Rights of Nature and Decolonial Pedagogies in Sustainable STEM Education: Policy Pathways for Environmental Justice in Europe and the Global South

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ABSTRACT:

Growing ecological crises demand a fundamental rethink of how STEM education teaches students to relate to nature. In order to bridge the gap between ecological knowledge and pro-environmental action, this review explores the relationship between Rights of Nature (RoN) legal frameworks, decolonial pedagogy, and sustainable STEM education throughout the Global South and Europe. The review article highlights that policy-driven integration of RoN principles is crucial. The doctrinal analysis triangulated with secondary empirical evidence has been used for this review. It applies three analytical lenses – legal positivism, critical legal theory, and decolonial frameworks rooted in Indigenous Buen Vivir traditions, to about fifty Scopus-indexed studies, constitutions, and legal texts published between 2020 and 2025. Findings show that despite RoN recognition in 66 countries and over 688 programmes globally, fewer than 28% of Global South curricula integrate RoN, and engagement in Europe remains equally fragmented. Yet Buen Vivir-inspired interventions produce 53-63% improvements in students' sustained behavioural engagement and SDG-aligned competencies. This review article recommends transdisciplinary curricula, decolonial teacher training, and formal integration of RoN literacy into GreenComp and Erasmus+ frameworks, offering an evidence-based roadmap for social transformation through sustainable STEM education.

Keywords: Rights of Nature, sustainable STEM education, decolonial pedagogy, environmental justice, ecological citizenship, GreenComp.

1. Introduction

Global ecological crises indicate that our collective existence is in crisis, yet school-based environmental education remains stuck delivering facts without cultivating behavioural change. When sustainability is integrated into STEM curricula, students develop stronger critical thinking skills, and the sustainable STEM framework increasingly adopts the concept of the Rights of Nature (RoN), which holds that nature has inherent rights to life and thriving. Decolonial models such as the Andean Buen Vivir exemplify RoN's relational harmony with nature. The UN Human Rights Council affirms that children have an intrinsic right to a healthy environment, and environmental education is a key enabler of that right (UNESCO, 2005). Incorporating RoN into STEM education strengthens children's connection to the environment (Rodrigues-Silva & Alsina, 2023). US-based research shows that sustainable alternative education enhances student-led advocacy for local environmental justice (Warner & Elser, 2025). And the place-based and community-based programme designs consistently produce higher engagement and stronger leadership outcomes in environmental action than traditional, classroom-only instruction (Ellington & Prado, 2025). This confirms that policy-driven STEM education can genuinely bridge the knowledge-action gap. Yet even though RoN has spread to 66 countries, empirical gaps persist in policy-driven STEM integration, especially in the Global South, where the Buen Vivir concept is rarely operationalised for youth equity (Misiaszek & Rodrigues, 2023).

European educational systems face a parallel challenge. The European Green Deal, the EU Biodiversity Strategy for 2030, and the European Sustainability Competence Framework GreenComp (Bianchi et al., 2022) together represent a growing mandate for transformative environmental learning. Yet European STEM curricula continue to reflect largely anthropocentric assumptions and rarely engage with RoN or the decolonial frameworks that have proved effective in the Global South. This review article responds to that gap with a cross-regional perspective addressing both contexts. The objective is to map educational gaps in worldwide RoN legal frameworks and propose integrated curricula that promote ecological citizenship. In addition, recommend legislative changes that ensure fair access in order to bridge the knowledge-action gap and support planetary governance for future generations (UNESCO, 2024). Sustainable STEM education exposes learners to real-life ecological problems, helping them develop a sustainability perspective and design eco-solutions (Routray & Mohanty, 2024). Table 1 compares the transformative, eco-centric framework of sustainable STEM with the anthropocentric approach of traditional STEM education, highlighting the Buen Vivir concept of justice.

Table 1: Comparison Between Traditional STEM Education and Sustainable STEM Education for Environmental Justice and RoN

Dimension	Traditional STEM	Sustainable STEM (RoN-integrated)	Empirical Evidence
Primary Focus	Content knowledge in STEM subjects.	Integrates sustainability, RoN, and environmental justice with STEM content.	Moderate positive effect size of 0.46 on learning outcomes (Cao et al., 2025).
Ethical Perspective	Anthropocentric.	Eco-centric.	40% higher empathy and pro-environmental behaviour (Li et al., 2024).
Relational Ontology	Individualistic; human-nature separation.	Interdependent worldview (Buen Vivir); humans as part of living ecosystems.	22% gains in SDG competencies; 15% reduction in rural inequalities (PEHRC,

Dimension	Traditional STEM	Sustainable STEM (RoN-integrated)	Empirical Evidence
			2024).
Connection to Nature	Abstract, limited direct engagement.	Direct engagement with local ecosystems.	32% higher connectedness; 45% sustained behavioural change (Rosa et al., 2023).
Outcomes	STEM literacy and workforce preparation.	Ecological consciousness, governance, and pro-environmental action.	0.52 cognitive effect size; 22% competency gains for SDGs (Ouyang & Xu, 2025).

Since Buen Vivir prioritises nature's intrinsic value, it was written into Ecuador's 2008 Constitution (Acosta, 2013) and later became the basis for STEM teacher training under Ecuador's PIENSA project, which integrated biodiversity with local communities and produced a 20% higher understanding of environmental knowledge among participants (Quick, 2018). This demonstrates Buen Vivir's empirical capacity to shift STEM education from an anthropocentric to an eco-centric approach, promoting equitable, place-based learning (Altmann, 2017).

Sustainable STEM is further grounded in the UN Human Rights Council's formal recognition of children's right to a healthy environment, given that children are disproportionately affected by environmental degradation (UNESCO, 2024). This reflects Article 29(1) of the Convention on the Rights of the Child, which requires education to encourage respect for the natural world (UNESCO, 2005); all EU member states are signatories. RoN and environmental justice perspectives should therefore be incorporated into STEM education so that children gain the values needed to become caretakers of the planet (Campbell & Speldewinde, 2022).

In September 2022, Spain awarded the Mar Menor lagoon legal personality in a historic move after a citizen-led movement garnered over 600,000 signatures (Spain, 2022; Salazar-Ortuño & Vicente Giménez, 2022). The law was affirmed by Spain's Constitutional Court in November 2024. In July 2025, Switzerland acknowledged the lagoon as a foreign legal body, granting it the right to request environmental data overseas (Eco Jurisprudence Monitor, 2025a, 2025b).

Beyond Spain, an eco-centric perspective is progressively making its way into European constitutional law through the French Charter of the Environment. It protects citizens' rights to a healthy environment without giving nature legal subjectivity (Fuchs, 2023). Despite this potential, involvement with the RoN concept is still dispersed over the continent, and European STEM curricula have been sluggish to include such advancements.

The ecological citizenship expands the notion of citizenship to encompass accountability for the welfare of nature (Koca and Çobanoğlu, 2024). Place-based learning, bolstered by educators' eco-pedagogy, is the foundation of sustainable STEM education. The outdoor classes foster students' connection to the natural world and develop their critical thinking skills on environmental justice. In order to promote social and environmental fairness, policy frameworks must guarantee that all children get nature-based education (Routray & Mohanty, 2024).

2. Methodology

In order to find trends, gaps, and links, this review uses a "Doctrinal Analysis Triangulated with Secondary Empirical Evidence" technique to analyse current legal texts, policies, and educational systems. This review is not a formal systematic review conducted according to PRISMA guidelines; rather, it employs a targeted doctrinal analysis of approximately fifty Scopus-indexed studies, constitutions, legal texts, and policy documents published between 2020 and 2025, identified through keyword searches and triangulated with secondary empirical evidence. RoN, Buen Vivir, ecological citizenship,

decolonial pedagogy, sustainable STEM education, and environmental justice were among the keywords. Publications that studied the connection between RoN legal frameworks and education or showed actual results in sustainable STEM programmes were included. A triangulation matrix and hermeneutic interpretation of Indigenous texts, laws, and theories were used in the analysis.

Three perspectives—legal positivism, critical legal theory, and decolonial viewpoints derived from Indigenous communities, especially Buen Vivir, are used in this review to analyse RoN and sustainable STEM. In line with mixed methods frameworks, this hybrid technique improves validity by combining legal interpretation with empirical results (Creswell & Poth, 2018; Lutfauziah et al., 2024).

For ethical reasons, primary data gathering involving minors was avoided. The researchers, who are Indian Global South scholars, gave priority to Southern sources (around 40% of the sample) in order to promote decolonial fairness and diverse voices in the analysis (Smith, 2021).

The analysis proceeded in four stages. First, the researchers mapped RoN's global legal presence using around 100 legal papers and case studies, finding that 688 programmes across 66 countries have recognised RoN (Eco Jurisprudence Monitor, 2026; Sachs, 2023). Two leading examples of landmark developments are Ecuador's 2008 Constitution and New Zealand's Te Awa Tupua Act of 2017. Implementation barriers also persist, such as the conflicts between Bolivia's Law of Mother Earth and mining interests (Stone, 2010). Table 2 summarises these variations.

Table 2: Comparative Table of RoN and Legal Provisions

Criteria	Countries with RoN laws (e.g., Ecuador, Bolivia, New Zealand, Colombia)	Countries without RoN laws (e.g., the US federal government, Australia, and China)
Legal Status	Explicit constitutional or statutory recognition of nature as a rights-bearing entity.	Nature is treated as property under anthropocentric law (e.g., the US Clean Water Act, 1972).
Enforcement	Guardianship systems, judicial remedies, Indigenous co-management.	Regulatory agencies with fines and permits; limited legal standing without human plaintiffs.
Outcomes	Blocked extractive projects (Ecuador); ecosystem restoration (New Zealand); enhanced biodiversity protection (Colombia).	Pollution control under the Clean Water Act, but continued species loss (50% decline in Australia over 25 years).

Second, around 30 international accords and state policies were analysed to identify laws connecting RoN to education, including Colombia's Environmental Education law and UNCRC General Comment No. 26, 2023 (Lutfauziah et. al., 2024). Role-playing exercises built around ecological champions and landmark court cases, such as New Zealand's river guardianship case, also emerged as a recurring teaching technique in this literature. The hermeneutic analysis was used to unpack terms such as sustainable development, revealing hidden anthropocentric biases in how they are typically taught. This step found that only 28% of Global South curricula link RoN to child rights. But the European Commission's Education and Training Monitor 2024 found that just 42% of EU youth reported a meaningful opportunity to learn about sustainability at school, despite 84% saying it mattered to them (European Commission, 2024).

Third, ethical theories were integrated into the policy assessment by examining tensions across more than 20 documents. 65% showed conflict

between profit-driven education-for-sustainable-development framing and Earth Jurisprudence's treatment of nature as a rights-holder. And the GreenComp framework was found to draw predominantly on Western sustainability discourse with limited space for Indigenous or Global South knowledge systems (Laherto et al., 2023).

Finally, secondary data from around 15 STEM studies were analysed and synthesised into recommendations, including proposals for the International Union for Conservation of Nature's (IUCN) RoN Toolkit for curricula and teacher training workshops (Begum et al., 2022). Table 3 summarises the resulting implementation deficits between RoN legal principles and their presence in environmental education curricula.

Table 3: Implementation Deficits of Rights of Nature and Related Principles in Environmental Education Curricula

Legal Principle	Curricula Representation	Implementation Deficit
Nature's Right to Regenerate (Ecuador Constitution)	Absent or marginal in 72% of Latin American science curricula.	Lack of teacher training in biocultural rights; only 16% integration rate in South American STEM.
Intergenerational Equity (UNCRC General Comment No. 26)	Limited or token references in EU sustainability programmes.	Only 42% of EU youth report a meaningful sustainability learning opportunity.
Ecological Kinship (Buen Vivir and related Indigenous frameworks)	Limited integration in European/hybrid STEM models; often treated as elective.	Predominant reliance on Western sustainability discourse; insufficient Indigenous inclusion.

3. Results

The doctrinal and empirical analysis yielded four categories of findings.

First, RoN frameworks have expanded rapidly worldwide, where 688 educational and legal programmes across 66 countries now recognise RoN in some form (Eco Jurisprudence Monitor, 2026; Sachs, 2023), anchored by landmark cases such as Ecuador's 2008 constitutional recognition of Pachamama, New Zealand's Te Awa Tupua Act (2017), and Spain's 2022 grant of legal personhood to the Mar Menor lagoon, later upheld by Spain's Constitutional Court in November 2024 and recognised by Switzerland as a foreign legal entity in July 2025 (Spain, 2022; Eco Jurisprudence Monitor, 2025a, 2025b).

Second, despite this legal expansion, curricular integration remains limited. Fewer than 28% of Global South science curricula reference RoN or ecosystem restoration rights, and just 16% of South American STEM programmes report integration despite policy mandates in eight nations (UNESCO, 2024). In Europe, only 42% of young people report a meaningful opportunity to learn about sustainability at school, even though 84% say it matters to them (European Commission, 2024). Notably, neither the GreenComp framework (Bianchi et al., 2022) nor the 2025 EU STEM Education Strategic Plan references RoN, ecological justice, or Indigenous knowledge systems.

Third, where decolonial and justice-oriented approaches have been implemented, the outcomes are consistently positive. Sustainable STEM education produces a moderate-to-large effect size of 0.46 to 0.52 on learning outcomes overall (Cao et al., 2025; Ouyang & Xu, 2025), and Buen Vivir-inspired programmes produce 32 to 45% improvements in sustained behavioural engagement (Rosa et al., 2023;

Ellington & Prado, 2025). Justice-oriented STEM interventions are associated with 40% higher empathy and pro-environmental behaviour (Li et al., 2024), 28% higher civic engagement among marginalised students, and 15% better SDG-aligned skills in rural relative to urban implementations (Doucette, 2023). In Ecuador, Buen Vivir-based national reforms produced 22% gains in SDG competencies and a 15% reduction in rural inequalities (PEHRC, 2024).

Fourth, teacher preparation emerged as a consistent lever. Teachers trained in justice-oriented, decolonial methods demonstrated 40% better expertise in sustainability teaching, which corresponded with a 25% improvement in student motivation (Taylor & Taylor, 2025).

Table 4: Summary of Key Quantitative Findings

Finding	Statistic	Source
Global RoN legal recognition	688 programmes, 66 countries	Eco Jurisprudence Monitor, 2026; Sachs, 2023
Global South curricular integration	Fewer than 28% of curricula	UNESCO, 2024
EU sustainability learning opportunity	42% report access (84% say it matters).	European Commission, 2024
Buen Vivir behavioural engagement gains	32–45% improvement	Rosa et al., 2023; Ellington & Prado, 2025
Sustainable STEM effect size	0.46–0.52	Cao et al., 2025; Ouyang & Xu, 2025
Teacher training impact	40% expertise gain and 25% motivation gain	Taylor & Taylor, 2025

4. Discussion

These findings confirm that the central challenge in environmental education is not a shortage of ecological knowledge but the persistent gap between knowledge and behaviour (Rodrigues-Silva & Alsina, 2023; Hussim et al., 2024). Building emotional ties to nature helps close the gap between knowledge and action. When STEM education becomes participatory, rights-based, and culturally inclusive, students shift from passively collecting facts to acting as agents of stewardship (Ajaps, 2023; Hua & Zarazaga, 2024). This is consistent with decolonial case studies from Brazil, where dialogic, community-rooted pedagogies have built relational bonds between students and the natural world (Blotta & Brianezi, 2024). The broader finding states that Buen Vivir functions not merely as a cultural philosophy but as an operational model linking education, territorial governance, and the legal protection of nature (Bermúdez-Restrepo & Vaca-López, 2026).

The results support a transdisciplinary approach to curriculum design. Ecological relationships can be examined in science classes, legal frameworks in social studies, and environmental ethics in language arts. The course materials should draw on Indigenous, legal, philosophical, and scientific voices (Campbell & Speldewinde, 2022; Kioupi & Voulvoulis, 2020). Place-based pedagogies that connect RoN to local ecosystems make otherwise abstract legal concepts tangible, which appears to be the mechanism behind the behavioural gains reported above. Equitable access to nature within school grounds also functions as a policy lever in its own right. Maintaining green space on campus addresses systemic inequities directly and should

be treated as a statutory right within school-based curricula rather than an optional enrichment (Davis et al., 2020; Louv, 2020).

There seems to be a tendentious gap linking 'environmental law obligations and STEM education forethoughts' in Europe. It has been established through the Mar Menor principle that there can be a development of binding legal norms when ecological citizenship is levelled at grassroots. The matter of fact is that the principles of European model STEM education strategies remain competitively intact, ignoring the ecological rights framework.

The GreenComp defines twelve sustainability competencies based on four categories: accepting complexity, performing for sustainability, visualising sustainable goals, and sustainable norms (Bianchi et al., 2022). It offers an equipped footing when paired with the 'RoN and Indigenous or Global South knowledge network'. In its absence, it risks reproducing a more sophisticated version of the anthropocentric and Eurocentric thinking that sustainable STEM aims to move beyond (Laherto et al., 2023).

The three things were said to be practised, such as RoN literacy to be incorporated in GreenComp and taking STEM at the secondary level in any European model committing the EU states to make more solidified educational aims by the year 2025 (European Commission, 2020b); programmes like Erasmus+ should go for building an idea of shared ecological governance literacy connecting European students to Global South counterparts (European Commission, 2021); and also teachers touching the RoN jurisprudence, utilising the Mar Menor case as a live legal teaching resource. National models such as Finland's 'cross-disciplinary environmental goals' and Germany's Bildung für nachhaltige Entwicklung approach already show that funded teacher preparation is a necessary precondition for this shift rather than simply its outcome (UNECE, 2012). There is a smaller gap over the legal models with emphasis on implementation and equity wherein India's NEP 2020 directs environment education in its model. However, it is hindered because of the existing urban-rural inequalities and weak enforcement of some models like the 2017 Ganges personhood ruling, leading to RoN integration lagging behind. There are some Buen Vivir inspired community-based models, where the river restoration activities and community participation tools have been used in the curriculum, such as IUCN's RoN, closing the gap with SDG 4 and SDG 13 models (Diaz Eaton et al., 2022; Bang & Medin, 2025). Despite this, teachers still face significant practical challenges. Many report inadequate preparation for ecological citizenship roles, the heavy burden of standardised curricula, and limited opportunities to use place-based pedagogies that engage with natural environments (Koca, 2024).

In global scenarios teaching methods are strict to one particular aspect, such as 'justice', with the decolonial philosophical approach of sustainability teaching inspiring more students (Taylor & Taylor, 2025; Koca, 2024).

All the above conclusive arguments have some limits, relying on secondary means and under-representing practitioner and classroom notions, with more emphasis over "published institutional ranks" wherein the prospects of research findings are based on primary surveys of teachers and students. This review carrying a rough sample study of around 50 samples covering different constitutional models and reports is compiled through a focused keyword search instead of using 'systematic review'. It has introduced 'selection bias' where empirical study covered a fraction of nation-states like Ecuador, Colombia, New Zealand, India, etc., wherever the 'RoN-integrated STEM' has been taken into account. The European analysis in particular is more policy-based than empirical, reflecting the genuine scarcity of published research on RoN integration in European STEM classrooms specifically. These limitations do not undermine this review's contribution but mark productive directions for future empirical research.

5. Conclusion

Decolonised STEM classrooms that recognise RoN offer a concrete, evidence-based route to closing the gap between ecological knowledge and environmental action. When teachers combine

Indigenous knowledge systems with justice-oriented pedagogy, students develop stronger ecological understanding and a genuine drive toward environmental action, translating passive knowledge into active stewardship (Blotta & Brianezi, 2024). Yet the analysis shows that legal recognition of RoN has outpaced curricular integration in both the Global South and Europe. While 688 programmes across 66 countries now recognise RoN in some form, fewer than three in ten Global South curricula integrate these principles. Similarly, fewer than half of European students report meaningful engagement with sustainability education.

Closing this gap requires action on three fronts. Firstly, the curriculum should be transdisciplinary and embedded through all educational streams using community and demography-based teachings, bridging the laws available with local customs and practices. Secondly, there should be proper training modules for teachers emphasising talks over 'RoN jurisprudence and decolonial pedagogy' for better student outcome-based education. Thirdly, all such policy initiatives, such as NEP 2020 in India and EU models like GreenComp and Erasmus+, should be well aligned with the 'RoN literacy and equitable sustainable education'. Amongst all three, the teacher training is the most relevant and crucial, which requires more strengthened certification programmes for better results for all corners of the world.

This review article's central contribution is to show that RoN and decolonial pedagogy are not limited to the Global South. They are also not merely an aspirational add-on for Europe. Instead, they offer a shared, evidence-based framework for STEM reform that can function across radically different legal and educational systems.

Future research should move beyond doctrinal and secondary-source analysis toward primary studies with teachers and students, particularly in Europe, where empirical evidence on RoN-integrated STEM remains scarce. The under-represented Global South contexts beyond Ecuador, Colombia, New Zealand, and India should also be covered in future.

By treating equal access to nature as a fundamental right within schools, and by grounding STEM education in both legal frameworks and lived ecological relationships, education systems in the Global South and Europe alike can equip young people to become considerate stewards of the environment and agents of social transformation for a more just and sustainable future.

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Author Declaration

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