Decolonizing STEM Education and Research: Integrating Indigenous Epistemologies

Ms Shivani

Assistant Professor, Department of Allied and Healthcare, NIILM University

Abstract

A very important step toward epistemic justice and sustainable development is to decolonize STEM (Science, Technology, Engineering, and Mathematics) education and research by including Indigenous ways of knowing. This chapter addresses the colonial legacy that positioned Western science as universal, marginalizing Indigenous knowledge systems despite their significant contributions to agriculture, medicine, navigation, and ecology. Indigenous epistemologies, characterized by relationality, holism, orality, reciprocity, spirituality, adaptability, and community ownership, offer complementary frameworks to Western STEM's objectivity and reductionism, providing sustainable solutions for global challenges like climate change and biodiversity loss.

The conversation is about how to decolonize education by changing Eurocentric curricula, using participatory teaching methods, and valuing Indigenous languages. Case examples from New Zealand, Canada, and South Africa show how these ideas might be put into action. In research, it supports moving from extractive approaches to reciprocal, community-led methods based on the values of respect, responsibility, and relevance. Examples of these methods are Canada's OCAP® framework and Inuit climate studies. Hybrid knowledge systems are emerging as critical to sustainability, combining Indigenous techniques (such as Andean farming or Polynesian water management) with STEM innovations in agriculture, healthcare, and conservation.

Challenges, including institutional resistance, tokenism, epistemic injustice, resource constraints, and appropriation risks, are addressed, emphasizing the need for Indigenous leadership, policy

reforms, and global solidarity. The way forward envisions pluralistic, hybrid systems through "two-eyed seeing," ensuring equitable benefits and ethical reciprocity. Ultimately, decolonizing STEM fosters inclusive knowledge that honors diversity, dismantles hierarchies, an aligns with life-affirming sustainable futures.

Keywords: Decolonization, STEM, Indigenous Epistemologies, Colonial Legacy, Epistemic Justice, Relationality, Holism, Reciprocity, Orality, Experiential Learning, Sustainability, Eurocentrism, Indigenous Knowledge, Curriculum Reform, Participatory Pedagogy, Indigenous Languages, Community-Led Research.

Introduction

Decolonizing STEM education and research is a critical intellectual and ethical imperative. Shaped by colonial histories, Western scientific paradigms have long been positioned as universal, often marginalizing Indigenous knowledge systems as inferior or unscientific. This erasure has resulted in incomplete and inequitable knowledge frameworks, prioritizing Western epistemologies while sidelining sustainable, place-based Indigenous wisdom. Decolonizing STEM is not merely a pedagogical shift but a transformative process to restore epistemic justice, integrate diverse knowledge systems, and address global challenges such as climate change and biodiversity loss. By recognizing Indigenous contributions and fostering dialogue between epistemologies, STEM can become more inclusive, equitable, and sustainable. This chapter examines the colonial legacy in STEM, the principles of Indigenous epistemologies, and strategies for decolonizing education and research, emphasizing hybrid systems that blend Western precision with Indigenous relationality to create knowledge systems that serve both humanity and the planet.

Literature Review

Linda Tuhiwai Smith – *Decolonizing Methodologies* (2012, 2nd ed.), A cornerstone text exposing the extractive history of Western research and offering pathways for community-led, ethical, and benefit-driven research.

Relevance: Anchors your argument that STEM must move from "subjects to sovereigns," legitimizing Indigenous control over agendas, data, and outcomes.

Eve Tuck & K. Wayne Yang – "Decolonization is Not a Metaphor" (2012), Challenges superficial "diversity" gestures and insists on material decolonization, not token inclusion.

Relevance: Strengthens your critique of tokenism in STEM, reinforcing that true reform requires Indigenous leadership, veto power, and systemic shifts.

Marie Battiste – *Decolonizing Education* (2013), Articulates how Eurocentric schooling erases Indigenous ways of knowing and calls for revitalizing language, land, and epistemic sovereignty.

Relevance: Directly informs your land-based, multilingual, and culturally sustaining STEM pedagogy framework.

Leroy Little Bear / Gregory Cajete – *Native Science* (2000), Defines Indigenous science as relational, spiritual, and empirical, transmitted through story, ceremony, and land.

Relevance: Provides philosophical grounding for hybrid STEM methods—where Western empiricism meets Indigenous relational epistemologies.

Robin Wall Kimmerer – *Braiding Sweetgrass* (2013), Blends Potawatomi teachings with botany, modeling gratitude and reciprocity as scientific practice.
Relevance: Offers case-style inspiration for integrating Indigenous values (gratitude, reciprocity) into STEM classrooms and labs.

Walter Mignolo – *The Darker Side of Western Modernity* (2011), Frames modernity and coloniality as inseparable, advocating "epistemic disobedience."
Relevance: Justifies your call for pluriversality—multiple centers of STEM knowledge rather than one Western universal.

Porter & Siddiqui – *Decolonizing STEM and Militarization* (2024), Critiques how militarized and colonial logics structure STEM curricula in UK higher ed, proposing radical pedagogical reforms.

Relevance: Helps expand your analysis beyond knowledge integration to institutional/political drivers of STEM content.

Nyaaba et al. – *Generative AI and Digital Neocolonialism* (2024), Explores how generative AI reinforces Western epistemic dominance, especially by marginalizing Indigenous languages.

Relevance: Gives your chapter a contemporary AI angle—digital STEM tools can either replicate colonial bias or be designed for liberation.

Gunawan &Indrawan – *Decolonising Science Education: A Bibliometric Analysis* (2025), Maps global research (2015–2025) on Indigenous knowledge in STEM, revealing fragmentation and tokenism.

Relevance: Situates your work within current scholarly trends, showing persistent systemic gaps you are directly addressing.

Anderson et al. – *Indigenous Rights-Based Research Approaches (Australia)* (2025), Develops an Indigenous rights-based framework (IRBA) for research governance, emphasizing sovereignty over data and outcomes.

Relevance: Strengthens your data sovereignty section with a concrete institutional model that universities and labs can adopt.

Colonial Legacy in STEM

The base of STEM education and research are deeply entwined with colonial history. From the 15th century, European empires imposed Western science as superior, rational, and universal, dismissing Indigenous knowledge as backward or mythological. This intellectual colonization created enduring hierarchies with profound consequences for modern education and research.

Long before colonial contact, indigenous tribes around the world created complex knowledge systems. Polynesian navigation depended on accurate readings of stars and ocean currents, African rotational farming guaranteed sustainability, and Andean terraces preserved soil and water. Colonial powers, however, disregarded these as being unscientific and exploiting science

for their own ends. For instance, Polynesian navigation methods were remarketed as Western discoveries, and quinine, which was used by Indigenous South Americans to cure malaria, was taken into European medicine without their consent. This pattern of erasure and appropriation served economic and political interests, justifying resource exploitation.

Colonial education systems entrenched these hierarchies by prioritizing European science and mathematics while sidelining Indigenous languages and knowledge. In Africa, Asia, and the Americas, colonial schools produced subjects to serve empires, not independent thinkers rooted in local epistemologies. Postcolonial curricula often perpetuate this Eurocentrism: Indian students study Newtonian physics but rarely Vedic mathematics, and African students learn Western agriculture while their ecological traditions are overlooked.

Research methodologies also bear colonial imprints. Western science privileges written documentation, controlled experiments, and quantifiable data, often dismissing oral traditions and experiential knowledge as unreliable. Indigenous taxonomies of plants or stars, frequently more context-specific than Western classifications, were ignored, creating an intellectual monoculture. Colonial universities, modeled on European institutions, prioritized projects like resource extraction over local needs, a trend that persists in funding and publishing systems. English-language journals and Western-led research dominate, marginalizing scholarship in Indigenous languages or methodologies. In the Global South, communities are often reduced to data sources, reinforcing epistemic dependency on the Global North.

This legacy does not negate Western science's achievements but highlights how its dominance has silenced other systems, leading to unsustainable practices. Western agriculture's monocultures and chemical reliance degrade soil, whereas Indigenous practices like crop rotation offer sustainable alternatives. Decolonizing STEM requires acknowledging this history, dismantling hierarchies, and fostering dialogue between knowledge systems to create a pluralistic, equitable framework for education and research.

Indigenous Epistemologies: A Relational Framework

Indigenous epistemologies offer a relational, holistic alternative to Western science's objectivity and reductionism. Rooted in millennia of observation and adaptation, these dynamic systems possess unique methods and ethics, vital for decolonizing STEM.

Relationality is central: knowledge emerges from relationships among humans, nature, and the spiritual realm. Land is viewed as a living entity, not a resource, as seen in Native American perspectives of rivers as sacred. This contrasts with Western detachment, emphasizing connection over objectivity.

Holism integrates science, spirituality, and community. Traditional Chinese medicine and Māori systems link health, environment, and ethics, unlike Western STEM's compartmentalized disciplines. This holistic lens is well-suited to complex issues like climate change, where interconnected solutions are essential.

Orality and experiential learning transmit knowledge through storytelling and practice. Aboriginal Dreamtime narratives encode ecological wisdom, serving as both cultural and practical guides. This dynamic approach ensures adaptability, unlike static Western texts.

Ethics of reciprocity guide knowledge use. Navajo *hózhó* (harmony) and Andean *ayni* (reciprocity) emphasize balance and responsibility, contrasting with Western science's focus on control. Knowledge is seen as a stewardship obligation, not a tool for domination.

Spirituality integrates ecological and scientific insights. Indigenous rituals reinforce environmental awareness, challenging Western science's secular bias. For instance, ceremonies tied to plant cycles enhance sustainability.

Adaptability ensures relevance. Inuit hunters blend traditional ice knowledge with satellite data, and African farmers combine ancestral planting techniques with climate models, creating hybrid systems that outperform singular approaches.

These principles offer practical solutions. Indigenous farming practices, such as Southeast Asian shifting cultivation, preserve biodiversity, while East African rotational grazing prevents desertification. Unlike Western models of individual ownership, Indigenous knowledge is

communal, challenging extractive research practices. Integrating these epistemologies with STEM creates sustainable, culturally grounded knowledge systems.

Decolonizing Education

Decolonizing STEM education requires rethinking curricula, pedagogy, and language to center Indigenous knowledge as equal to Western science, fostering intellectual justice and sustainability.

Curriculum Reform

STEM curricula are often Eurocentric, celebrating figures like Newton and Darwin while overlooking Mayan mathematics, African fractals, or Polynesian navigation. Decolonizing involves integrating these as rigorous contributions. For example, teaching Ayurveda alongside biomedicine examines its principles of balance, not as a cultural aside but as a valid framework. Indigenous concepts like *hózhó* or Ubuntu can inform environmental science, emphasizing sustainability. This pluralistic approach counters the myth that progress is solely Western, fostering epistemic humility.

Pedagogical Transformation

Western education's hierarchical, teacher-centered model contrasts with Indigenous pedagogies, which are participatory and land-based. Students should learn ecology from elders in forests or mathematics through cultural patterns, connecting abstract concepts to lived realities. Such methods make learning meaningful and inclusive, grounding STEM in community contexts.

Language and Accessibility

Colonial education sidelined Indigenous languages, alienating students from their heritage. Indigenous terms for plants or stars carry ecological and ethical nuances lost in translation. Bilingual STEM education, using local and global languages, preserves these insights and affirms cultural identity. Developing materials in Indigenous languages ensures accessibility and relevance.

Case Studies

In New Zealand, Māori epistemologies are integrated into science curricula, emphasizing environmental interconnectedness. In Canada, First Nations land-based programs teach ecology through elders' guidance. South African curricula incorporate Indigenous mathematics, challenging Eurocentric narratives. These examples demonstrate decolonization's practicality.

Challenges

Institutional resistance often stems from fears of diluting rigor, while tokenism risks superficial inclusion. Teachers may lack training, and power imbalances persist over whose knowledge is prioritized. Collaboration with Indigenous communities is essential to ensure authenticity and leadership, avoiding appropriation.

Decolonizing education cultivates pluralistic thinking, preparing students for global challenges with creativity and responsibility. It aligns STEM with sustainable development, valuing cultural and ecological diversity.

Decolonizing Research Methodologies

Due to its colonial extractive roots, Western research places a high value on objectivity and quantification, frequently seeing Indigenous cultures as little more than subjects. Decolonizing research embeds Indigenous ethics and moves toward reciprocity and community leadership.

From Extraction to Reciprocity

Colonial science gathered information for imperial benefit while ignoring Indigenous contributions. In "helicopter research," specialists from the Global North oversee studies in the Global South; this pattern is still seen today. Decolonized research embraces participatory approaches like participatory action research (PAR), where communities co-create questions and outcomes to ensure mutual benefit and relevance.

Indigenous Ethics

Four principles guide decolonized research:

- **Respect**: Honor community protocols and seek consent from elders.
- **Reciprocity**: Ensure benefits return to communities, such as shared knowledge or policy influence.
- **Responsibility**: Avoid harm, prioritizing community and ecological well-being.
- **Relevance**: Address community priorities, not just academic curiosity. Canada's OCAP® principles (Ownership, Control, Access, Possession) ensure Indigenous data sovereignty, challenging academic norms where data resides externally.

Holistic Methods

Indigenous methodologies value oral histories, ceremonies, and lived experiences alongside quantitative data. Māori *whakapapa* (genealogy) or Inuit climate observations complement satellite data, producing richer insights. These hybrid approaches bridge epistemologies without assimilation.

Case Studies

Inuit partnerships with scientists enhance climate research with traditional knowledge. Aboriginal fire management in Australia, studied collaboratively, reduces wildfire risks and supports biodiversity, respecting Indigenous authority. These models demonstrate that research can be both rigorous and equitable.

Challenges

Academic priorities—speed and publications—clash with Indigenous research's relational pace. Funding often favors Western methods, and superficial decolonization risks appropriation. True change requires humility and structural reform.

Decolonized research democratizes knowledge, fostering inclusivity and sustainability through ethical, community-led practices.

STEM and Indigenous Epistemologies for Sustainability

Integrating STEM with Indigenous epistemologies creates hybrid systems for sustainable development, addressing climate change, food security, and biodiversity loss.

Agriculture

Western agriculture's monocultures degrade soil, whereas Indigenous practices like Andean potato diversity or African Zai techniques ensure resilience. Paired with modern soil science, these enhance productivity and sustainability.

Water Management

Western dams often disrupt ecosystems, but Indigenous systems like Persian qanats or Balinese subak are adaptive. Combined with modern hydrology, they provide equitable water solutions.

Healthcare

Biomedicine excels in acute care but often neglects holistic well-being. Indigenous systems like Ayurveda emphasize prevention, complementing modern pharmaceuticals derived from plants like willow bark. Hybrid healthcare models improve cultural sensitivity.

Biodiversity

Indigenous sacred groves and conserved areas preserve ecosystems. Paired with remote sensing, these practices enhance conservation, empowering communities as co-managers.

Hybrid systems require respectful partnerships, ensuring Indigenous control over knowledge to avoid appropriation.

Challenges and Barriers

Decolonization faces multiple barriers:

- **Institutional Resistance**: Universities and funding bodies often prioritize Western paradigms, viewing Indigenous knowledge as less rigorous. Journals favor quantifiable methods, marginalizing oral traditions.

- **Tokenism**: Superficial inclusion reduces Indigenous knowledge to fragments, ignoring its philosophical depth.
- **Epistemic Injustice**: Indigenous knowledge is often dismissed unless validated by Western science, perpetuating hierarchies.
- **Tensions**: Universal Western methods clash with context-specific Indigenous practices, requiring careful dialogue.
- **Resources**: Financial constraints limit curriculum reform and Indigenous-led research.
- **Appropriation**: Communities fear knowledge commodification, given historical exploitation.
- **Internalized Colonialism**: Some Indigenous groups undervalue their knowledge due to colonial education.

Overcoming these requires systemic change, community leadership, and humility from dominant institutions.

The Way Forward

Decolonizing STEM involves:

- **Indigenous Leadership**: Indigenous scholars and elders must lead curriculum and research design with decision-making authority.
- **Policy Reform**: Mandate Indigenous knowledge in curricula and fund community-led projects, using frameworks like OCAP®.
- **Curriculum and Pedagogy**: Integrate Indigenous contributions and shift to land-based, participatory learning.
- **Hybrid Systems**: Blend STEM with Indigenous wisdom, as in "two-eyed seeing," for resilient solutions.
- **Epistemic Justice**: Value all knowledge equally, ensuring equitable benefits.
- **Global Solidarity**: Foster intercultural dialogue to support global sustainability.

This pluralistic approach bridges epistemologies, prioritizing sustainability and justice.

Conclusion

Using Indigenous epistemologies to decolonize STEM is a revolutionary step toward epistemic justice. Indigenous wisdom was neglected by colonial legacies that established hierarchies, yet combining relational, holistic Indigenous concepts with STEM provides answers to the world's problems. We develop inclusive, sustainable knowledge frameworks by redefining courses, emphasizing community-led research, and encouraging hybrid systems. The way forward depends on Indigenous leadership, policy reform, and international solidarity, notwithstanding obstacles including institutional resistance and tokenism. Through respecting variety and promoting a fair and sustainable future, this vision guarantees that knowledge serves life.

References

1. Agrawal, A. (1995). Dismantling the divide between Indigenous and scientific knowledge. *Development and Change*, *26*(3), 413–439. https://doi.org/10.1111/j.1467-7660.1995.tb00560.x
2. Aikenhead, G. S., & Michell, H. (2011). Bridging cultures: Indigenous and scientific ways of knowing in science education. *Pearson*.
3. Bang, M., & Medin, D. (2010). Cultural processes in science education: Supporting the navigation of multiple epistemologies. *Science Education*, *94*(6), 1008–1026. https://doi.org/10.1002/sce.20392
4. Battiste, M. (2013). Decolonizing education: Nourishing the learning spirit. *Purich*.
5. Berkes, F. (2018). *Sacred ecology* (4th ed.). Routledge.
6. Cajete, G. (2000). *Native science: Natural laws of interdependence*. Clear Light Publishers.
7. Deloria, V. (1999). *Spirit and reason: The Vine Deloria, Jr. reader*. Fulcrum Publishing.
8. Fatigato, S. (2024). *Decolonising research methodologies in Indigenous contexts* [Sapienza – University working paper], *9*.
9. Gunawan, S., & Indrawan, D. (2025). Decolonising science education: A bibliometric analysis of Indigenous knowledge integration in global STEM. *ResearchGate preprint*. *Journal of Posthumanism*, *5*(5), 2598–2622. https://doi.org/10.63332/joph.v5i5.1651

10. Harding, S. (1998). *Is science multicultural? Postcolonialisms, feminisms, and epistemologies*. Indiana University Press. https://doi.org/10.2979/2095.0
11. Kimmerer, R. W. (2013). *Braiding Sweetgrass: Indigenous wisdom, scientific knowledge, and the teachings of Plants*. Milkweed Editions.
12. Kovach, M. (2009). *Indigenous methodologies: Characteristics, conversations, and contexts*. University of Toronto Press.
13. Little Bear, L. (2000). Jagged worldviews colliding. In M. Battiste (Ed.), *Reclaiming indigenous voice and vision* (pp. 77–85). UBC Press.
14. Mignolo, W. D. (2011). *The darker side of western modernity: Global futures, decolonial options*. Duke University Press. https://doi.org/10.2307/j.ctv125jqbw
15. Nyaaba, B. et al. (2024). *Generative AI and digital neocolonialism in global education*. *arXiv preprint arXiv:2406.02966*.
16. Porter, S., & Siddiqui, Y. (2024). Addressing colonial and militarized themes in STEM education. *Frontiers in Education*, *9*, Article 1480199. https://doi.org/10.3389/feduc.2024.1480199
17. Simpson, L. B. (2014). Land as pedagogy: Nishnaabeg intelligence and rebellious transformation. Decolonization: Indigeneity. *Education and Society*, *3*(3), 1–25.
18. Smith, L. T. (2012). *Decolonizing methodologies: Research and indigenous peoples* (2nd ed.). Zed Books.
19. Snively, G., & Corsiglia, J. (2001). Discovering Indigenous science: Implications for science education. *Science Education*, *85*(1), 6–34. https://doi.org/10.1002/1098-237X(200101)85:1<6::AID-SCE3>3.0.CO;2-R
20. Tuck, E., & Yang, K. W. (2012). Decolonization is not a metaphor. *Decolonization: Indigeneity*. *Education and Society*, *1*(1), 1–40.
21. University of Edinburgh. (2024). How to decolonise the STEM curriculum: A practical guide. In *Equality & diversity hub*.
22. Wilson, S. (2008). Research is ceremony: Indigenous research methods. *Fernwood*.