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Decolonising Science Education: A Bibliometric Analysis of Indigenous Knowledge Integration in Global STEM

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Abstract

This study presents a systematic bibliometric review of research on Indigenous knowledge integration within global STEM education between 2015 and 2025. Using keyword co-occurrence mapping and cluster analysis, the study identifies thematic patterns, research trajectories, and conceptual gaps in the emerging discourse on decolonizing science education. The findings reveal that integration efforts remain fragmented, often limited to isolated case studies or tokenistic curriculum adaptations. Genuine transformation requires coherent frameworks that position Indigenous epistemologies as foundational rather than peripheral to scientific inquiry. The study highlights the critical need for community collaboration, contextualised pedagogy, and systemic reform to foster epistemic justice and educational equity. By mapping current research landscapes, this review contributes to advancing more inclusive and pluralistic models of science education worldwide.

Keywords: *Decolonizing Education; Indigenous Knowledge Integration; STEM Education; Bibliometric Analysis; Epistemic Justice.*

Introduction

The decolonisation of science education has emerged as a critical movement aimed at challenging the dominance of Western scientific paradigms and recognising the legitimacy of multiple ways of knowing, particularly those rooted in indigenous knowledge systems. Historically, science curricula around the world have marginalised indigenous epistemologies, framing Western science as the universal and objective standard of knowledge, while positioning other systems as culturally relative or anecdotal (Baynes, 2015; Brown, 2017a; Rofe et al., 2015). This epistemic hierarchy has contributed to the systemic exclusion of indigenous learners and the erosion of local knowledge traditions, particularly within STEM (Science, Technology, Engineering, and Mathematics) fields that are central to global development agendas (Boisselle, 2016; Medvecky et al., 2023). Indigenous knowledge offers alternative, yet equally rigorous, understandings of the natural world, often characterised by relationality, sustainability, and deep ecological wisdom (Baquete et al., 2016; Keane et al., 2016; Venkatesan & Burgasser, 2017). Integrating indigenous epistemologies into STEM education not only rectifies historical injustices but also enriches scientific inquiry by broadening the scope of legitimate knowledge systems (Eglash et al., 2020; E.-J. A. Kim et al., 2017; Latip et al., 2024). Recent global movements advocating for epistemic justice, social sustainability, and educational equity have intensified calls for reimagining science education through decolonial

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frameworks that value indigenous voices and worldviews (Alkholy et al., 2017; Cirkony et al., 2023; Seehawer, 2018).

While there is growing scholarly attention to the integration of indigenous knowledge into STEM education, the field remains notably fragmented and uneven. Existing studies often concentrate on isolated case studies, curriculum adaptations, or specific pedagogical strategies without systematically synthesising the broader patterns, challenges, and opportunities that characterise this emergent area (Brown, 2017a; Keane et al., 2016; Seehawer, 2018). Although significant work has explored the blending of indigenous and Western epistemologies in classroom contexts, much of the literature remains grounded in localised settings, thus limiting its generalisability and broader theoretical contributions (Mandikonza, 2019; Rofe et al., 2015). Moreover, few studies employ bibliometric or cluster analysis approaches to map the conceptual landscape of decolonisation efforts in science education globally, leaving substantial gaps in understanding the interconnected themes, trends, and research trajectories (David-Chavez et al., 2020; Jin, 2021). The lack of systematic synthesis across contexts and the predominance of anecdotal or locally rooted findings hinder the development of cohesive frameworks necessary to guide policy and practice in integrating indigenous knowledge meaningfully within STEM curricula (Ogegbo & Ramnarain, 2024). Addressing these gaps through advanced bibliometric methodologies and comprehensive, contextually grounded research is crucial for moving the field towards a more coherent, inclusive, and epistemically just science education landscape.

This study seeks to address these gaps by conducting a systematic bibliometric analysis of scholarly literature focused on indigenous knowledge integration in STEM curricula worldwide. By mapping the conceptual clusters, identifying dominant themes, analyzing highly cited contributions, and synthesizing challenges and opportunities, the study aims to provide a comprehensive overview of the current state and future directions of decolonizing science education.

Specifically, the study is guided by the following overarching questions:

RQ1: What are the major thematic clusters emerging from the scholarly discourse on indigenous knowledge integration in science education?

RQ2: What challenges persist in decolonizing science education across pedagogical, curricular, methodological, and institutional dimensions?

RQ3: What opportunities and innovative strategies are being developed to foster epistemic justice and transform STEM education globally?

Method

Research Design

This study employed a systematic bibliometric analysis combined with keyword co-occurrence mapping and cluster analysis to explore the conceptual landscape of indigenous knowledge integration in global STEM education. Bibliometric methods offer a robust framework for quantitatively assessing research trends, thematic structures, and scholarly contributions across interdisciplinary domains (Charles et al., 2022; Singh & Gupta, 2022). Such approaches enable a visual and statistical mapping of academic landscapes, effectively identifying prevailing themes as well as under-researched areas that warrant further inquiry (Al-Hawary et al., 2025; Alturas, 2021a). Moreover, the application of systematic review principles within bibliometric analysis ensures transparency, replicability, and comprehensiveness in data collection and interpretation processes, thereby enhancing the rigour and reliability of the findings (Hodge, 2025). Keyword co-occurrence mapping, specifically, visually delineates thematic clusters within scholarly discourse, facilitating the identification of conceptual interrelations and emerging research trajectories (Alturas, 2021b; Farooq et al., 2021).

Data Source and Search Strategy

The data were extracted from the **Scopus** database, which was selected for its comprehensive coverage of peer-reviewed journal articles across multiple disciplines, including education, science, and indigenous studies. The search was conducted in March 2025 using a combination of keywords designed to capture literature on indigenous knowledge and STEM education integration. The search string used was:

TITLE-ABS-KEY ("decolonizing science education" OR "decolonization of science education" OR "decolonial science education" OR "indigenous knowledge" OR "traditional ecological knowledge" OR "local knowledge" OR "indigenous science") AND TITLE-ABS-KEY ("STEM curriculum" OR "science curriculum" OR "STEM education" OR "science education")

No restrictions were placed on publication type, but only documents published in English were included.

Inclusion and Exclusion Criteria

The following criteria were applied to select relevant documents:

Inclusion Criteria	Exclusion Criteria
Articles focusing on indigenous knowledge integration in science or STEM education	Articles unrelated to education or indigenous knowledge
Peer-reviewed journal articles	Conference abstracts, editorials, book reviews
Publications available in English	Publications in languages other than English
Publications from 2015 to 2025	Publications before 2015

Table 1. Inclusion and Exclusion Criteria For Document Selection

A total of 109 documents were retrieved and included in the final analysis after screening titles, abstracts, and full texts for relevance.

Data Analysis Procedures

The bibliometric analysis was conducted using **VOSviewer** 1.6.19, a specialized software for constructing and visualizing bibliometric networks. To analyze the thematic structure of indigenous knowledge integration in STEM education, several bibliometric techniques were employed. First, keywords from the titles and abstracts of the selected documents were extracted and mapped based on their co-occurrence frequency to identify major research themes. A minimum threshold of 11 occurrences was set for a keyword to be included in the mapping, ensuring that only thematically significant terms were considered in the analysis. Subsequently, cluster analysis was conducted using VOSviewer's clustering algorithm, which grouped related keywords into distinct clusters, each representing a major thematic area within the corpus. Each cluster was then qualitatively interpreted by examining the composition and interrelations of keywords, enabling the identification of dominant research foci emerging from the literature. In addition to mapping thematic structures, an analysis of highly cited documents was undertaken to highlight key scholarly contributions and influential works within the field. By identifying the most cited articles, the study was able to contextualize the thematic findings within the broader development of indigenous knowledge discourse in science education. Finally, the results were visualized through keyword co-occurrence networks and cluster maps, which provided graphical representations of the thematic structures and the strength of relationships among key concepts. These visualizations offered an accessible and intuitive overview of the intellectual organization of the field and facilitated the synthesis of emerging trends and research directions.

Results

Overview of the Dataset

Following the application of the inclusion and exclusion criteria, a total of 109 articles were retained for bibliometric analysis. These publications span a ten-year period, from 2015 to 2025, reflecting the progressive growth of scholarly interest in the integration of indigenous knowledge within STEM education. This temporal range captures the emergence and evolution of critical discussions surrounding decolonisation efforts and epistemic diversity in science curricula. The distribution of publications over time is illustrated in Figure 1.

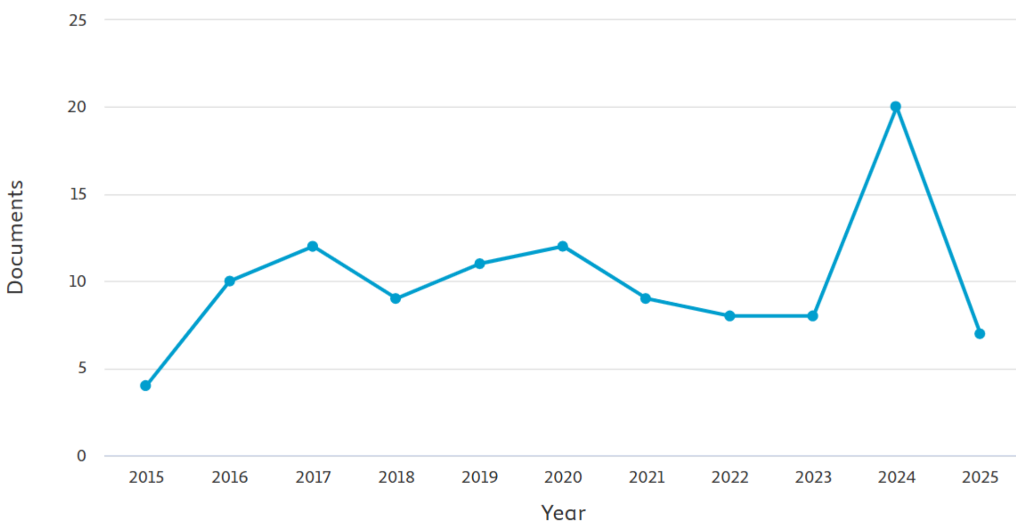

Figure 1. Growth of Publications Over Time

The analysis of publication trends from 2015 to 2025 (Figure 1) shows a steady increase in scholarly interest toward the integration of indigenous knowledge within STEM education. The number of documents grew from just **4 publications in 2015** to a peak of **20 publications in 2024**. Notable growth periods occurred between **2016 and 2017**, and again between **2023 and 2024**, indicating a renewed scholarly emphasis possibly linked to global movements advocating for decolonizing education and climate justice. Despite a slight decrease in 2025 (**7 publications**), the overall trend reflects a growing and sustained academic engagement with the topic over the past decade. This trend suggests that indigenous knowledge integration in STEM curricula is gaining significant momentum as a global educational priority. The geographical distribution of the selected publications highlights the countries most actively contributing to research on indigenous knowledge integration in STEM education, as shown in Figure 2.

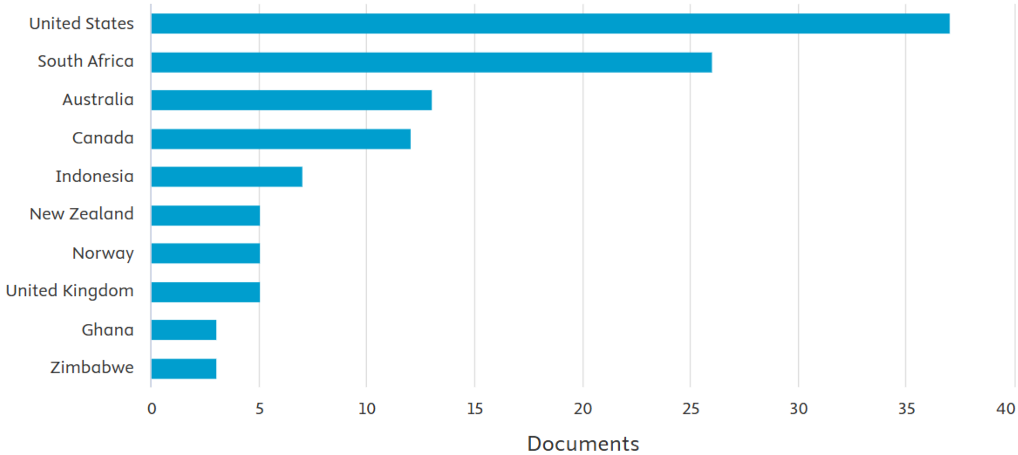

Figure 2. Top Contributing Countries To Research On Indigenous Knowledge Integration In STEM Education (2015–2025)

The distribution of publications by country (Figure 2) highlights the global nature of the research landscape, albeit with certain regional concentrations. The United States leads with 37 documents, followed by South Africa with 26 documents and Australia with 13 documents. Other notable contributors include Canada (12 documents), Indonesia (7 documents), and New Zealand (5 documents), while contributions from African countries such as Ghana and Zimbabwe indicate an emerging interest from the Global South. This distribution underscores that, although the decolonisation of science education has become a global discourse, much of the scholarly leadership remains concentrated within Global North institutions, with growing participation from nations in the Southern Hemisphere. The institutional distribution of publications further highlights the universities and research centres most actively engaged in advancing studies on indigenous knowledge integration within STEM education, as illustrated in Figure 3.

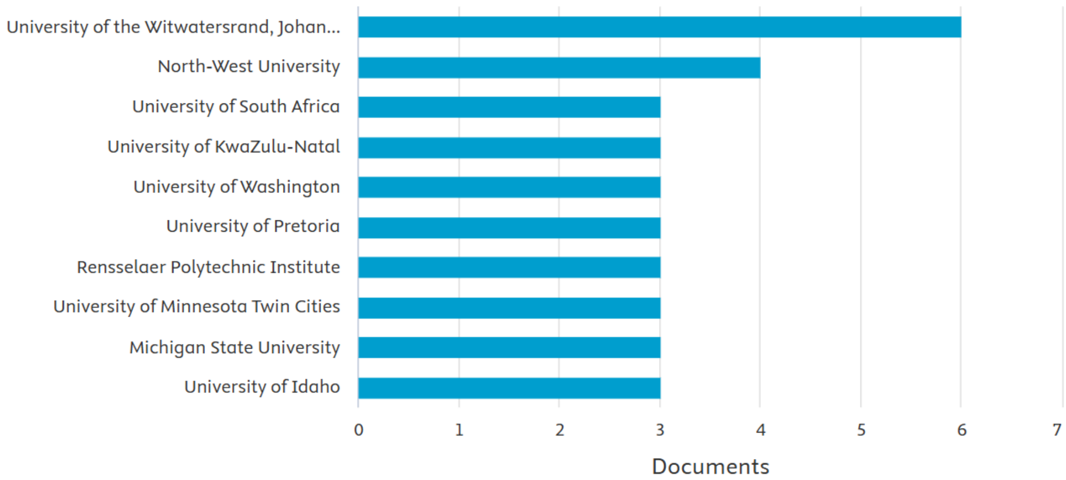

Figure 3. Top Contributing Institutions To Research On Indigenous Knowledge Integration In STEM Education (2015–2025)

Institutional analysis (Figure 3) reveals that the most active contributors are predominantly universities located in South Africa and the United States. The University of the Witwatersrand, Johannesburg, ranks first with six documents, followed by North-West University with four documents. Several other institutions, including the University of South Africa, the University of KwaZulu-Natal, the University of Washington, the University of Pretoria, and the University of Minnesota Twin Cities, each contributed three documents. The prominence of South African universities reflects the country's deep engagement with decolonisation debates, particularly in the post-Apartheid era, while the contributions from United States institutions indicate a growing critical consciousness regarding indigenous epistemologies within the Global North. The analysis of author contributions identifies key scholars who have significantly advanced the discourse on indigenous knowledge integration within STEM education, as presented in Figure 4.

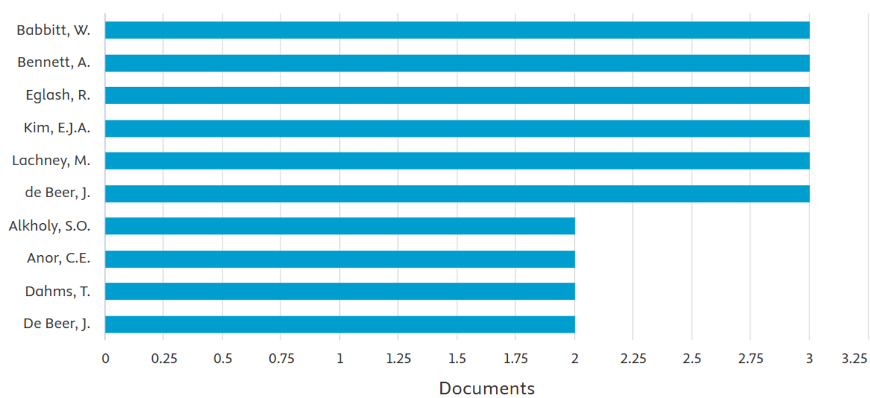

Figure 4. Top Contributing Authors to Research on Indigenous Knowledge Integration in STEM Education (2015–2025)

The most prolific authors contributing to this field (Figure 4) include Babbitt, W. (Rensselaer Polytechnic Institute, Troy, United States), Bennett, A. (University of Michigan, Ann Arbor, United States), Eglash, R. (University of Michigan, Ann Arbor, United States), Kim, E.J.A. (Griffith University, Brisbane, Australia), and de Beer, J. (Michigan State University, East Lansing, United States), each of whom contributed three documents. Several other authors, such as Alkholy, S.O., Anor, C.E., Dahms, T., and Seehawer, M., each contributed two documents. This diverse authorial base, spanning institutions across North America and Australia, reflects the engagement of both emerging and established scholars with the integration of indigenous knowledge across various disciplinary and geographical contexts. It further highlights the interdisciplinary and international character of this growing research field, demonstrating the increasingly global recognition of indigenous epistemologies within science education discourses. The disciplinary distribution of the analysed publications reveals the diverse fields contributing to research on indigenous knowledge integration within STEM education, as depicted in Figure 5.

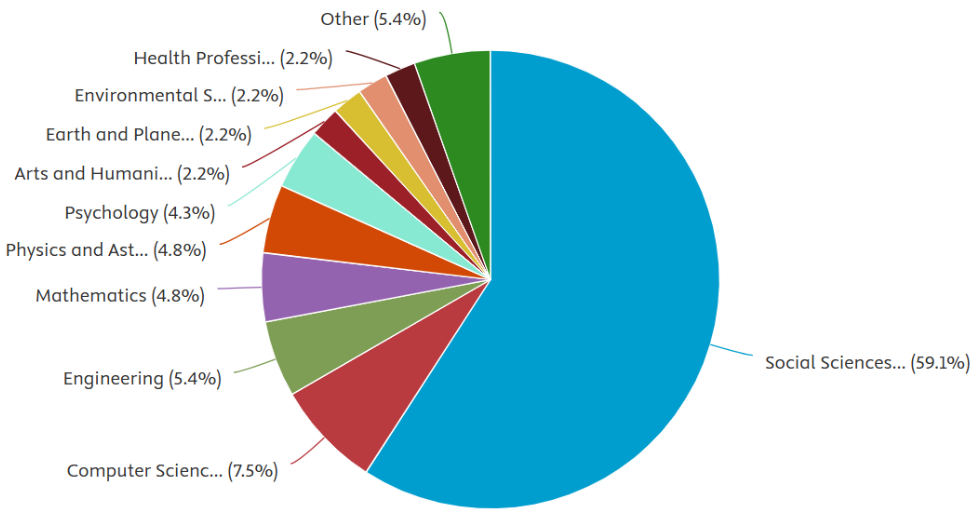

Figure 5. Subject Area Distribution of Research On Indigenous Knowledge Integration in STEM Education (2015–2025)

An analysis by subject area (Figure X) demonstrates the interdisciplinary nature of research in this domain. Social Sciences dominate the field, accounting for 59.1% of the documents (110 documents), reflecting the inherently sociocultural dimensions of decolonisation. Significant contributions also emerge from Computer Science (7.5%), Engineering (5.4%), Mathematics (4.8%), Physics and Astronomy (4.8%), and Psychology (4.3%). Other fields represented include Arts and Humanities, Environmental Science, Earth and Planetary Sciences, and Health Professions, each contributing approximately 2.2% of the publications. This disciplinary spread confirms that indigenous knowledge integration is not confined to educational theory alone but extends across STEM disciplines, underscoring the complexity and interdisciplinarity required for meaningful and sustainable curriculum reform. Table 2 presents the ten most cited publications within the dataset, highlighting key scholarly contributions.

Author(s)	**Year**	**Title**	**Affiliations**	**Cited by**
Zidny et al.	2020	A Multi-Perspective Reflection on How Indigenous Knowledge and Related Ideas Can Improve Science Education for Sustainability	Germany	158
Brown	2017	A metasynthesis of the complementarity of culturally responsive and inquiry-based science education in K-12 settings: Implications for advancing equitable science teaching and learning	USA	95
Cajete	2020	Indigenous science, climate change, and indigenous community building: A framework of foundational perspectives for indigenous community resilience and revitalization	USA	45
Eglash et al.	2020	Decolonizing education with Anishinaabe arcs: generative STEM as a path to indigenous futurity	USA	42
Baynes	2015	Teachers' Attitudes to Including Indigenous Knowledges in the Australian Science Curriculum	Australia	42
Boisselle	2016	Decolonizing Science and Science Education in a Postcolonial Space (Trinidad, a Developing Caribbean Nation, Illustrates)	UK	38
Kim et al.	2017	A Critical Review of Traditional Ecological Knowledge (TEK) in Science Education	Canada	36
Morris et al.	2021	Using Local Rural Knowledge to Enhance STEM Learning for Gifted and Talented Students in Australia	Australia	36
Seehawer	2018	South African science teachers' strategies for integrating indigenous and western knowledges in their classes: Practical lessons in decolonisation	Norway	33
Gondwe & Longnecker	2015	Scientific and Cultural Knowledge in Intercultural Science Education: Student Perceptions of Common Ground	Australia	32

Table 2. Highly Cited Documents

The analysis of the most highly cited documents (Table 2) highlights seminal contributions that have shaped the discourse on indigenous knowledge integration within STEM education. Zidny et al. (2020) lead with 158 citations, reflecting the growing emphasis on sustainability-oriented approaches that incorporate indigenous perspectives into science education. Brown's (2017) metasynthesis, with

95 citations, underscores the critical role of culturally responsive and inquiry-based frameworks in promoting equitable STEM learning environments. Other influential works, such as those by Cajete (2020) and Eglash et al. (2020), further advocate for decolonising educational practices and foregrounding indigenous epistemologies in STEM fields. The prominence of studies from diverse national contexts—including Germany, the United States, Australia, the United Kingdom, Canada, and Norway—illustrates the global resonance of this scholarly movement. Collectively, these highly cited documents reveal a converging interest in challenging dominant Western paradigms, fostering epistemic diversity, and advancing culturally relevant pedagogies in science education.

Keyword Co-Occurrence Mapping

To further understand the thematic structure of the literature on indigenous knowledge integration within STEM education, a keyword co-occurrence analysis was conducted using VOSviewer. This mapping technique identifies how frequently keywords appear together across documents and groups them into conceptual clusters, thereby illuminating the major research themes within the field.

The analysis identified a total of 74 unique keywords that met the minimum occurrence threshold. These keywords were grouped into five distinct clusters, each representing a significant thematic area within the corpus of literature. The clusters demonstrate how the discourse around decolonizing science education is distributed across curriculum development, pedagogical practices, student engagement, methodological approaches, and institutional frameworks. To further elucidate the thematic structure identified through the keyword co-occurrence analysis, Table 3 summarizes the main characteristics of each cluster. This table presents the number of keywords, key representative terms, and overarching thematic focus for each cluster, providing a comprehensive overview of the conceptual landscape shaping research on indigenous knowledge integration in STEM education.

Cluster	**Number of Keyword**	**Key Representative Terms**	**Thematic Focus for Each Cluster**
Cluster 1	18	education, culture, indigenous student, learning, pedagogy, science education	Indigenous pedagogies and culturally responsive education
Cluster 2	15	indigenous knowledge, integration, framework, scientific knowledge, sustainability	Integration frameworks for indigenous knowledge in STEM curricula
Cluster 3	14	student, STEM, technology, engineering, perception, western science	Student engagement and critique of Western epistemologies
Cluster 4	14	methodology, science curriculum, practice, project, teacher, study	Research methodologies and classroom implementation practices
Cluster 5	13	school, cultural knowledge, relationship, indigenous knowledge systems, science classroom	Institutional structures and sociocultural contexts for indigenous knowledge integration

Table 3. Cluster Formation

The keyword mapping visualized through VOSviewer (Figure 6) shows the interconnectedness of these clusters, where larger nodes represent higher frequency keywords and thicker lines indicate stronger co-occurrence relationships.

The spatial organization of the clusters suggests that while each thematic area has distinct focal points, significant overlaps exist — particularly between curriculum development, pedagogical strategies, and institutional frameworks. This mapping provides a foundational structure for the cluster-specific analysis presented in the following section.

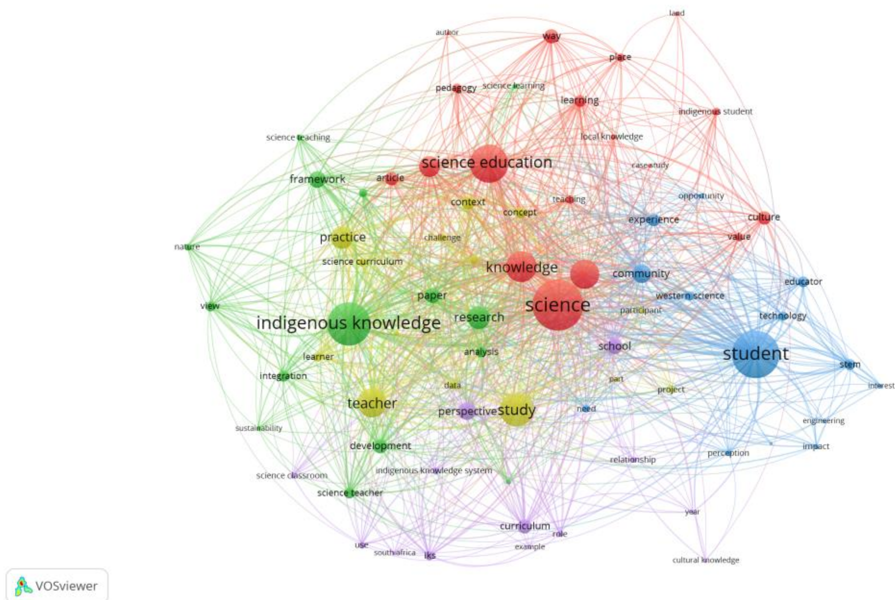

Figure 6. Keyword Co-Occurrence Mapping

Cluster Analysis

Building upon the keyword co-occurrence mapping, a deeper cluster analysis was performed to explore the major thematic domains shaping the discourse on indigenous knowledge integration within STEM education.

Each cluster represents a group of interrelated concepts, reflecting different but interconnected aspects of how indigenous epistemologies are being engaged, integrated, and contested within formal educational systems. The following sections describe and interpret the five clusters identified through the analysis.

Cluster 1: Education and Indigenous Pedagogies

Cluster 1, comprising 18 keywords, centres around educational approaches grounded in indigenous perspectives and cultural contexts. Key terms such as science, education, local knowledge, culture, pedagogy, learning, and science education dominate this cluster. This thematic focus emphasises the development of pedagogical practices that are responsive to indigenous worldviews and local contexts. It reflects a shift towards culturally responsive science education that validates diverse ways of knowing and promotes place-based and community-centred learning. The prominence of keywords such as indigenous student and place further underscores the centrality of students' cultural identities and lived experiences within transformative educational models.

Cluster 2: Indigenous Knowledge Integration and Curriculum Development

Cluster 2 contains 15 keywords focused on the systematic integration of indigenous knowledge into STEM curricula. Keywords such as indigenous knowledge, integration, framework, scientific knowledge, science learning, and science teaching are particularly prominent. This cluster highlights the need for coherent frameworks that move beyond the tokenistic inclusion of indigenous content, calling instead for a structural transformation of science curricula that fully embraces indigenous epistemologies as equally legitimate and foundational to scientific inquiry. The emergence of sustainability as a related concept further underscores the growing recognition of the intrinsic link between indigenous knowledge systems and principles of environmental stewardship.

Cluster 3: Student Engagement and STEM Fields

Cluster 3, comprising 14 keywords, revolves around student engagement within STEM fields and critiques of the dominance of Western science. Key terms such as student, STEM, technology, engineering, perception, and western science are particularly prominent within this cluster. This thematic focus highlights the agency of students in navigating epistemic diversity and challenges the epistemological hegemony of Western scientific traditions in STEM education. Issues related to identity, perception, and access to culturally relevant STEM learning experiences emerge as critical considerations within this thematic area. Furthermore, the cluster suggests a pressing need to rethink STEM education in ways that are more inclusive and representative of multiple knowledge systems, thereby fostering greater epistemic justice and diversity within scientific fields.

Cluster 4: Research Methodologies and Implementation Practices

Cluster 4 comprises 14 keywords related to methodological approaches and classroom practices. Terms such as methodology, science curriculum, practice, project, teacher, and study are particularly prominent within this cluster. The thematic focus centres on the practical challenges and innovations involved in integrating indigenous knowledge into classroom teaching. It underscores the need for methodological pluralism that respects indigenous ways of knowing, alongside the development of innovative pedagogical strategies tailored to diverse cultural and educational contexts. Moreover, the prominence of keywords such as study and project suggests an emphasis on empirical research that documents both the processes and impacts of decolonising educational initiatives.

Cluster 5: Institutional and Sociocultural Structures

Cluster 5 encompasses 13 keywords concerning institutional frameworks and sociocultural dynamics. Key terms such as school, science classroom, cultural knowledge, relationship, indigenous knowledge systems, and South Africa are particularly prominent. This thematic focus illustrates that the success or failure of indigenous knowledge integration is heavily influenced by institutional cultures and structural dynamics. Schools are not merely framed as sites of knowledge transmission but are instead positioned as contested spaces where different epistemologies negotiate legitimacy and authority. The prominence of these keywords signals a critical need for institutional reforms that actively support epistemic diversity, promote community engagement, and create more inclusive and equitable educational environments.

The cluster analysis reveals that decolonizing science education is a complex, multi-layered endeavour, involving transformations in pedagogy, curriculum frameworks, student agency, research methodologies, and institutional structures.

In the following section, a critical discussion is presented to interpret these findings within broader theoretical and practical contexts, addressing current challenges and proposing future directions for advancing indigenous knowledge integration in global STEM education.

Discussion

Decolonizing Science Education: An Emerging Multidimensional Agenda Pembukaan umum untuk Discussion.

The findings of the bibliometric and cluster analyses reveal that efforts to integrate indigenous knowledge into STEM education represent a complex, multidimensional transformation rather than a singular reform initiative. This emerging agenda encompasses the restructuring of pedagogical practices (Baynes, 2015; Gumbo et al., 2021; Rofe et al., 2015), the development of inclusive curriculum frameworks that authentically incorporate indigenous worldviews (Keane et al., 2016; Mandikonza, 2019), the empowerment of students as epistemic agents through culturally responsive pedagogies (Eglash et al., 2020; Zocher & Hougham, 2020), the innovation of research methodologies that honour indigenous ways of knowing (Haffejee, 2024; Tolbert, 2015), and the reform of institutional cultures to enable systemic change (Dupuis & Abrams, 2017). At its core, decolonising science education challenges the historical dominance of Western epistemology, advocating for the recognition of diverse knowledge systems as equally valid and valuable (Brown, 2017a; Eglash et al., 2020). Importantly, the integration of indigenous knowledge is not merely an additive process but necessitates a fundamental rethinking of how knowledge is defined, validated, and transmitted within educational settings. The subsequent discussion critically examines each thematic cluster identified through the analysis, situating them within broader debates on epistemic justice, transformative pedagogy, and sustainable educational reform. Through this examination, the discussion seeks to illuminate both the challenges and the opportunities inherent in advancing a decolonial approach to science education globally

Indigenous Pedagogies and Culturally Responsive Science Education

Efforts to decolonise science education necessitate not only the integration of indigenous knowledge into curricula but also a profound transformation of pedagogical approaches. Traditional models of science education, which predominantly transmit Western epistemologies, often marginalise the cultural identities and lived experiences of indigenous learners (Boisselle, 2016; Tolbert, 2015). In response, culturally responsive pedagogy has emerged as a vital alternative framework, emphasising the importance of aligning teaching practices with students' cultural backgrounds and ways of knowing (Brown, 2017a; Seehawer, 2018). Indigenous pedagogies, grounded in relationality, place-based knowledge, and communal learning practices, offer critical pathways for fostering inclusive and epistemically just science education (Jin, 2021; Zocher & Hougham, 2020). The incorporation of local knowledge systems enables students to engage more deeply with scientific concepts through culturally meaningful contexts, thereby promoting relevance, belonging, and epistemic agency (Gumbo et al., 2021; Handayani et al., 2018). However, the successful implementation of culturally responsive strategies faces notable challenges, including systemic resistance to curriculum reform, insufficient teacher training, and entrenched biases favouring Western scientific traditions (Nashon, 2022; Ogegbo & Ramnarain, 2024). Moreover, broader societal structures, such as gendered and colonial assumptions within science, further complicate the task of establishing truly inclusive educational environments (Keane et al., 2016; Parmin & Trisnowati, 2024). Recognising the significance of indigenous pedagogies and local knowledge systems thus becomes critical for reimagining science education as a transformative and socially just practice (David-Chavez et al., 2020; Khupe, 2017; Opoku & James, 2021). By embracing epistemic plurality and fostering community-based approaches to teaching and learning, educators can create environments that empower all students to navigate and contribute to the scientific enterprise in ways that honour both indigenous and Western knowledge systems (Haffejee, 2024; M. Howard et al., 2024; Sánchez Tapia et al., 2018).

Culturally responsive teaching (CRT), as conceptualised by Gay (2002), positions students' cultural experiences, knowledge, and frames of reference at the centre of the educational process, recognising them as foundational elements for effective teaching and learning. Rather than treating culture as peripheral to academic achievement, CRT asserts that students learn best when instruction is directly connected to their lived realities, thereby fostering inclusivity and relevance within the classroom environment (Baynes, 2015; Gay, 2002). Within the context of decolonising science education, CRT serves as a critical framework for validating indigenous worldviews, practices, and knowledge systems in STEM disciplines (Brown, 2017a). Embedding indigenous epistemologies into pedagogical designs enables educators to create science learning environments that not only acknowledge but also celebrate cultural diversity, thus fostering a sense of belonging and epistemic agency among indigenous learners (Baquete et al., 2016; Gumbo et al., 2021). Furthermore, CRT offers a pathway for reconceptualising the nature of scientific knowledge itself, moving beyond Eurocentric paradigms to embrace diverse and contextually grounded ways of knowing. By aligning curriculum content and teaching practices with indigenous perspectives, educators can cultivate more equitable, engaging, and socially just STEM learning spaces, thereby advancing both academic success and cultural affirmation for indigenous students.

An essential dimension of culturally responsive science education is the recognition of local knowledge systems and the application of place-based learning approaches. Indigenous knowledge, deeply rooted in the ecological, social, and spiritual contexts of specific communities, offers valuable scientific insights that are often overlooked by conventional curricula (Baynes, 2015; Keane et al., 2016). Place-based science education encourages students to engage with their natural environment through culturally meaningful lenses, aligning learning experiences with their lived realities and affirming the validity of ancestral knowledge (Eglash et al., 2020; Rofe et al., 2015). For indigenous learners, integrating local ecological practices, traditional environmental stewardship, and indigenous cosmologies into science instruction not only fosters a deeper understanding of scientific concepts but also strengthens community resilience (Baquete et al., 2016; Mandikonza, 2019). Such an approach bridges indigenous and Western scientific paradigms, enabling students to perceive science as relevant and reflective of their cultural heritage (Jin, 2021; Zocher & Hougham, 2020). Moreover, educators who incorporate place-based indigenous knowledge into STEM education create transformative and sustainable learning environments that promote holistic understandings of environmental issues and advance principles of social and epistemic justice (Cirkony et al., 2023; Gumbo et al., 2021; G. Howard, 2021). By valuing the complexities of local environments and indigenous epistemologies, science education becomes a powerful vehicle for fostering inclusive academic engagement and cultivating future generations of culturally grounded and ecologically conscious learners.

Transforming science education to authentically integrate indigenous knowledge necessitates a fundamental redefinition of the teacher's role and curriculum structure. Rather than acting merely as transmitters of content, teachers must evolve into facilitators of epistemic dialogue, enabling the coexistence and critical engagement of multiple knowledge systems within the classroom (Baynes, 2015; Keane et al., 2016). This transformation demands a high degree of cultural competence, as educators are required to cultivate inclusive spaces where both indigenous and Western scientific epistemologies are explored with equal legitimacy and critical reflection (Baquete et al., 2016;

Gumbo et al., 2021). Parallel to this pedagogical shift, curriculum design must transcend tokenistic inclusion and move towards a deep embedding of indigenous perspectives across learning objectives, instructional content, and assessment practices (Brown, 2017a; Mandikonza, 2019). A decolonised curriculum does not position indigenous knowledge as supplementary or anecdotal but recognises it as a coequal and rigorous framework for scientific inquiry (Eglash et al., 2020; Tolbert, 2015). By fostering environments that honour epistemic plurality, science education can advance a more pluralistic, inclusive, and socially just vision that benefits all learners, particularly those from historically marginalised communities (M. Howard et al., 2024; Nyamupangedengu & Khupe, 2024).

Building Frameworks for Indigenous Knowledge Integration in STEM Curricula

While culturally responsive pedagogies create the necessary conditions for acknowledging indigenous knowledge within science education, sustainable and meaningful integration demands more than pedagogical adaptations. A deliberate construction of robust and coherent curricular frameworks is required to ensure that indigenous epistemologies are not treated as peripheral but are recognised as foundational components of scientific inquiry and understanding (Baynes, 2015; Brown, 2017b; Michie et al., 2023; Tolbert, 2015). Without intentional and systemic frameworks, integration efforts risk becoming fragmented, tokenistic, or vulnerable to marginalisation within dominant Western-centric structures of STEM education (McKinley & Stewart, 2012; Ngulube, 2020; Seehawer, 2018). Effective integration frameworks must facilitate authentic collaboration with indigenous communities, co-constructing curricula that genuinely reflect indigenous knowledge systems, practices, and worldviews (Alkholy et al., 2017; Ogegbo & Ramnarain, 2024; Simaan, 2020). Critical frameworks, such as "Two-Eyed Seeing," offer strategies for reconciling indigenous and Western epistemologies while maintaining the integrity of both (Cirkony et al., 2023; Nyaaba et al., 2024). Without such deliberate curricular reform, efforts remain susceptible to superficial inclusion, misrepresentation, and perpetuation of educational inequities (Haffejee, 2024; Oladejo et al., 2025). Thus, constructing inclusive science education requires not only embedding indigenous knowledge at the curricular core but also redesigning assessment practices, teacher training programmes, and institutional policies to uphold epistemic justice and promote transformative educational equity (Eglash et al., 2020; Gumbo et al., 2021; Rofe et al., 2015). Key Principles for Effective Indigenous Knowledge Integration Frameworks are shown in Table 4.

Principle	**Description**	**Supporting References**
Authentic Collaboration with Indigenous Communities	Curricula must be co-constructed with indigenous elders, educators, and knowledge holders to ensure relevance, authenticity, and respect for indigenous epistemologies.	Alkholy et al. (2015); Simaan (2020); Ogegbo & Ramnarain (2024)
Positioning Indigenous Knowledge as Foundational	Indigenous knowledge systems should be integrated as coequal frameworks for scientific inquiry, not treated as supplementary or anecdotal.	Baynes (2015); Gumbo et al. (2021)

Systematic and Coherent Curriculum Design	Curricular frameworks must deliberately embed indigenous perspectives throughout objectives, content, pedagogy, and assessment to avoid tokenism.	Brown (2017); Ngulube (2020); Michie et al. (2023)
Facilitation of Epistemic Dialogue	Teachers should act as facilitators of dialogue between multiple knowledge systems, fostering critical engagement and epistemic plurality.	Tolbert (2015); Cirkony et al. (2023); Nyaaba et al. (2024)
Institutional and Policy Support	Integration efforts must be supported by systemic changes in institutional policies, teacher education programmes, and resource allocations.	Rofe et al. (2015); Medvecky et al. (2023); Johnson (2024)
Avoidance of Simplification and Misrepresentation	Indigenous worldviews must be represented in their full complexity, avoiding oversimplification or romanticisation.	Seehawer (2018); Haffejee (2024); Oladejo et al. (2025)
Culturally Responsive and Place-Based Pedagogy	Teaching strategies should connect learning to local contexts, community practices, and ecological knowledge systems.	Eglash et al. (2020); Jager (2019); Gumbo et al. (2021)
Iterative and Reflective Curriculum Development	Frameworks should be continuously refined through feedback from indigenous communities and evolving understandings of epistemic justice.	David-Chavez et al. (2020); Tapia et al. (2017); Rahmawati et al. (2020)

Table 4. Key Principles for Effective Indigenous Knowledge Integration Frameworks

An effective framework for integrating Indigenous knowledge into STEM curricula must be anchored in principles of epistemic inclusivity, community collaboration, and contextual relevance. First, such frameworks must recognise Indigenous knowledge systems as complete and coherent epistemologies, rather than treating them as peripheral cultural artefacts or supplementary content (Keane et al., 2016; Mandikonza, 2019). The acknowledgement of Indigenous knowledge as a valid scientific paradigm fosters epistemic justice and challenges historical hierarchies embedded in conventional science education (David-Chavez et al., 2020; Eglash et al., 2020). Second, the integration process must be co-constructed with Indigenous communities, ensuring participatory curriculum design that honours local cultural narratives and lived realities (Rofe et al., 2015; Zocher & Hougham, 2020). Collaborative engagement not only enhances curricular authenticity but also strengthens the relational accountability between educational institutions and Indigenous peoples (Nkopodi et al., 2024; Photo & McKnight, 2024). Third, content and pedagogical strategies must be grounded in local ecological practices, cosmologies, and knowledge systems, enabling students to make meaningful connections between scientific inquiry and their environmental and cultural contexts (Eglash et al., 2020; Tolbert, 2015). Place-based and ecopedagogical approaches have proven effective in promoting critical thinking and holistic learning (Jin, 2021; Zocher & Hougham, 2020). Furthermore, targeted professional development for educators is necessary to equip them with the competencies to bridge Indigenous and Western knowledge systems authentically (Morris et al., 2021; O'Connor, 2020; Zocher & Hougham, 2020). Adhering to these principles enables curriculum frameworks to transcend tokenistic inclusion, fostering dynamic educational environments where diverse epistemologies coexist and enrich the scientific enterprise.

Despite growing recognition of the importance of Indigenous knowledge integration, numerous challenges and pitfalls persist in curriculum design and implementation. A common issue is tokenism, where Indigenous knowledge is superficially added to curricula without genuine epistemological engagement, often relegated to isolated units or cultural enrichment activities rather than being positioned as a core scientific perspective (Baynes, 2015). Such tokenistic approaches fail to affirm the epistemic integrity of Indigenous knowledge systems, perpetuating their marginalisation within educational frameworks (Keane et al., 2016; Rofe et al., 2015). Furthermore, essentialism presents another critical pitfall, wherein Indigenous knowledge is inaccurately portrayed as static, homogenous, or universally applicable, thus erasing the rich diversity, dynamism, and locality inherent to different Indigenous communities (Eglash et al., 2020). This reductionist framing misrepresents the complexity of Indigenous worldviews and undermines efforts toward authentic integration.

Additionally, epistemic hierarchies remain deeply entrenched, often positioning Western scientific paradigms as inherently superior while relegating Indigenous knowledge to the realm of anecdotal, subjective, or inferior understanding (Jin, 2021). Such hierarchies reinforce colonial attitudes within science education and inhibit the cultivation of truly inclusive learning environments (de Beer et al., 2022; Zocher & Hougham, 2020). Addressing these challenges requires critical reflexivity among curriculum developers and educators, who must interrogate their assumptions and biases to foster authentic epistemological inclusion (Baynes, 2015; Tolbert, 2015). Sustained partnerships with Indigenous knowledge holders are equally essential to co-create curricular approaches that respect and accurately represent Indigenous epistemologies (Alkholy et al., 2017; David-Chavez et al., 2020). By embracing critical collaboration and rejecting tokenism and essentialism, education systems can move towards genuinely transformative and equitable Indigenous knowledge integration within STEM fields.

To move beyond tokenistic approaches and foster authentic Indigenous knowledge integration, curriculum frameworks must be constructed through meaningful community collaboration. Engaging Indigenous elders, knowledge keepers, educators, and community members from the outset of curriculum development ensures that Indigenous epistemologies are represented accurately, respectfully, and dynamically (Keane et al., 2016; Mandikonza, 2019). Such collaborations must be characterised by reciprocity, shared authority, and mutual respect, positioning Indigenous communities not as subjects of educational reform but as co-creators of scientific knowledge within the learning process (David-Chavez et al., 2020; Michie et al., 2023). Strategies such as community-based curriculum design workshops, participatory research, and co-teaching models with Indigenous educators have been recognised as effective in facilitating deeper integration and promoting epistemic equity (Baynes, 2015; Zocher & Hougham, 2020). Contextually embedded, community-driven frameworks also allow curricula to remain adaptive to evolving needs and aspirations, thereby cultivating authentic engagement and sustainable impacts (Nkopodi et al., 2024; Photo &

McKnight, 2024). Ultimately, frameworks that prioritise local rootedness, participatory governance, and continual evolution provide the most promising pathways for decolonising STEM education and nurturing the full richness of Indigenous ways of knowing within contemporary scientific landscapes (de Beer et al., 2022; Eglash et al., 2020).

Empowering Student Agency and Navigating Epistemic Diversity

While curricular frameworks and pedagogical innovations are indispensable for decolonising science education, genuine transformation ultimately hinges on how students engage with, interpret, and internalise multiple knowledge systems. Empowering student agency entails more than simply exposing learners to Indigenous knowledge; it requires fostering educational environments where students critically interrogate dominant scientific paradigms and affirm the legitimacy of diverse epistemologies (Baynes, 2015; Tolbert, 2015). In particular, for Indigenous learners, nurturing epistemic agency is vital for building cultural identity, epistemic confidence, and a sense of belonging in STEM fields that have historically marginalised their ways of knowing (M. A. Howard & Kern, 2019; M. Kim, 2017).

Epistemic agency, in the context of decolonising science education, refers to students' capacities to question, critically engage with, and contribute to multiple systems of knowledge, rather than passively absorbing dominant scientific narratives (Harper, 2016; Tolbert, 2015). It foregrounds learners as active co-constructors of scientific understanding, bringing their cultural knowledge, lived experiences, and community wisdom into the educational process (Michie et al., 2023; Opoku & James, 2021). Fostering epistemic agency among Indigenous learners is therefore critical to challenging epistemic hierarchies and creating more inclusive, dynamic forms of scientific inquiry (Eglash et al., 2020; Keane et al., 2016).

Despite growing efforts toward inclusivity, Indigenous students often confront profound challenges within STEM environments that privilege Western epistemologies, leading to alienation, diminished self-efficacy, and epistemic dissonance (M. Kim, 2017; Sumarni et al., 2022). Curricula, assessments, and teaching practices frequently treat Western science as the sole arbiter of truth, relegating Indigenous knowledge systems to peripheral or anecdotal status (Baynes, 2015; M. A. Howard & Kern, 2019). These experiences erode student engagement and hinder persistence within STEM pathways (Keane et al., 2016; Nyaaba et al., 2024).

Cultivating epistemic agency thus requires intentional pedagogical strategies that encourage critical dialogue, epistemological pluralism, and the development of intercultural scientific literacy (Michie et al., 2023; Tolbert, 2015). Approaches such as dialogic teaching, inquiry-based learning grounded in local Indigenous contexts, and co-teaching models with Indigenous knowledge holders can empower students to engage meaningfully with both Indigenous and Western scientific traditions (Harper, 2016; Seehawer, 2018). Moreover, integrating storytelling, place-based education, and digital technologies attuned to cultural contexts supports a richer, more inclusive model of science education (Eglash et al., 2020; Nyaaba et al., 2024). Ultimately, fostering epistemic agency transforms learners into critically conscious participants who can bridge cultural and epistemic divides, thus contributing to a more equitable and socially just scientific community (Michie et al., 2023; Tolbert, 2015).

Methodological Innovations and the Operationalization of Decolonization

While pedagogical reforms and student empowerment are critical dimensions of decolonising science education, these efforts must also be underpinned by innovative methodological approaches that reflect and respect Indigenous epistemologies. Traditional research paradigms in science education, often dominated by positivist and quantitative methodologies, have historically marginalised Indigenous ways of knowing, privileging objectivity, generalisability, and quantification (Carter, 2004; Higgins & Kim, 2019). This epistemic hierarchy systematically devalues relational, contextual, and experiential knowledge, thus perpetuating colonial power structures within educational research and evaluation (David-Chavez et al., 2020; Donoghue, 2015). Decolonising science education therefore demands a profound methodological shift that not only challenges positivist assumptions but also reconfigures the foundations of knowledge production and validation.

Methodologies such as narrative inquiry, participatory action research (PAR), and Indigenous research paradigms have emerged as vital alternatives for operationalising decolonisation authentically (David-Chavez et al., 2020; McGinty & Bang, 2016). Narrative inquiry, for instance, foregrounds storytelling and lived experiences as legitimate epistemic forms, offering a counterbalance to decontextualised, statistical approaches (McGinty & Bang, 2016). Similarly, PAR fosters relational accountability, ensuring that Indigenous communities become active co-creators of knowledge rather than subjects of extractive research practices (David-Chavez et al., 2020). Moreover, Indigenous methodologies emphasise relationality, reciprocity, respect, and responsibility, challenging the notion of detached scientific objectivity and situating knowledge within lived cultural, spiritual, and environmental contexts (Donoghue, 2015; Johnson, 2024).

Innovative frameworks such as Two-Eyed Seeing further illustrate how Indigenous and Western epistemologies can coexist synergistically in research and education (Cirkony et al., 2023; Michie et al., 2023). This relational paradigm fosters a holistic understanding that values both Indigenous and scientific worldviews, resisting the epistemic subordination inherent in traditional science education (Cirkony et al., 2023). Community-led evaluation frameworks also offer important methodological innovations, shifting assessment metrics from standardised outcomes towards indicators such as cultural revitalisation, community empowerment, and epistemic justice (David-Chavez et al., 2020; Johnson, 2024).

Operationalising decolonisation thus requires a sustained ethical commitment to relational, long-term engagement with Indigenous communities, critical reflexivity concerning researcher positionality and power dynamics, and a redefinition of success metrics to align with Indigenous values and aspirations (Donoghue, 2015; Higgins & Kim, 2019). Methodological innovation in decolonising science education is not a mere technical adjustment but a radical philosophical and ethical reorientation, transforming how knowledge is generated, legitimised, and shared. By embedding Indigenous epistemologies at the heart of research practice, science education can evolve into a truly inclusive, relational, and socially just enterprise (Carter, 2004; David-Chavez et al., 2020).

Institutional Structures and Epistemic Justice in Schools

While curriculum reforms, pedagogical innovations, and methodological shifts are essential for decolonising science education, these efforts cannot achieve lasting transformation without concurrent changes at the institutional level. Schools are not neutral spaces; rather, they are deeply embedded within social, political, and epistemic structures that have historically privileged Western knowledge systems while marginalising Indigenous ways of knowing (Baynes, 2015; Keane et al., 2016; Rofe et al., 2015). Achieving epistemic justice within science education thus necessitates a critical examination of how institutional policies, leadership practices, resource allocations, and cultural norms either reinforce or challenge epistemic hierarchies (Adendorff & Blackie, 2022; Boisselle, 2016). This recognition positions schools as contested sites of epistemic negotiation, where competing knowledge systems vie for legitimacy, representation, and authority (Baquete et al., 2016; Mandikonza, 2019).

Within institutional frameworks, practices such as rigid curriculum standards, standardised assessments, and narrow definitions of scientific literacy tend to reify Western scientific paradigms, leaving limited space for Indigenous epistemologies to thrive (Adendorff & Blackie, 2022; Cronje et al., 2015). Institutional inertia further compounds this issue, as educational structures often resist transformative change, preserving historical biases against Indigenous knowledge systems (Adendorff & Blackie, 2022; Nashon, 2022). Moreover, the underrepresentation of Indigenous educators in leadership positions significantly curtails the visibility and authority of Indigenous epistemologies within school governance and classroom practices (Adendorff & Blackie, 2022; Nashon, 2022). Without addressing these systemic barriers, initiatives aimed solely at curriculum reform risk being superficial or tokenistic.

To dismantle systemic obstacles and foster epistemic justice, institutions must engage in deliberate, sustained reforms. First, curriculum policies should be reimagined to embed Indigenous knowledge throughout the educational continuum rather than confining it to marginalised modules (Govender & Mudzamiri, 2022; Handayani et al., 2018). Second, there must be strategic investment in Indigenous leadership development to ensure that Indigenous scholars occupy pivotal roles in curriculum design, governance, and teacher education (Latip et al., 2024; Opoku & James, 2021). Third, professional development programmes must cultivate educators' abilities to engage with multiple epistemologies, stressing critical reflexivity, cultural humility, and relational pedagogy (Koirala, 2023; Lipe, 2023). Finally, assessment frameworks should move beyond standardised metrics to embrace holistic, culturally responsive indicators of scientific inquiry and literacy (Dupuis & Abrams, 2017; Shizha, 2011).

In reconfiguring schools as spaces of epistemic negotiation, recognition, and justice, it is not sufficient to modify what is taught; it is equally crucial to transform how educational institutions operate at a systemic level (Sable, 2019; Tolbert, 2015; Upadhyay & Sadykova, 2024). Through institutional restructuring, science education can advance beyond reproducing colonial knowledge hierarchies toward fostering genuinely inclusive, pluralistic, and socially just learning environments (Randell-Moon & Ruddell, 2023).

Limitations and Future Research Directions

While this bibliometric and cluster analysis provides valuable insights into the landscape of indigenous knowledge integration within STEM education, several limitations must be acknowledged. First, the study relied exclusively on the Scopus database, which, although comprehensive, may not encompass all relevant literature, particularly publications in indigenous-led journals, grey literature, or non-indexed community reports. Second, the analysis was restricted to English-language documents, potentially excluding significant contributions published in indigenous or other local languages. Third, the keyword co-occurrence analysis depended on the frequency and selection of keywords within titles and abstracts, which may not fully capture the nuanced discussions or conceptual innovations present in the full texts. Finally, while bibliometric methods are effective for mapping research landscapes quantitatively, they are limited in their ability to assess the qualitative depth, epistemological positioning, and contextual sensitivity of individual studies.

Building on the findings and addressing the noted limitations, several avenues for future research are proposed. First, expanding the analysis to include multiple databases (such as Web of Science, ERIC, or specialized indigenous knowledge repositories) and non-English publications would provide a more comprehensive and globally inclusive understanding of the field. Second, future studies could combine bibliometric mapping with systematic qualitative synthesis to capture deeper epistemological nuances and case-specific insights. Third, more research is needed on longitudinal impacts of indigenous knowledge integration on student outcomes, scientific identity formation, and community empowerment, particularly through empirical case studies. Fourth, comparative cross-regional studies could elucidate how indigenous knowledge integration varies across different sociocultural and political contexts, providing valuable models for policy and practice. Finally, advancing research on institutional change processes—including leadership strategies, teacher professional development, and policy reform for epistemic justice—remains a critical area for supporting sustainable decolonization in science education.

Conclusion

This study provides a comprehensive synthesis of the challenges and opportunities surrounding the decolonization of science education through the integration of indigenous knowledge systems into global STEM curricula. The findings reveal that, despite significant efforts, indigenous knowledge integration remains constrained by systemic barriers, including epistemic marginalization, curriculum tokenism, methodological biases, and institutional inertia. However, the emergence of culturally responsive pedagogies, community-based curriculum frameworks, student agency initiatives, and innovative research methodologies offers promising pathways toward building more inclusive, equitable, and epistemically just educational environments. Advancing the decolonization agenda demands systemic interventions that transcend superficial curricular reforms, involving deep transformations in pedagogy, institutional policy, methodological practices, and knowledge validation frameworks, all rooted in sustained collaboration with indigenous communities. Ultimately, only through ethically grounded, relational, and long-term commitments can science education evolve into a truly transformative space that honours the plurality of knowledge systems and empowers all learners to participate fully and authentically in the scientific enterprise.

Implications

The findings of this bibliometric review yield several critical implications for research, policy, and practice in the field of science education globally. First, the fragmentation and unevenness of Indigenous knowledge integration efforts underscore the urgent need for the development of coherent, systemic frameworks that position Indigenous epistemologies as central—rather than peripheral—to STEM curricula. Without such structural reforms, attempts to decolonize science education risk remaining superficial and tokenistic, failing to address the epistemic injustices entrenched within conventional scientific education systems.

Second, the conceptual clusters identified through bibliometric and co-occurrence analyses reveal that decolonization in science education is inherently multidimensional, requiring simultaneous transformations across pedagogy, curriculum, research methodologies, and institutional cultures. This demands a holistic, interdisciplinary approach that bridges Indigenous and Western knowledge systems through epistemic dialogue rather than epistemic domination.

Third, the paucity of bibliometric and systematic mapping studies on Indigenous knowledge integration highlights a methodological gap that future research must address. Greater utilisation of bibliometric methods can provide critical meta-analytical insights into emerging trends, research gaps, and interdisciplinary linkages, thereby informing more strategic and globally informed decolonization initiatives.

Fourth, policy frameworks must be reoriented to support sustained partnerships with Indigenous communities in the co-design of science curricula. Authentic collaboration ensures that Indigenous knowledge systems are not homogenised or essentialised, but rather incorporated in ways that honour their diversity, locality, and dynamism.

Fifth, there are urgent implications for teacher education and professional development. Educators must be equipped not only with cultural competence but also with critical reflexivity and the pedagogical skills necessary to facilitate epistemically inclusive classrooms. Training programmes must move beyond surface-level multiculturalism towards deep engagements with Indigenous worldviews and methodologies.

Finally, the broader project of decolonizing science education is intimately linked with the pursuit of educational justice, environmental sustainability, and global equity. Recognising Indigenous knowledge systems as vital to addressing complex contemporary challenges—such as climate change, biodiversity conservation, and social resilience—positions decolonized STEM education as a transformative force not only within schools and universities, but across societies at large.

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