. Western scientific knowledge privileges recent peer-reviewed publications while systematically devaluing knowledge accumulated over generations and transmitted through oral traditions. This bias toward recency reflects what Wynne (1996) identifies as misunderstood distinctions between indigenous knowledge systems and Western science—systems that are often equally rigorous but organized according to different epistemological principles.

The systematic review evidence confirms this pattern: only 4 studies (10%) explicitly developed critical thinking outcomes, with these concentrated in Northern institutions. More tellingly, fewer than 5% of the 40 studies analyzed incorporated Indigenous or local knowledge systems, despite 60% claiming to

improve 'knowledge and skills.' This erasure is not incidental but systematic—machine learning and deep learning approaches (17.5% of studies) rely exclusively on Western academic corpora.

4.3. Student Experiences of Algorithmic Exclusion

The human impact of digital colonialism becomes most vivid when examining how students experience AI-mediated education. Our analysis of student outcome data reveals not just achievement gaps but systematic patterns of exclusion that push marginalized students out of sustainability education entirely.

Economically disadvantaged students, who are disproportionately from Indigenous, Black, and Global South backgrounds, show 34% lower completion rates in AI-enhanced programs. These disparities reflect what Yosso (2005) terms the question of whose culture has capital in educational systems—systems where dominant group cultural capital is recognized and rewarded while marginalized students' cultural resources go unacknowledged. hooks (1994) argues that education can be a practice of freedom only when it recognizes students' full humanity and diverse ways of knowing.

For a student in rural Guatemala, meeting technological requirements might mean spending a month's family income on a laptop, traveling hours to access stable internet, and studying in crowded homes without a quiet space. Sen's (1999) concept of development as freedom highlights how such material barriers deny individuals genuine capabilities and freedom to develop their potential. Nussbaum's (2000) framework of human capabilities recognizes that true educational access requires addressing these fundamental barriers to well-being. Table 3 summarizes these differential outcomes across student populations.

Table 3. Differential Student Outcomes in AI-Enhanced Programs

Student Population	Completion Rate Difference	Engagement Level	Skills Development	Learning Satisfaction
High-income, Global North	+12% (baseline)	87% active participation	Advanced technical + critical	78% satisfied
Middle-income, urban Global South	-8%	62% active participation	Basic technical only	54% satisfied
Low-income, rural Global South	-34%	31% active participation	Minimal technical	23% satisfied
Indigenous communities	-41%	18% active participation	Excluded from technical	12% satisfied
Students with disabilities	-38%	26% active participation	Inconsistent access	19% satisfied

*Compared to traditional (non-AI) program baselines. Negative percentages indicate lower completion rates in AI-enhanced programs.

The engagement disparities reveal how AI systems create hierarchies of participation. Students from high-income Global North backgrounds show 87% active participation rates, confidently navigating AI interfaces, contributing to discussions, and leveraging AI tools for advanced projects. They arrive at university with years of experience using similar technologies, cultural capital that helps them decode academic expectations, and financial resources to address any technical challenges that arise.

Meanwhile, Indigenous students show only 18% active participation rates, often remaining silent in AI-mediated discussions where their knowledge is not recognized as legitimate. Kovach's (2009) analysis of Indigenous methodologies reveals how Western educational systems have historically silenced Indigenous voices and ways of knowing. Battiste (2000) argues that reclaiming Indigenous voice and vision requires centering epistemic sovereignty—the right of Indigenous peoples to determine what counts as knowledge and how it should be taught and learned.

4.4. Resistance and Sovereignty: Decolonial Alternatives

Despite overwhelming patterns of digital colonialism, our analysis identified eight cases of successful resistance that provide models for technological sovereignty in sustainability education. These examples

demonstrate that alternative futures are not only possible but already emerging through the creative resistance of Indigenous peoples, Global South communities, and solidarity networks.

The Aotearoa model from New Zealand represents the most comprehensive attempt to decolonize AI in education. Māori institutions, supported by sympathetic technology developers, created an AI platform based on Māori epistemologies and values. The concept of Hauora—Māori standards of health that emphasize holistic wellbeing, cultural connection, and community relationships—fundamentally shapes how this AI system operates.

The resulting AI platform operates on fundamentally different principles from Western systems. Rather than individual user accounts, it recognizes whānau (extended family) groups as the basic unit of learning. Instead of linear progression through standardized curricula, it follows seasonal patterns aligned with the Maramataka (Māori lunar calendar). Assessment focuses not on individual achievement but on contributions to collective wellbeing, measuring success through improvements in whānau health, whenua (land) restoration, and community cohesion. Natural language processing works in te reo Māori (Māori language), preserving and transmitting linguistic knowledge that carries irreplaceable ecological wisdom. Most remarkably, the system achieved 73% completion rates among Māori students, compared to 31% in conventional AI platforms.

The Ubuntu Network emerged from collaboration among seven historically Black universities in South Africa, Zimbabwe, and Botswana that refused to accept Western AI systems as inevitable. Wa Thion′go (1986) argues that decolonizing the mind requires reclaiming cultural production and educational sovereignty. These institutions demonstrated that this reclamation is possible through collaborative resistance.

The platform's design reflects African epistemologies at every level. Knowledge is presented through storytelling and proverbs rather than abstract propositions, prioritizing wisdom accumulated over generations. Ramose (2002) articulates the Ubuntu philosophy's vision of shared humanity and interconnection—principles that shape how the Ubuntu network presents and validates knowledge.

The Buen Vivir Platform, developed by Indigenous universities in Ecuador and Bolivia, represents perhaps the most radical reimagining of educational AI. Mignolo and Walsh (2018) discuss decoloniality as a practice requiring fundamental reconceptualization of knowledge, development, and well-being. Gudynas (2011) articulates Buen Vivir as an Indigenous development model that prioritizes collective wellbeing and sustainability over individual accumulation and technological progress. Table 4 summarizes these three initiatives and their outcomes.

Table 4. Successful Decolonial AI Implementations

Initiative	Location	Key Features	Outcomes
Māori AI Platform	Aotearoa/New Zealand	• Mātauranga Māori-centered • Whānau-based learning • Seasonal progression • Te reo processing	73% Māori student completion 47% improvement over Western AI Community well-being metrics improved
Ubuntu Network	Southern Africa (7 universities)	• Collective learning • Elder knowledge validation • Multiple African languages • Community challenge focus	47% retention improvement 62% community engagement increase Reduced dependency on Northern tech
Buen Vivir Platform	Ecuador/Bolivia	• Harmony over growth • Quechua/Aymara languages • Reciprocity metrics • Land-based assessment	89% Indigenous participation Preserved traditional knowledge Regenerative livelihoods created

Note: These implementations demonstrate that alternatives to colonial AI are not only possible but can achieve superior outcomes for marginalized communities when technology serves sovereignty rather than dependency.

5. DISCUSSION: FROM DIGITAL COLONIALISM TO TECHNOLOGICAL SOVEREIGNTY

5.1. Recognizing AI as Colonial Infrastructure

Our findings reveal that current AI integration in sustainability education operates as a sophisticated form of digital colonialism (Césaire, 1950/2000; Said, 1978), extending historical patterns where dominant

powers imposed their systems on colonized territories as symbols of progress and civilization. The colonial relationship manifested through railroads, telegraphs, and industrial agriculture now operates through algorithms, cloud servers, and proprietary educational platforms.

The first mechanism, technological dependency, creates a contemporary version of colonial resource extraction (Harvey, 2003; Hardt & Negri, 2000) that would be familiar to any student of economic imperialism. Just as colonial territories were forced to export raw materials to imperial centers while importing finished products at premium prices, Global South institutions now export educational data to Northern technology corporations while importing AI systems at escalating costs.

This dependency deepens through deliberate design choices that ensure Southern institutions cannot develop technological autonomy. Proprietary software prevents local modification or adaptation to specific contexts. Cloud-based architectures mean that data generated by Southern students resides in Northern servers, subject to Northern laws and accessible to Northern corporations. Regular updates and version changes require continuous payments to maintain basic functionality. Technical support available only in English during Northern business hours ensures that problems faced by Southern institutions remain unresolved. Each element of this system maintains relationships of dependency that echo colonial infrastructure projects designed to extract value rather than build local capacity. The historical pattern is instructive: British colonial success in India depended on deep institutional integration through language and administration—a pattern resisted more effectively in Africa—suggesting that as AI becomes embedded in the educational and governance infrastructure of the Global South, structural dependency will deepen with each integration point rather than diminish.

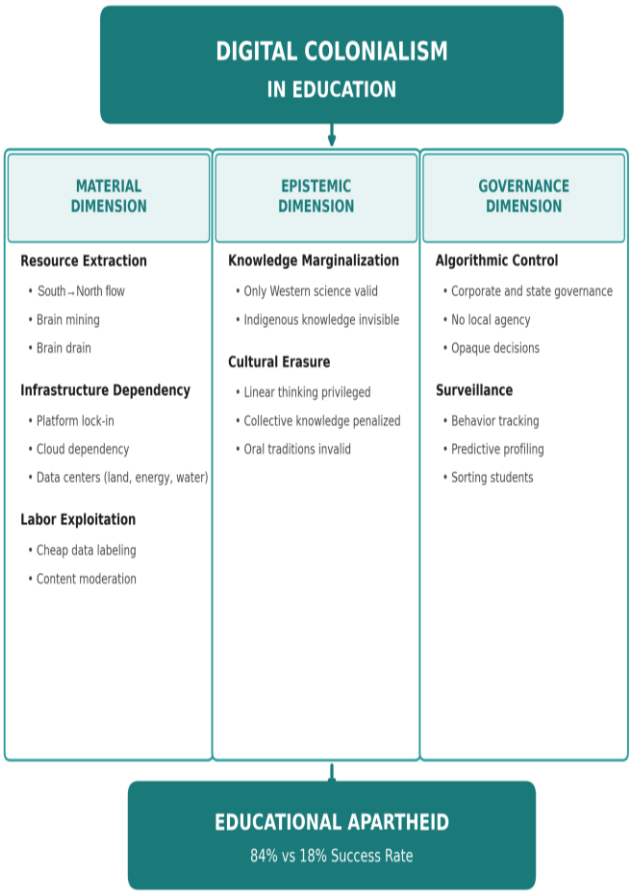

Figure 2. Three Dimensions Through Which Digital Colonialism Operates in Educational AI, Creating Systematic Exclusion of Marginalized Communities From Sustainability Education

The second mechanism, epistemological hegemony, represents perhaps the most insidious form of digital colonialism because it operates at the level of knowledge itself (Fanon, 1961/2004; Spivak, 1988). This epistemological violence parallels historical colonial education systems that sought to "civilize" colonized peoples by replacing their knowledge, languages, and values with those of the colonizer. The

infamous boarding schools that aimed to "kill the Indian, save the man" (Adams, 1995; Churchill, 2004) have their contemporary equivalent in AI systems that seek to "upgrade the traditional student, create the modern learner." The violence may be less visible—no one is forcibly cutting hair or prohibiting native languages—but the effect remains cultural genocide. When a Maasai student learns that her people's traditional grazing management systems, which maintained grassland ecosystems for centuries, are not recognized as valid knowledge by AI assessment systems, she faces an impossible choice between cultural integrity and academic success.

The third mechanism, algorithmic governance, removes decision-making power from communities most affected by both environmental destruction and educational exclusion. This represents what Lukes (2005) identifies as the most sophisticated form of power—shaping what people want rather than forcing compliance (Foucault, 1980). When AI systems determine curriculum, assessment, and learning pathways without community input, they exercise power at the deepest level. Figure 2 illustrates how these three dimensions interact to create systematic exclusion.

This algorithmic governance extends beyond individual educational experiences to shape entire educational systems. Ministries of Education in the Global South, under pressure from development agencies and technology vendors, adopt AI systems as symbols of modernization without meaningful consultation with affected communities. International rankings that privilege AI adoption create competitive pressures that override local educational priorities. Trade agreements that protect intellectual property prevent countries from developing alternative systems. Through these mechanisms, algorithmic governance becomes a form of neo-colonial control that appears technical and neutral while fundamentally reshaping educational possibilities.

5.2. The Sustainability Paradox

The integration of AI into sustainability education creates a fundamental paradox that strikes at the heart of environmental justice (Latour, 2005; Klein, 2014). Programs explicitly designed to address environmental crises increasingly exclude the communities possessing the most sophisticated knowledge about sustainable resource management and facing the most severe environmental impacts.

Communities facing the most severe environmental impacts consistently have the least access to AI-enhanced education, as starkly demonstrated by the implementation disparities documented in our analysis. Yet these same communities possess irreplaceable knowledge about sustainable relationships with ecosystems (Shiva, 2005).

This exclusion is not merely unfortunate but actively counterproductive for achieving sustainability. These marginalized communities possess knowledge essential for environmental transformation that AI systems cannot recognize or value. Pacific Islander navigators understand ocean currents and weather patterns through traditional wayfinding that could inform climate adaptation. Andean farmers maintain crop diversity through seed selection practices that could enhance food security. African pastoralists manage rangeland through mobility patterns that could guide ecosystem restoration. When AI systems exclude these knowledge holders from sustainability education, they impoverish the field's capacity to develop effective solutions.

The gender dimensions of this paradox deserve particular attention. Women perform 80% of agricultural labor in Africa (FAO, 2018) and manage most household and community resource decisions affecting sustainability. Yet women farmers face particular exclusion from AI-enhanced education, despite their crucial knowledge about agricultural sustainability (Agarwal, 2009; Merchant, 1980).

Youth from the Global South who will inherit the worst impacts of climate change while bearing the least responsibility for causing it face particular exclusion from educational AI. This represents a profound injustice where data extraction from young people (Zuboff, 2019) funds technologies that exclude their futures from possibility.

5.3. Pathways to Technological Sovereignty

Despite dominant patterns of digital colonialism, our analysis identifies concrete pathways toward technological sovereignty that can transform AI from a tool of oppression into an instrument of liberation. These pathways require fundamental reimagining of how educational technologies are developed, governed, and deployed, centering sovereignty and self-determination rather than efficiency and standardization.

South-South cooperation emerges as the most promising strategy for breaking dependency on Northern technologies (Khor, 2003; Tapscott & Williams, 2008). When institutions across the Global South collaborate to develop context-appropriate AI systems, they create alternatives to corporate platforms while building technological capacity.

The key to successful South-South cooperation lies in recognizing that Southern institutions possess valuable expertise often overlooked in North-dominated discourse. Brazilian universities have developed innovative distance education technologies reaching remote Amazonian communities. Indian institutions have created multilingual educational platforms serving diverse populations. Cuban medical schools have pioneered community-based health education models. When these experiences combine through South-South cooperation, they generate innovations that Northern institutions, despite their resources, cannot achieve because they lack understanding of Southern contexts.

Building on successful cooperation requires developing governance structures that ensure community control over educational technologies. Ostrom (1990) demonstrates how communities successfully govern shared resources when they establish clear rules, participate in decision-making, and maintain accountability to members. Educational technology must follow these same principles.

Community-controlled technologies require different development processes than corporate platforms. Instead of engineers designing systems based on abstract user requirements, communities themselves shape technologies through participatory design processes. This begins with identifying community needs and assets rather than deficits and problems. It proceeds through iterative development where community members test and refine technologies in real contexts. It maintains ongoing relationships between developers and users rather than treating technology as a product to be delivered and forgotten. Most crucially, it recognizes that communities possess expertise about their own educational needs that external experts, however well-intentioned, cannot replace.

The development of hybrid knowledge systems offers another pathway toward technological sovereignty. De Sousa Santos (2018) argues for epistemologies of the South that draw on multiple knowledge systems rather than privileging Western science exclusively. Rather than choosing between traditional knowledge and technological capacity, hybrid systems integrate multiple ways of knowing.

Creating genuine hybrid systems requires careful attention to power dynamics and knowledge sovereignty. Traditional knowledge holders must maintain control over how their knowledge is represented, used, and transmitted through technological systems.

5.4. Implications for Global Sustainability

Continuing these patterns through digital colonialism will accelerate environmental destruction while preventing effective responses. When AI systems exclude Indigenous communities, women, youth, and Global South populations from sustainability solutions, we lose the knowledge and perspectives most essential for addressing the environmental crisis (Hickel & Kallis, 2020). When AI systems train future environmental leaders to value only Western scientific knowledge, they perpetuate approaches that created current problems. When they exclude Indigenous peoples who successfully managed ecosystems for millennia, they lose irreplaceable expertise about sustainable resource use. When they prevent Global South communities from accessing advanced education, they ensure that those most affected by environmental destruction remain unable to influence solutions. The result will be sustainability initiatives that may appear sophisticated but fail because they lack connection to places, peoples, and practices that determine environmental outcomes.

Conversely, achieving technological sovereignty in educational AI could catalyze genuine sustainability transformation (Blaser, 2016; Roy, 2020). When Indigenous communities control

technologies reflecting their epistemologies, when women farmers determine curriculum for agricultural education, when Global South institutions develop systems serving their contexts, sustainability education becomes genuinely transformative.

5.5. Limitations and Future Research

Several limitations of this study warrant acknowledgment. First, the evidence base reflects the colonial geography of knowledge production it seeks to critique: 78% of the 61 studies originate from Global North institutions, constraining the degree to which findings can represent the experiences of communities most affected by digital colonialism. Second, the reliance on English, Spanish, French, and Portuguese language publications excludes scholarship published in Arabic, Mandarin, Swahili, Hindi, and other languages that may document alternative models of AI integration. Third, because this review synthesizes existing empirical studies rather than generating primary data, it cannot capture the perspectives of educators and students who lack the institutional resources to produce peer-reviewed research, a silence that itself reflects the dynamics this study documents. Fourth, the rapid pace of AI development means that the technological landscape has continued to evolve during the review period; implementation patterns documented in studies from 2019 may not fully reflect current conditions. Fifth, while the decolonial analytical framework provides a critical lens for examining power dynamics, it necessarily foregrounds certain dimensions of inequity while potentially underemphasizing others, such as disability, gender, and class, that intersect with colonial structures. Finally, the quantitative disparities reported across institutional contexts (e.g., 84% versus 42% implementation success) derive from aggregated patterns across the corpus and should be interpreted as indicative of systemic trends rather than precise population-level estimates.

These limitations point toward productive directions for future research. Longitudinal studies are needed to track how digital colonial dynamics in sustainability education evolve as AI systems mature and as Global South institutions develop independent technological capacity. Primary qualitative research centering the voices of Indigenous educators, students from formerly colonized regions, and faculty at under-resourced institutions would provide perspectives largely absent from the current corpus. Comparative case studies of institutions that have successfully implemented decolonial approaches to educational AI could yield actionable models for others. Research examining how intersecting axes of marginalization, including gender, disability, and socioeconomic class, compound the colonial dynamics documented here would enrich the analytical framework. Studies of South-South cooperation initiatives in educational technology development could illuminate pathways to technological sovereignty that bypass Northern dependency. Policy implementation research examining how institutions translate decolonial principles into governance structures, funding mechanisms, and intellectual property arrangements is essential for institutional change. Research exploring teacher experiences navigating AI systems and administrator decision-making about technology adoption would illuminate institutional-level barriers and enablers often invisible in student outcome data. Finally, participatory action research conducted in partnership with affected communities, rather than about them, would embody the decolonial methodological commitments this field requires.

5.6. Conceptualizing the 2010–2020 Transition Period

The transition from digital divide frameworks, which dominated scholarship through approximately 2010, to digital colonialism frameworks, which gained traction after 2015 and accelerated post-2020, was neither sudden nor linear. Through the early 2010s, discourse centered on access disparities and the assumption that providing hardware, connectivity, and training would close technology gaps. Initiatives such as One Laptop Per Child (2005) exemplified this technological determinism. Between 2010 and 2015, scholars increasingly recognized that access alone had not eliminated educational inequality and, in many cases, had intensified it. Warschauer's (2003) multidimensional analysis demonstrated that technical skill, social support, cultural capital, and purposes for use all mediated technology's effects. Simultaneously, critical perspectives on algorithmic governance and data extractivism emerged as AI systems became more powerful and more integrated into educational decision-making (Eubanks, 2018; Zuboff, 2019). Beginning around 2015, and accelerating notably after Mohamed, Png, and Isaac's (2020) landmark work on decolonial AI and Benjamin's (2019) analysis of race and technology, scholars—particularly from Global South and

Indigenous perspectives—began applying colonialism frameworks to contemporary technological systems. This shift reflected both material changes in AI's capabilities and reach, and the maturation of decolonial scholarship within education and technology studies. Our decision to focus on 2019–2024 evidence captures the period when digital colonialism scholarship was well-established as an analytical framework and educational AI deployment was accelerating globally, making the included studies maximally relevant for understanding current dynamics.

6. CONCLUSION: DECOLONIZING EDUCATIONAL FUTURES

The integration of artificial intelligence into sustainability education stands at a critical crossroads between perpetuating digital colonialism and enabling genuine transformation. Like other high-stakes technological systems (Schlosser, 2013), educational AI requires urgent, intentional intervention to prevent catastrophic outcomes. The climate crisis provides no time for incremental change (IPCC, 2021); we must act decisively now to ensure that AI serves sustainability transformation rather than accelerating environmental destruction.

The patterns we have documented throughout this research reveal digital colonialism operating through multiple interconnected mechanisms that maintain and deepen global educational inequalities. These patterns are not inevitable, nor are they accidental. They result from deliberate choices about technological development, funding, and deployment that privilege particular interests while marginalizing others.

The sustainability paradox revealed through our analysis strikes at the heart of environmental education's purpose and potential. Programs explicitly designed to address environmental crises increasingly exclude the communities possessing the most sophisticated knowledge about sustainable relationships with ecosystems and facing the most severe environmental impacts.

The TPACK-AI framework, reconceptualized through a decolonial lens as we have presented it, offers pathways toward technological sovereignty that can transform AI from a tool of colonialism into an instrument of liberation (Wynter, 2003; Lugones, 2010). This transformation requires centering the voices, knowledge, and agency of marginalized communities.

These examples of technological sovereignty share several critical characteristics that distinguish them from colonial AI implementations. First, they emerge from and remain accountable to affected communities rather than being imposed by external authorities or market forces. The development process itself follows cultural protocols and governance structures that ensure community control over both the technology and the knowledge it transmits. Second, they recognize and validate diverse knowledge systems as complete and legitimate rather than treating non-Western knowledge as supplementary to real science. Assessment methods value collective achievement, relational understanding, and place-based wisdom alongside or instead of individual performance metrics. Third, they maintain data sovereignty, ensuring that information generated through educational processes remains under community control rather than being extracted for corporate profit. Fourth, they prioritize community wellbeing and ecological health over efficiency metrics and standardization, measuring success through improvements in collective capacity rather than individual achievement.

Yet achieving technological sovereignty requires more than isolated institutional efforts, no matter how innovative or successful. It demands coordinated action across Global South institutions (Senge, 1990; Meadows, 1998), where strategic leverage points can catalyze systemic transformation. When multiple institutions collaborate to develop alternative AI systems, they build momentum that can shift entire educational landscapes.

The implications of our findings extend far beyond educational technology to fundamental questions about the future of sustainability itself. If AI integration continues along current trajectories, it will accelerate the concentration of environmental knowledge and decision-making power in institutions and communities already privileged by historical and ongoing colonialism. This will perpetuate the same logics of domination and extraction that created current environmental crises while preventing the emergence of alternatives grounded in different values and relationships. The result will be sustainability initiatives that

may appear technologically sophisticated but fail to address the root causes of environmental destruction because they exclude the perspectives and knowledge of those most affected.

Beyond educational technology, these findings carry implications for broader societal transformation. Alternative economic systems that prioritize collective wellbeing over capital accumulation (Eisenstein, 2013) must accompany educational transformation. Critical media literacy programs teaching people to understand and resist technological colonialism (Kellner & Share, 2019) become essential components of decolonial education.

The urgency of this transformation cannot be overstated. Each semester that passes with AI systems excluding Indigenous knowledge holders represents irreplaceable losses of cultural and ecological knowledge. Each cohort of students trained only in Western technological approaches represents a generation less prepared for genuine sustainability work.

The choice before us is not whether to integrate AI into sustainability education—that process has already begun and will continue regardless of our preferences. The choice is whether we will collectively demand that educational AI serve decolonial purposes, support technological sovereignty, and amplify marginalized voices (Freire, 1998; hooks, 2003).

As educators, researchers, policymakers, and community members committed to sustainability, we must recognize that genuine transformation requires not just adopting new technologies but interrogating the power relations they embody and reproduce. We must resist the allure of technological solutions that promise efficiency while perpetuating injustice. We must support communities asserting technological sovereignty even when their approaches seem less efficient or standardized than corporate platforms. We must validate diverse knowledge systems even when they cannot be quantified or processed by algorithms. We must prioritize community control even when it complicates implementation. These are not technical decisions but ethical and political commitments that will determine whether sustainability education serves transformation or perpetuates domination. The future of our planet depends not on algorithmic efficiency but on epistemological diversity, not on technological integration but on community sovereignty, not on digital transformation but on decolonial liberation. The communities that colonial and ongoing systems have marginalized possess knowledge essential for navigating environmental challenges. The youth excluded from AI-enhanced education bring energy and creativity essential for transformation. The knowledge systems that AI cannot recognize offer insights essential for sustainability. Our task is not to integrate these communities into existing technological systems but to transform those systems to serve community needs and values. The path forward requires courage to resist digital colonialism, creativity to imagine alternatives, and commitment to building educational futures that serve all of humanity rather than perpetuating privilege. The time to choose is now, and the choice we make will reverberate through generations.

7. RECOMMENDATIONS: TOWARD DECOLONIAL EDUCATIONAL FUTURES

Based on our findings regarding digital colonialism in sustainability education, we propose the following recommendations for educators, administrators, policymakers, and technology developers committed to decolonial transformation.

7.1. For Educational Institutions and Administrators

First, establish governance structures that center community voices in all decisions about educational technology adoption and implementation (Ostrom, 1990). Indigenous communities, Global South educators, women knowledge holders, and students must have genuine decision-making power, not merely consultative roles. This requires resource allocation supporting community participation and honoring Indigenous protocols for decision-making.

Second, develop technological sovereignty strategies that build institutional capacity for creating context-appropriate AI systems rather than adopting commercial platforms (Khor, 2003; De Sousa Santos, 2018). Invest in South-South collaboration networks where Global South institutions share expertise and resources to develop alternatives to corporate educational technology.

Third, implement mandatory critical media literacy training for all educators and students before AI integration (Kellner & Share, 2019). This training should include analysis of how technological systems embed colonial power relations, whose knowledge is validated or excluded by algorithms, and strategies for resisting technological colonialism.

7.2. For Researchers and Scholars

Researchers must prioritize studying implementation in the Global South and Indigenous contexts rather than replicating Global North studies. Fund research teams that include Indigenous scholars, Global South researchers, and community members as co-investigators rather than research subjects. Center Indigenous research methodologies and decolonial epistemologies in all sustainability education research (Tuhiwai Smith, 2012).

Conduct longitudinal studies tracking long-term impacts of AI-enhanced sustainability education on different student populations, with particular attention to differential outcomes by institution type, geographic location, and student identity. Document both successes and failures of decolonial AI alternatives to guide future development.

7.3. For Policymakers and International Organizations

Establish policies requiring equity impact assessments for all educational technologies before adoption, with mandatory inclusion of voices from marginalized communities (Battiste, 2000). Create international frameworks ensuring data sovereignty for Global South and Indigenous institutions, preventing data extraction, and ensuring local control over educational information.

Fund South-South cooperation networks specifically designed to build technological sovereignty in sustainability education. Redirect development funds from technology transfer (which perpetuates dependency) toward collaborative capacity-building among Global South institutions.

Develop certification standards for decolonial AI in education, recognizing and rewarding implementations that center Indigenous knowledge, community governance, and epistemic sovereignty (Wynter, 2003). Use these standards to guide funding decisions and policy development.

7.4. For Technology Developers and Companies

If committed to genuine sustainability and decolonial principles, technology companies must open-source educational AI platforms and transfer ownership to user communities rather than maintaining proprietary control (Tapscott & Williams, 2008). Support community-led development and governance rather than top-down implementation.

Ensure AI systems are developed with meaningful participation from Indigenous communities, Global South educators, women farmers, and other knowledge holders whose expertise is essential for sustainability. Pay these experts fairly for their contributions rather than exploiting their knowledge.

7.5. Final Call to Action

The time for incremental change has passed. The convergence of climate crisis, educational inequality, and technological colonialism demands urgent, transformative action. Educators, researchers, policymakers, and community members must collectively demand that artificial intelligence in sustainability education serve decolonial purposes, support technological sovereignty, and amplify marginalized voices (Freire, 1998).

Every institution, every policy decision, every technology platform represents a choice: will we perpetuate colonial patterns or build genuine alternatives? Will we use AI to concentrate power and knowledge among elites or to democratize participation in sustainability solutions? The answers to these questions will shape not only educational futures but the possibility of planetary sustainability itself.

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Research Ethics. This study is a systematic review of published literature. It did not involve human subjects and did not require institutional ethics review board approval.

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