Fostering Indigenous Student Success in Tertiary STEM: A Student-Centric, Culturally Responsive Approach

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ABSTRACT

CONTEXT

Aboriginal and Torres Strait Islander students remain significantly underrepresented in Australian tertiary STEM fields, despite efforts to increase participation. Traditional teaching approaches, rooted in Western knowledge systems, often fail to resonate with Aboriginal students' cultural backgrounds and learning styles, leading to disengagement. Addressing this issue requires exploring student-centric, culturally responsive pedagogies to foster belonging and empowerment for Aboriginal learners in STEM disciplines, aligning with SDG 4 (Quality Education) and SDG 10 (Reduced Inequalities).

PURPOSE OR GOAL

This study explores Aboriginal student perspectives on tertiary STEM education to identify student-centric strategies and culturally responsive pedagogies that promote engagement and belonging. The goal is to develop recommendations and a framework to enhance teaching practices and learning environments, supporting Aboriginal student success in STEM programs.

APPROACH OR METHODOLOGY/METHODS

This research introduces the Culturally Responsive STEM Integration Framework to analyse mismatches between traditional STEM curricula and Aboriginal knowledge systems, particularly from rural, regional, and remote communities. A mixed-methods approach could inform the development of culturally relevant tools and curricular adjustments, promoting inclusive STEM environments that support Aboriginal student success in alignment with SDG 4 and SDG 10.

ACTUAL OR ANTICIPATED OUTCOMES

This paper anticipates transformative outcomes for tertiary STEM education, fostering greater inclusivity and empowerment for Aboriginal learners through the proposed Culturally Responsive STEM Integration Framework (SDG 4, SDG 10). The study will provide evidence-based recommendations addressing culturally responsive pedagogies, assessment design, and mentorship structures, offering a powerful tool to critically assess programs and catalyse the integration of diverse knowledge systems, directly supporting Aboriginal student success within STEM fields.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

This research highlights the need for a paradigm shift in tertiary STEM education to support Aboriginal student success by addressing mismatches with traditional Western-centric curricula. The Culturally Responsive STEM Integration Framework provides a foundation for developing culturally responsive learning environments, aligning with SDG 4 and SDG 10.

KEYWORDS

Culturally Responsive Pedagogy; Aboriginal learners; Tertiary STEM Education; Place-based STEM-Alignment Framework; Culturally Responsive STEM Integration Framework.

Introduction

The persistent underrepresentation of Aboriginal and Torres Strait Islander peoples in Science, Technology, Engineering, and Mathematics (STEM) fields in Australia is a pressing concern with significant ramifications for both individuals and the nation (E. C. Burns et al., 2023). Despite increased efforts to promote Indigenous participation in STEM education, a considerable gap remains, hindering the potential contributions of Aboriginal and Torres Strait Islander peoples to these critical fields (Timms et al., 2018). This disparity not only perpetuates historical inequities but also limits the diversity of perspectives and knowledge systems that are essential for addressing complex challenges in STEM.

Existing research has illuminated several key factors contributing to this underrepresentation. A prominent issue is the cultural dissonance between traditional Western-centric STEM curricula and the diverse knowledge systems and learning preferences of Aboriginal students (E. A. Burns et al., 2023). This mismatch often leads to feelings of alienation and disengagement, hindering academic progress and creating barriers to success. As highlighted by (Bullen & Flavell, 2020; Kind & Osborne, 2017; Wohling, 2009), the epistemological foundations of Western science, with its emphasis on objectivity, reductionism, and mechanism, often clash with Indigenous knowledge systems that are holistic, interconnected, and spiritually grounded. This cultural dissonance is further exacerbated by the historical legacy of colonialism and systemic discrimination faced by Aboriginal students in educational institutions (Wahed & Pitterson, 2024). Keegahn et al (Keegahn, 2022) found that in Nebraska, a state with a sizable Indigenous population, Indigenous students are underrepresented in advanced math and science courses, mirroring national trends. In Australia, the historical and ongoing colonisation of Aboriginal lands and knowledge systems has had a lasting impact on educational opportunities and outcomes for Indigenous students, perpetuating systemic barriers to their full participation in STEM fields (Wohling, 2009)

To address this complex issue, a multifaceted approach is required that recognises and values the unique cultural strengths and knowledge systems of Aboriginal students. Culturally responsive pedagogies (CRP) have emerged as a promising avenue for bridging the cultural divide in STEM education. CRP acknowledges and values the cultural backgrounds, experiences, and knowledge systems of Aboriginal students, fostering a sense of belonging and empowerment within STEM disciplines. (Aziz, 2024; Chow et al., 2020; Hernandez, 2022; Kondo, 2022; Pinkerton & Martinek, 2023) emphasise that CRP is not merely a pedagogical approach but a social responsibility in higher education, aiming to empower students intellectually, socially, emotionally, and politically by using cultural referents to impart knowledge, skills, and attitudes.

This study aims to contribute to this growing body of research by introducing the Culturally Responsive STEM Integration Framework, a comprehensive framework that guides the integration of culturally responsive pedagogies, student-centric approaches, and Indigenous knowledge systems into tertiary STEM education. By sourcing input from key Indigenous education, student perspectives, curriculum content, and teaching practices through a mixed-methods approach, this important data would be used to develop this framework that will inform the development of culturally relevant tools and adjustments to existing curricula. Ultimately, this research seeks to empower educators and institutions to create a more equitable and inclusive STEM education system that recognises and values the diverse knowledge systems and learning preferences of Aboriginal students, fostering their success and contributions to STEM fields.

Literature Review

The persistent underrepresentation of Aboriginal and Torres Strait Islander peoples in Science, Technology, Engineering, and Mathematics (STEM) fields in Australia is a pressing concern with significant ramifications for both individuals and the nation. This extensive literature review delves into the multifaceted factors influencing the success of Aboriginal students in tertiary STEM education, drawing on research from Australia and around the world. The review focuses on culturally responsive pedagogies, student-centric approaches, and the integration of Indigenous Knowledge Systems (IKS) (Shizha, 2014) as key strategies for fostering Indigenous student success in STEM.

Cultural Dissonance and Western-Centric Pedagogies

A dominant theme in the literature is the cultural dissonance between Western-centric STEM curricula and Indigenous knowledge systems (IKS). This dissonance, rooted in historical colonisation and ongoing systemic discrimination, can lead to feelings of alienation and disengagement among Aboriginal students, hindering academic progress and creating barriers to success. Research suggests that integrating Indigenous knowledge systems and perspectives into STEM curricula can enhance the relevance and engagement of Aboriginal learners (Breidlid, 2009; Onwu & Mosimege, 2004; Shizha, 2014).

Culturally Responsive Pedagogies and Student-Centred Approaches

Culturally responsive pedagogies (CRP) have emerged as a potential solution to bridge this cultural dissonance. CRP acknowledges and values the cultural backgrounds, experiences, and knowledge systems of Aboriginal students, fostering a sense of belonging and empowerment within STEM disciplines (Gay, 2010b; Matthews et al., 2015). Hall et al. (2023) highlight CRP as a social responsibility in higher education, emphasizing its potential to empower students intellectually, socially, emotionally, and politically by using cultural referents to impart knowledge, skills, and attitudes.

Kumi-Yeboah & Amponsah (2023) explored the implementation and experiences of culturally responsive teaching (CRT) in online learning environments, finding that both faculty and students understand its importance in creating inclusive learning environments (Kumi-Yeboah & Amponsah, 2023). Their research identifies strategies such as providing multicultural materials, fostering open communication, and advocating for diversity, equity, and inclusion (DEI) to promote CRT. (McLoughlin, 1999) emphasise the importance of understanding and incorporating Aboriginal perspectives on technology and learning to create more effective and culturally relevant STEM education. In addition, the concept of "ancestral computing" (Moreno Sandoval, 2019) highlights the potential of integrating Indigenous knowledge systems into computer science education to empower students and promote social change. By valuing cultural identity, community engagement, and student-centred learning, this approach not only enhances students' understanding of computer science concepts but also fosters a stronger sense of cultural identity and agency, leading to increased participation and success in STEM fields. This approach aligns with the broader movement towards decolonising STEM education by recognising and valuing the contributions of Indigenous knowledge systems.

Place-Based Education and Mentorship

Place-based education, which connects learning to the local environment and community, has been identified as a culturally relevant approach for engaging Indigenous students in STEM (Lowenstein et al., 2018; Yemini et al., 2023). By incorporating Indigenous knowledge and perspectives into STEM curricula and activities, educators can create meaningful learning experiences that resonate with Aboriginal students' cultural identity and knowledge. The presence of Indigenous mentors and role models in STEM fields is also crucial for inspiring and supporting Indigenous students. Mentorship programs provide guidance, support, and encouragement, while role models demonstrate the possibilities of success in STEM careers. Studies have shown that mentorship and role models can increase Aboriginal students' confidence, motivation, and persistence in STEM.

The Need for a Comprehensive Framework

While existing research highlights the importance of culturally responsive pedagogies, student-centric approaches, place-based education, and mentorship, there remains a need for a comprehensive framework that guides the integration of these strategies into tertiary STEM education. This study aims to address this gap by introducing the Culturally Responsive STEM Integration Framework. By analysing student perspectives, curriculum content, and teaching practices through a mixed-methods approach, this framework will inform the development of

culturally relevant tools and adjustments to existing curricula. Ultimately, this research seeks to empower educators and institutions to create a more equitable and inclusive STEM education system that recognises and values the diverse knowledge systems and learning preferences of Aboriginal students, fostering their success and contributions to STEM fields.

Proposed Culturally Responsive STEM Integration Framework

The Culturally Responsive STEM Integration Framework is a proposed model designed to address the persistent underrepresentation of Aboriginal and Torres Strait Islander students in STEM fields. It recognises the critical need to move beyond traditional Western-centric approaches and create an inclusive and empowering learning environment that fosters the academic success and engagement of Aboriginal students.

The framework draws upon and integrates the four key components identified from the previous section: Culturally Responsive Pedagogies (CRP), Student-Centric Approaches, Place-Based Education, and Mentorship and Role Models. The proposed framework is also informed by our institutions designated graduate learning outcomes, with specific relevance to the implementation of Graduate Learning Outcome 8 (GLO8) by Deakin University, which emphasizes global citizenship and engagement with Aboriginal and Torres Strait Islander peoples, provides a supportive policy framework for this model (*Graduate Learning Outcome 8 (GLO8)*).

Culturally Responsive Pedagogies (CRP)

CRP involves teaching practices that acknowledge, respect, and incorporate the cultural backgrounds, experiences, and knowledge systems of Aboriginal students. The goal is to create a sense of belonging and empowerment within STEM disciplines, countering the alienation often experienced due to the dissonance between Western-centric curricula and Indigenous ways of knowing.

The framework advocates for a multi-pronged approach to implementing CRP in STEM education:

- **Curriculum Design:** The curriculum should be redesigned to integrate Aboriginal cultural perspectives and knowledge systems.
    - **STEM Disciplines:** This could involve incorporating Indigenous ecological knowledge into environmental science courses, exploring the mathematical principles behind traditional Aboriginal art and design, or examining the engineering ingenuity of ancient Aboriginal tools and structures.
    - **IT and Computer Science:** For Information Technology (IT) and Computer Science (CS) courses at universities, curriculum design can include modules focusing on the practical applications of technology in preserving and promoting Aboriginal culture. Students could develop apps for language preservation, create databases for tracking community resources, or design digital platforms for storytelling and sharing cultural knowledge.
- **Teaching Strategies:** Culturally relevant teaching strategies should be employed to enhance engagement and understanding.
    - **Storytelling & Experiential Learning:** Storytelling is a powerful tool for conveying knowledge and values in Aboriginal cultures. Educators can use traditional stories to explain scientific concepts, making them more relatable and engaging for Aboriginal students. Additionally, incorporating experiential learning activities like field trips, hands-on experiments, and community-based projects can provide opportunities for students to apply STEM knowledge in real-world contexts and connect it to their cultural heritage.
    - **IT and CS Specific Strategies:** In IT and CS courses, educators can use culturally relevant examples and projects to illustrate key concepts. For instance, students could learn coding by creating interactive games that teach Aboriginal language or develop digital tools to support cultural preservation efforts.

- **Assessment Methods**: The framework proposes the development of assessment methods that value diverse ways of knowing and demonstrating knowledge.
  - o **Inclusive Assessment**: This includes oral presentations, project-based assessments, and community-based research projects. These methods respect the holistic and interconnected nature of Indigenous knowledge systems and allow Aboriginal students to demonstrate their understanding in ways that are culturally meaningful.
  - o **STEM and IT/CS Specifics**: In IT and CS, assessments can include practical projects, coding assignments, and digital portfolios that showcase students' work on culturally relevant projects. For STEM subjects, assessments could involve field research reports, lab experiments that incorporate traditional knowledge, and environmental impact studies that consider Indigenous perspectives.
  - o **Feedback and Support**: Continuous assessment and feedback mechanisms should be implemented to ensure that students understand their progress and areas for improvement. This can involve peer reviews, regular check-ins with instructors, and reflective journals. Providing culturally sensitive feedback and support can help Aboriginal students navigate the challenges of tertiary STEM education and build their confidence and self-efficacy.

Place-Based Education

Place-based education connects learning to the local environment and community, making education more relevant and meaningful for students, especially Aboriginal students whose cultural and geographical contexts are integral to their identity and learning.

The framework suggests the following strategies for implementing place-based education:

- **Community Involvement**: Involve local Aboriginal communities in the development and delivery of STEM curricula. This includes inviting community elders to share their knowledge and experiences and partnering with local organisations for field trips and practical learning experiences. For IT/CS, community projects could involve creating digital archives of cultural heritage or developing community-focused technology solutions that address local needs and challenges.
- **Local Contexts**: Use local environmental and cultural contexts as the basis for learning activities. For example, studying local ecosystems in biology, using local historical sites for mathematics projects, and exploring traditional Aboriginal technologies in engineering courses. In IT, students could map local cultural sites using GIS technology or create databases for community resources.
- **Field Trips and Experiential Learning**: Organise field trips and hands-on learning experiences that connect classroom learning to real-world contexts within the community. This includes visits to significant Aboriginal sites, participation in community projects, and collaborative research with local organisations. IT students could visit tech companies or attend hackathons that focus on community problems, gaining valuable practical experience and exposure to potential career paths.

Mentorship and Role Models

Mentorship and role models play a critical role in supporting and inspiring Aboriginal students in STEM fields. Mentors provide guidance, support, and encouragement, while role models demonstrate the possibilities of success in STEM careers.

The framework suggests the following strategies for incorporating mentorship and role models:

- **Mentorship Programs**: Establish mentorship programs connecting Aboriginal students with Indigenous and non-Indigenous STEM professionals. These programs can include one-on-one mentoring, group mentoring sessions, and peer mentoring programs. In IT, mentorship could involve coding boot camps or partnerships with tech startups, providing students with valuable industry connections and insights.

- **Role Models**: Highlight and celebrate the achievements of Aboriginal STEM professionals through guest lectures, career talks, and media showcases. This can help students see the relevance of STEM careers to their own lives and aspirations. Showcasing successful Aboriginal professionals in IT and CS can provide tangible examples of career pathways and inspire students to pursue similar goals.
- **Peer Support**: Foster a supportive community among students through peer mentoring and study groups. This helps build a sense of belonging and mutual support among students, crucial for their academic success. In IT courses, peer coding groups and collaborative projects can enhance learning and provide a platform for students to share knowledge and support each other.

The proposed framework integrates above strategies to encourage Indigenous students to pursue STEM and IT studies later in their tertiary education. Providing a culturally responsive and supportive environment from the beginning increases the likelihood of students developing a strong interest in these fields.

The Culturally Responsive STEM Integration Framework and GLO8

The recent implementation of Graduate Learning Outcome 8 (GLO8) by Deakin University, which emphasizes **global citizenship** and engagement with Aboriginal and Torres Strait Islander peoples, provides not only an imperative for such an approach but also a supportive policy basis for the proposed Culturally Responsive STEM Integration Framework. GLO8 focuses on engaging ethically and productively in the professional context, and with diverse communities and cultures in a global context. It emphasises the importance of understanding the self in relation to others, developing a worldview, and adapting knowledge to particular environments and situations.

Key Elements of Global Citizenship in GLO8 includes,

- **Developing a Worldview**: Understanding and processing local information and comparing it to global contexts to build knowledge.
- **Research and Perspectives**: Drawing on both local and international perspectives for comprehensive research.
- **Interdependency and Adaptation**: Recognising the interdependency of events and conditions from local and global perspectives and adapting knowledge accordingly.
- **Critical Analysis**: Analysing issues and situations critically, considering global perspectives.
- **Cultural Curiosity**: Demonstrating curiosity for understanding different cultural perspectives and fostering a sense of community.
- **Inclusivity and Collaboration**: Appreciating the importance of inclusivity and collaborating ethically and positively with others.
- **Civic Engagement**: Participating in civic-focused activities and understanding ethical community behaviour.

By aligning tertiary STEM education with grounding themes, such as the Global Citizenship graduate learning outcome, and implementing the proposed framework, universities could create a more inclusive and culturally responsive learning environment that fosters the success of Indigenous students.

Conclusion

The proposed Culturally Responsive STEM Integration Framework offers a comprehensive approach to addressing the underrepresentation of Aboriginal and Torres Strait Islander students in STEM fields. By creating a more inclusive and culturally responsive learning environment, this framework has the potential to transform tertiary STEM education in Australia, promoting greater equity and inclusion in STEM disciplines. Through the adoption of culturally responsive pedagogies, student-centric approaches, place-based education, and mentorship, educational

institutions can support the success and contributions of Indigenous students in STEM, aligning with the goals of SDG 4 (Quality Education) and SDG 10 (Reduced Inequalities).

By addressing these critical areas, the proposed research provides a clear, actionable roadmap for educators and institutions to follow, ensuring that Aboriginal students are supported, empowered, and given the opportunity to succeed in STEM disciplines. This framework not only enhances the academic performance of Indigenous students but also fosters a sense of identity, belonging, and cultural pride, ultimately contributing to a more inclusive and diverse STEM workforce.

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