Integrating Indigenous Science and STEM: Challenges and Learning in Curriculum Design and Delivery.

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Abstract

This paper describes the lessons arising from creating a common core first-year unit which integrates Indigenous Science and academic literacy for undergraduate students in STEM within an Australian university. The unit, delivered across 2 local and 5 Global Campuses, represents a departure from conventional science courses as it was co-developed and is co-taught by facilitators from the Centre for Aboriginal Studies and the Faculty of Science and Engineering. Challenges included delivering two differing epistemologies, Indigenous Knowledges of the Australian Continent and Western scientific protocols, in a single learning experience, for 1000 first year commencing students whose existing scientific literacy is primarily developed by a western-lens education system. We discuss classroom pedagogy as well as activities used in the unit. Reflections from teaching staff indicate transformative learning from both staff and students. Subsequently, the unit has been featured by the Australian Council of Deans of Science (2021) as a model for similar programs, and has received awards for excellence, including AAUT Citation for Outstanding Contributions to Student Learning.

Acknowledgement
We at Curtin University would like to pay our respects to the Aboriginal and Torres Strait Islander members of our community by acknowledging Wadjak Boodjar (Perth land) where Curtin University sits by the Derbal Yerrigan (Swan River). The Traditional Owners of this land, the Wadjuk people from the Noongar nation, have continuing connection to country, sea, sky and community, and we pay our respects to Elders, past present and emerging. We especially acknowledge Senior Knowledge Holders, their descendants and kin for sharing of Kaaritkjan. We would like to acknowledge Tracy Kickett (Balardong), for initial development of Aboriginal and Torres Strait Islander Curriculum within the unit.

Introduction

Bachelor's degree programs in STEM have historically focused primarily on technical knowledge and skills, with much less attention devoted to the broader societal and ethical dimensions of scientific practice. STEM degrees in Australia, particularly in the physical sciences, have traditionally taken a Euro-centric or western-lens approach to scientific principles, practices and protocols, dismissing other knowledge systems as invalid or inferior. This can deliver a narrow interpretation of science that overlooks the role of cultural and social factors that drove many scientific movements and norms, consequently also overlooking the impact of a narrow scientific practice on society and the environment.

A core issue that must be addressed by Australian universities is the recognition of Australia as a nation founded in colonialism and therefore the existence of the multiple cultures and knowledge systems that function on this continent (Universities Australia, 2011). Addressing this within STEM degrees requires acknowledging that, although the foundational principle of science – developing an accurate understanding the world via experimentation and observation – is universal, the ways in which science is conducted, recorded, and communicated can have substantial variation between cultures (Bang & Medin, 2010). There can be particular challenges for cohorts educated in systems that promote discipline separation and prioritise written records and written communication when encountering knowledge systems like those of First Nations peoples in Australia, which take a holistic approach. These knowledge systems relied more on nature and country as a guide, instead of laboratory equipment, and are founded in oral and visual forms of expression (Woodward, Harkness, & Archer, 2020). Respectful delivery is challenging because of persistent bias and lack of understanding owing to epistemological differences, power imbalance, discrimination and resistance to change.

Embedding Indigenous Knowledge systems, perspectives, and scientific approaches into STEM education is therefore essential to empowering future cohorts of scientists to fully understand the richness and complexity of the human world in which they are operating. Including authentically taught cultural competency skills and Indigenous perspectives in bachelor's degree programs can address this gap by infusing a human-centered approach to scientific inquiry (Universities Australia Indigenous Strategy, 2017). Indigenous Knowledges emphasize the interconnectedness between peoples, nature, and a holistic philosophy of practice and knowledge almost eliminated by colonialism. Therefore, it is critical that the discussion of impact of colonisation across the globe should highlight the importance of ethical, social, and cultural dimensions to education (Harvey & Russell-Mundine, 2019). Incorporating these perspectives into STEM curricula adds depth and richness to students' learning experiences, fostering a deeper appreciation for the human dimensions of STEM knowledge and its implications for society.

This paper describes the creation of a core unit for undergraduate students which integrates Indigenous Knowledges and Cultures and academic literacy in STEM across all first-year science and computing degree programs in the Faculty of Science and Engineering at Curtin University. It was a major innovative curriculum reform and involved a departure from conventional science courses and new ways of thinking for many science staff and students. The unit introduces students to Indigenous science, history, cultures, knowledges, and practices. It focuses on developing students' capacities to research, evaluate, and communicate scientific and cultural information and arguments using written, visual, and oral presentation techniques. Moreover, it fosters inter-cultural awareness, scientific standards, and academic integrity. The engagement with Indigenous Science and Western Science perspectives to address global challenges was underpinned by the generous reciprocity of Aboriginal peoples, being co-developed and co-taught by facilitators from the Centre for Aboriginal studies and the Faculty of Science and Engineering.

Challenges in Integrating Indigenous Knowledges into STEM Education

Curtin university was one of the earliest organisations to develop a Reconciliation Action Plan (Curtin University, 2008), and its Health Science degrees have successfully delivered on Indigenous Knowledges and Cultures for 22 years with the Centre for Aboriginal Studies (Kickett, Hoffman, & Flavell, 2014; Bullen & Flavell, 2017). Within the Faculty of Science and Engineering, embedding Indigenous perspectives into curricula has been a priority for

several years (Universities Australia, 2011); however, it has been difficult to action, as many STEM staff and students perceived Indigenous Knowledges and perspectives as supplementary rather than integral to the curriculum. Additionally, many Faculty teaching staff viewed Indigenous Knowledges and Cultures as "*irrelevant to science*" and/or "*too hard to put into practice*". Although the hurdle of non-Aboriginal Staff discomfort has been identified and overcome in other disciplines (Wolfe, Sheppard, Le Rossignol, & Somerset, 2018; Bullen, et al. 2021), it persists in STEM fields.

The most significant challenge in developing a science unit involved bringing together two differing epistemologies – Indigenous Knowledge systems, with a history spanning 65,000 years (Griffiths and Russell, 2018) and Western science (Desmarchelier, 2020) – in a unit also developing academic literacy where students' work would be assessed based on metrics commonly used in university education. Further complexities that had to be addressed included the diversity in staff teaching backgrounds, experience and perspectives, along with the logistics of managing the unit across Australian and five Global campuses.

Navigating Unit and Staff Development

A collaborative partnership was formed between staff from the Centre for Aboriginal Studies (CAS) and the Faculty of Science and Engineering (FSAE) in 2019, to authentically integrate Indigenous Knowledges and Cultures into science courses. This partnership resulted in the conception and development of a foundational first-year unit titled *Integrating Indigenous Science and STEM*, aimed at introducing Indigenous ways of knowing and being into the science curriculum. A primary desire of the development team was to implement a unique curriculum that included innovative delivery by foregrounding Indigenous voices. This critical aspect would ensure an increase of educators at the Centre for Aboriginal Studies, and hence bringing more Indigenous expertise into the institution.

A critical component in developing the unit was the careful building of relationships within a culturally heterogenous team. This included staff from a variety of First Nations backgrounds and non-Indigenous staff from multiple science disciplines, all with varying levels of teaching experience. Carefully cultivating these relationships involved fostering open communication to build trust and mutual respect (reciprocity) by actively listening to all team members, valuing their contributions, and acknowledging their unique perspectives and expertise. Developing cultural sensitivity and awareness through training and ongoing education about Indigenous Cultures, histories, and Knowledge systems helped non-Indigenous team members understand and respect Indigenous perspectives.

Ongoing development over the past 4 years included weekly meetings of the teaching staff to engage in conversation (yarn), build rapport and routinely evaluate each week's pedagogical strategies, instructional approach and student support initiatives. Through a collaborative process of reflection-in-action and reflection-on-action (Schön, 1983) based on evaluation and feedback processes from all stakeholders, staff were motivated to strive for continuous improvement and best practice (Bullen, et al. 2021). This iterative process enabled a focus on enhancement of the quality of the curriculum and learning materials, teaching delivery, and the lived experience of the learners.

Navigating Student Cohort Expectations

The student cohort predominantly consists of recent high school graduates who have studied various science subjects such as physics, mathematics, chemistry, etc in secondary education. Their prior education reflects a segmented approach typical of high school curricula and based on a Western-centric approach. Additionally, these students face challenges associated with transitioning to university-level education, including adapting to different pedagogical approaches and higher academic literacy and integrity standards in the tertiary sector. Hence, it can be challenging for students to fully engage with and appreciate Indigenous Knowledge systems and diverse scientific paradigms.

The Integrating Indigenous Science unit is undertaken by students enrolled in their first semester in various science courses and majors in the Faculty of Science and Engineering, including Actuarial Science, Agribusiness, Biochemistry, Chemistry, Coastal and Marine Science, Computing, Geology, Earth Science, Environmental Science, Extractive Metallurgy, Data Science, Information Technology, Mathematics, Mining, Physics, and Surveying. Notably, the largest cohort of students are studying Computing and Information Technology, which presents inherent challenges in fostering interdisciplinary perspectives owing to the highly specialized and technical nature of their field.

Innovative Pedagogy

The CAS-SAE co-teaching model is conducted in small workshops of 40-45 students. This enables authorities of Indigenous Knowledges and Cultures (Aboriginal and Torres Strait Islander staff) and experienced science staff to develop and deliver unit content that is both meaningful and relevant to learners. This approach not only prioritizes the dissemination of culturally relevant material but ensures cultural competency education, thereby fostering an inclusive and enriching learning environment for all students (Yunkaporta & McGinty, 2009) alongside the interactive learning and application of scientific literacy practices and academic integrity (Grellier & Goerke, 2018).

The co-teaching model, which foregrounded Aboriginal and Torres Strait Islander staff within the workshops represented an innovative and pioneering educational strategy. This initiative not only facilitated cultural representation but also provided many students with their first interpersonal interaction with a First Nations person, thereby enriching their educational experience through direct engagement.

Central to this pedagogical framework, staff are role-models for respectful communication and provide visible integration in a science context. Aboriginal pedagogy and protocols, such as yarning (Mooney, Riley, & Blacklock, 2018) and ethical considerations, are incorporated to promote culturally appropriate learning outcomes, alongside scientific literacy and academic integrity. Through the intentional integration of these principles, the CAS-SAE co-teaching model embodies a commitment to creating inclusive and respectful learning environments that promote cultural safety, understanding and engagement with Indigenous Knowledges and Cultures within the science education domain.

Innovative Curriculum and Assessment

The Indigenous Knowledges framework used in the unit was initiated by Tracey Kickett (Balardong) and incorporated a diverse range of Aboriginal Knowledges and Traditional

practices from Western Australia. This framework included Knowledges in science, intergenerational storytelling, and traditional ecological knowledge related to seasons, astronomy, and land management. By engaging with these diverse elements, students gain a comprehensive understanding of Indigenous ways of Knowing and Being prior to colonisation, fostering a deeper appreciation for Indigenous Knowledges and Cultures within the STEM context. This gentle introduction to Indigenous epistemologies and ontologies lays the groundwork for understanding the extensive body of knowledge that has been marginalised or suppressed. This aims to shift the focus from the pervasive deficit perspective of Indigenous Peoples (Fforde, Bamblett, Lovett, Gorringe, & Fogarty, 2013) to one that highlights significant contributions and impacts that Indigenous peoples have made and continue to make.

The instructional approach adopted by the program was characterized by critical inquiry, learner-centric teaching, and continuous interaction between peers and educators. The curriculum employed scaffolded materials (Verenikina, 2008) to navigate the distinct epistemologies of Indigenous science and Western science, emphasizing the importance of diverse cultural perspectives in scientific inquiry. The historic use of scientific ideas to justify social and political actions such as eugenics and segregation is specifically explored to demonstrate the damage that can be done when science is propagated via a single cultural lens. These topics enable students to explore how the social practice of science has resulted in human and environmental consequences through the lens of privilege and scientific bias. For a commencing cohort this can be especially challenging if they have never been exposed to other ways of knowing; with a view of the world through a western-scientific lens and adherence to the concept that all scientific practice is objective.

The curriculum also integrates essential content and instruction on scientific, academic and literacy skills and competencies including research methodologies, paraphrasing and referencing as well as academic integrity. This enables students to conduct rigorous research, construct well-supported arguments, and adhere to ethical standards in their scholarly work.

The workshops incorporate elements of active-learning methods (Freeman et al., 2014) and transformative learning (Mezirow, 2008), which require students to critically reflect on their assumptions, values, beliefs, and feelings, and relate these reflections to their own scientific fields. Through group work and case studies, learners examine concepts, analyse new knowledge, and actively engage in discourse (yarn), to evaluate evidence and alternate points of view. Furthermore, students are encouraged to be open to new perspectives and be willing to consider the beliefs and views of others.

Discussions of privilege and oppression are introduced early in the semester. Students examine biases, prejudices, and persistent issues of discrimination faced by First Nations peoples, both within science professions and more broadly (Chaudhury & Colla, 2020). An intersectionality framework enables students to relate their own positionality, including but not limited to biases and privileges, to those prevalent in science, both historically and in contemporary contexts (500 Women Scientists Leadership, 2020). This approach aims to foster a foundational understanding of the scientific and social basis of modern science and its open-endedness as a way of realising the existence of alternative epistemologies.

In the middle of the teaching semester, students are asked to critically examine the social impact of scientific practices by investigating the historical context of Terra Nullius, colonisation, the Western Australian 1905 Act, and similar actions and policies in the name of science that has led to the ongoing adverse impact on Aboriginal and Torres Strait Islander peoples. Moreover,

truth-telling processes regarding the history and Knowledges of First Nations peoples empower students to critically evaluate their pre-existing knowledge (or lack thereof), thereby assisting in a process of deconstruction and ultimately the reconstruction of more informed and culturally appropriate attitudes and behaviours.

In the latter part of the semester, students are encouraged to draw insight from more recent events, such as Rio Tinto's handling of the Juukan Gorge case (Macdonald, Gringart, Garvey, & Hayward, 2022). Pertinent case studies, such as those on Indigenous innovations, traditional practices in wildfire mitigation, and current research into Indigenous astronomy, are also presented, demonstrating the positive contributions of Indigenous peoples to knowledge and science. Through this analysis, students evaluate how they, as future science professionals, can work within a reconciliation framework to foster positive and meaningful collaborations with Indigenous communities, industry, and government that are key to these teachings. This critical evaluation aims to equip students with the skills and knowledge necessary to engage in ethical and culturally respectful scientific practices with Indigenous communities, in their future careers.

Assessments in this unit encourage students to analyse, evaluate and deconstruct both science-based articles and academic research articles on Indigenous Knowledges (Bettez 2011). Students are asked to demonstrate understanding of research-based claims, to construct claims, counterclaims and rebuttals supported by research evidence in clear paragraphs regarding their research on Indigenous Knowledges. They are also asked to reflect on the unit content and write an academic reflection.

The assessments have a broader focus that includes the 476 million Indigenous peoples across the globe (United Nations, 2023) and recognise those societies and knowledges which have also been adversely affected by colonisation. This recognises aspects of both commonality and diversity in Indigenous perspectives and supports students, particularly in off-shore campuses, to recognise the global relevance of the unit. Students are encouraged to research a diverse range of Indigenous innovations – for example, the Inuit polar ice map (Wilson, Arreak, Sikumiut Committee, Bell, & Ljubicic, 2021) – which illustrate the global contributions and resilience of Indigenous communities.

The curriculum's flexibility and assessment design have been tailored to accommodate this diverse cohort, enabling successful implementation to international campuses located in Dubai, Malaysia, Mauritius, Singapore, and Sri Lanka. This transnational teaching has resulted in the development of a wider collaborative approach, facilitating the acknowledgement of First Nations epistemologies at a global level.

Through the learning undertaken in this unit, students are invited to reflect on how the decolonization of science and the broadening of perspectives around different knowledge systems can enhance their scientific careers. Students explore related ethical issues within STEM, are introduced to the nature of science, scientific behaviours, the role and relevance of science and of other knowledge systems in society, particularly Indigenous Knowledges. Methods of scientific inquiry are discussed and studied to foster students' professional identities as scientists in the STEM fields of the 21st century.

Educator and Student Reflections

The strength of the unit as described by Aboriginal and Non-Aboriginal staff was attributed to the close working relationships and mutual respect developed from co-teaching in the workshops. Most staff members expressed a sense of unexpected professional growth and a strong sense of community within the teaching team, driven by a shared purpose. In particular, in creating a safe classroom, Aboriginal educators commented on addressing hurtful or offensive questions that are asked by naive students to set the record straight. Science staff commented on the re-examination of their perceived and actual privileges, and possible preconceived notions regarding First Nations Peoples, as well as addressing the bias of Western Science and their struggle to communicate this with students. Students stated they found the non-confrontational presentation and the facilitation of open discussions on complex emotional topics enlightening. They found the educators to be accessible, passionate, and informative, creating a comfortable environment for sharing personal experiences and engaging in challenging inquiries.

It was observed that students were inspired and motivated to learn through this open critical enquiry, student-centred teaching, constant peer and teacher interaction in class activities and discussions utilising scaffolded materials in approaching two differing epistemologies of Western and Indigenous science; which in itself is a critical innovation and undertaking that students realise they are part of; and which also elicits much interest from students in the program.

The program's impact was most evident in the transformative learning experiences of many students (Mezirow, 2008), as opposed to traditional student feedback metrics. Reading student's final reflections over the last four years has been rewarding for staff, knowing that their work has had a transformative effect on student perspectives. Students reported a broadened perspective on racial privilege, with some students recounting a newfound understanding of societal structures favouring certain racial groups, which shed light on the challenges faced by Indigenous Australians. In addition, some students recognised the need to amplify First Nations voices rather than speaking on behalf of oppressed groups, and the universal relevance of ethical considerations in science. Many students valued the direct engagement with Noongar Educators in class, which not only informed their scientific pursuits but also inspired advocacy for cultural recognition.

In conclusion, while students have engaged with learning critical scientific and academic literacy skills, competencies and academic integrity in this integrated Unit, their exposure to Indigenous Knowledge Systems has been instrumental in fostering a sense of empathy, respect and appreciation for differing epistemological frameworks, thereby enriching students' capacity to collaborate across various disciplinary and cultural fronts.

Persistent Challenges and Considerations

Innovations in epistemologies often encounter resistance, particularly among students and staff hesitant to explore alternative viewpoints and knowledge systems (Bullen & Roberts, 2018). An ongoing challenge is the development of perspectives among students who are less receptive to change. The complex and sometimes contentious issues addressed in the unit, which directly relate to Indigenous knowledges and communities, may challenge students' preconceived notions and push them out of their comfort zones. For instance, debates on topics such as the Voice to Parliament and the WA Heritage Act have provoked mixed reactions. It is

crucial to support students to remain open to new perspectives and consider the beliefs and views of others. This openness is essential for fostering a more inclusive and comprehensive understanding of diverse knowledge systems within the scientific community.

Notably, the computing student cohort often requires additional time to engage with and find relevance in the Indigenous Knowledges content, given their focus on computational studies. Case studies that demonstrate the direct application of IT to environmental issues, data sovereignty, and Indigenous collaboration are instrumental in supporting these students to identify the relevance of cultural perspectives to their future roles.

Knowledge Sharing and Recognition

The program has received recognition and awards for excellence in teaching and curriculum design, highlighting its success and impact within the broader educational community. The significant impact of Integrating Indigenous Science and STEM has been shared with colleagues both locally and nationally (Ramiah et al., 2020; Rohl et al., 2020; Ramiah & Rohl, 2021; Ramiah & Rohl, 2022), informing national research (Cawthorne, 2022) and Australian Indigenous Communities of Practice.

The program has received awards for excellence, including the Australian Awards for University Teaching (AAUT) Citation for Outstanding Contributions to Student Learning. This award recognises teams who have made significant and sustained innovative and impactful contributions to student learning in higher education. It was highlighted by the Australian Council of Deans of Science (Ramiah, Rohl, Kickett, & Blyth, 2020b) as a model for similar programs.

Conclusion

Integrating Indigenous Science into Bachelor of Science courses represents a transformative approach to STEM education, challenging traditional narratives and fostering a more inclusive learning environment. By recognizing Indigenous Knowledge Systems as essential contributors to scientific discourse, universities can humanize STEM education and address global challenges more effectively.

Indigenous Peoples possess a wealth of intergenerational Knowledges and experiences pertaining to science, the environment and ecological relationships. This knowledge presents significant opportunities for its integration into science and natural resource management practices. However, traditional science education approaches have often marginalized Indigenous Knowledges, treating it merely as historic or another facet of ecological understanding within a curriculum framework dominated by Western scientific paradigms. This unit supports the argument that broadening the teaching of science and addressing the discomfort of truth-telling versus traditional science narratives is essential for a transformative pedagogical experience.

Central to this transformation is the recognition and the engagement with discomfort associated with reevaluating the historical applications of science, such as privilege and eugenics, as a crucial aspect of this transformative process. Such critical engagement not only disrupts the entrenched STEM tradition but also challenges the cloak of objectivity and neutrality, calling for a re-evaluation of the nature of science in a broader social and cultural context.

Throughout this integrated unit, students have engaged with critical scientific and academic literacy skills, competencies, and academic integrity. Their exposure to Indigenous Knowledge Systems has been instrumental in fostering empathy, respect, and an appreciation for differing epistemological frameworks. This experience has significantly enriched the capacity of many students to collaborate across various disciplinary and cultural boundaries, ultimately preparing them for more inclusive and interdisciplinary scientific practices.

Although modern scientific knowledge is widely accepted, this science alone is often not sufficient to address complex global issues facing the world (Gadgil, et al., 2021), and Indigenous Science can make a significant contribution. The unit underscores the importance of recognizing Indigenous Knowledge systems as essential contributors to global problem-solving efforts alongside modern scientific knowledge.

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