



OPEN ACCESS

EDITED BY

Hannah F. Rogers,
University of Leeds, United Kingdom

REVIEWED BY

Ying Liang,
Guilin University of Electronic
Technology, China
Alison Bird,
Pacific Geoscience Center, Natural Resources
Canada, Canada

*CORRESPONDENCE

Thomas J. Jones,
✉ thomas.jones@lancaster.ac.uk

RECEIVED 03 March 2025

ACCEPTED 19 May 2025

PUBLISHED 12 June 2025

CITATION

Jones TJ, Williams-Jones G and Nyce H Jr.
(2025) Braiding Indigenous knowledge
systems and Western science through
co-creation and co-teaching.
Front. Earth Sci. 13:1587092.
doi: 10.3389/feart.2025.1587092

COPYRIGHT

© 2025 Jones, Williams-Jones and Nyce. This
is an open-access article distributed under
the terms of the [Creative Commons
Attribution License \(CC BY\)](https://creativecommons.org/licenses/by/4.0/). The use,
distribution or reproduction in other forums is
permitted, provided the original author(s) and
the copyright owner(s) are credited and that
the original publication in this journal is cited,
in accordance with accepted academic
practice. No use, distribution or reproduction
is permitted which does not comply with
these terms.

Braiding Indigenous knowledge systems and Western science through co-creation and co-teaching

Thomas J. Jones ^{1*}, Glyn Williams-Jones ² and
Harry Nyce Jr. ^{3,4}

¹Lancaster Environment Centre, Lancaster University, Lancaster, United Kingdom, ²Centre for Natural Hazards Research, Department of Earth Sciences, Simon Fraser University, Burnaby, BC, Canada, ³Wilp Wilxo'oskwhl Nisga'a Institute, Gitwinksihlkw, BC, Canada, ⁴University of Northern British Columbia, Prince George, BC, Canada

Co-production of Indigenous Knowledge Systems with Western science is increasingly recognised as an important component of education and research. When done correctly, it draws on the strengths of the respective knowledge systems, ensures Indigenous data sovereignty, empowers communities, supports reconciliation, and fosters mutual respect. However, despite these clear benefits and alignment with the United Nations Declaration of the Rights of Indigenous Peoples, few examples, guidance, or frameworks exist, especially in the context of science education. Here, we illustrate how co-designing and co-teaching courses can effectively enhance knowledge systems. We show that students value the weaving of Indigenous Knowledge with science, both within (Westernised) academic settings and during place-based experiential learning. It can deepen connections to Indigenous ways of knowing and provides a source of healing as co-production studies are re-connections to Indigenous history and identity. We conclude by addressing some of the challenges faced and provide some actionable solutions for the global effort needed to decolonise and Indigenise both research and education.

KEYWORDS

reconciliation, knowledge co-production, indigenous knowledge systems, science-based knowledge, rural and remote community, all knowledge is data, co-creation

Highlights

- Students value the weaving of Indigenous Knowledge with science, both within Westernised settings and during place-based learning
- Co-production can deepen connections to Indigenous ways of knowing and support re-connections to Indigenous history and identity
- Actionable solutions are provided for the global effort needed to decolonise and Indigenise both research and education.

1 Introduction

There is growing recognition in Canada and internationally of the importance and value of weaving or braiding diverse knowledge systems in scientific research (e.g., Adams et al., 2014; Cunningham and Mercury, 2023; Jones et al., 2024; Venkatesan et al., 2019) as well as K-12 and post-secondary science education (e.g., Black and Tylianakis, 2024a; Michie et al., 2018; Smythe et al., 2017; Todd et al., 2023). To do this meaningfully, collaborative efforts are required to co-develop research projects and educational courses that respect and leverage the strengths of both knowledge systems (Bartlett et al., 2012). The goal is not to integrate or merge knowledge systems to create a single, unified view, but rather braid or weave the perspectives from the different knowledge systems. As such, the original identity of each system is retained while valuing and respecting the different ways of knowing.

Although most prevalent in the co-creation and implementation of research, globally there is a series of established constructs that exist to weave both Indigenous and non-Indigenous knowledge systems. These concepts, such as *Etuaptmumk*, translated from *Mi'kmaq* as Two-Eyed Seeing (Bartlett et al., 2012; Cirkony et al., 2023), *He awa whiria* which is sometimes referred to as the Braided River approach (Macfarlane and Macfarlane, 2019; Macfarlane et al., 2015; Martel et al., 2022), Both-ways (Ober and Bat, 2007) and *Kūlana Noi'i* (Anolani Alegado et al., 2023; Kūlana Noi'i Working Group, 2021) all help draw on the individual strengths and different perspectives of both knowledge systems. However, even when implementing such constructs, measures and assurances need to be put in place to ensure Indigenous Data Sovereignty (Anderson and Christen, 2013; Jones et al., 2024; Walter and Suina, 2023). Similar to the constructs that exist for drawing on different knowledge systems, a series of frameworks, protocols, and networks exist to support Indigenous Data Sovereignty. These include, the Ownership, Control, Access, Possession principles from Canada (OCAP; Kukutai and Taylor, 2016), the United States Indigenous Data Sovereignty Network (United States Indigenous Data Sovereignty Network, 2024), and the Te Mana Raraunga Indigenous Data Sovereignty Network's Charter (Te Mana Raraunga, 2018) from Aotearoa New Zealand. However, despite these numerous resources which provide excellent starting points, specific guidance and examples for educators on how to implement these practices remains limited (Cirkony et al., 2023; Ma Rhea and Russell, 2012).

In the education context, worldwide there is a strong and increasing desire to Indigenousise programmes by building Indigenous Knowledge into curricula and teaching it alongside Western science (e.g., Black and Tylianakis, 2024a; Cirkony et al., 2023; McKinley et al., 2023). This requires transitioning, at least in part, from colonial education systems through a process of decolonisation that results in lasting structural change. There are many factors driving this important change that are needed for reconciliation (Truth and Reconciliation Commission of Canada, 2015). For example, Indigenous Knowledge provides vital and fundamental insights into ecological protection, environmental stewardship, climate change, and natural hazards (Cámara-Leret and Dennehy, 2019; Cronin et al., 2004; Gilio-Whitaker, 2019; Reyes-García and Benyei, 2019; Wildcat, 2009); all of which are pressing topics for our planet and link to numerous United

Nations Sustainable Development Goals (SDG; United Nations, 2002). Furthermore, the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP; United Nations General Assembly, 2007) imposes an obligation on educators to ensure that teaching and learning is conducted in a manner that is appropriate to Indigenous cultural methods.

A valuable approach to design courses that draws from established frameworks is co-creation—Indigenous and non-Indigenous peoples coming together to create resources and knowledge based upon mutually set priorities and deliverables. Through co-creation, educators and communities not only address knowledge gaps but also foster mutual respect, understanding, and a more holistic approach to scientific inquiry (David-Chavez et al., 2020). However, globally, and especially in the geosciences, there are very few examples of both co-design and co-teaching of an educational course (Bang and Medin, 2010; Dalbotten et al., 2014; Kennedy et al., 2024; McKinley et al., 2023; Smythe et al., 2017). This study fills this gap and explores an innovative approach to geoscience education that blends the rich, contextually grounded and place-based insights of Indigenous Knowledge with the methodologies of Western science. We discuss the impact that co-designing and co-teaching enhanced pedagogy can have on Indigenous communities and individual students. We conclude by addressing some of the challenges faced in knowledge co-production and provide some actionable solutions.

2 Methods

2.1 Positionality statements

We deliberately share our identities and positionalities to make the reader aware of our backgrounds and the perspectives that have shaped this work (e.g., Karhulahti, 2024; McKinley et al., 2023). Thomas J. Jones, the lead author, has a Ph.D. in Volcanology and is currently a Reader in Volcanology and a United Kingdom Research and Innovation Future Leaders Fellow, at Lancaster University, United Kingdom. Glyn Williams-Jones also has a Ph.D. in Volcanology and is a Professor in the Department of Earth Sciences, Simon Fraser University, Canada. Both Thomas and Glyn are of Western European ancestry and their recent work has focused, in part, on understanding the physical evolution of *Sii Aks* volcano, in British Columbia, Canada. Harry Nyce Jr is a faculty member at the *Wilp Wilxo'oskwhl Nisga'a* Institute and a Ph.D. candidate in the Natural Resources and Environmental Studies Graduate Program at the University of Northern British Columbia, Canada. Harry is a member of the Nisga'a and Ts'imsyan Nations and his research focuses on ways to hold space for Indigenous knowledge Systems in all fields of study.

2.2 Course origin and development

The mid-1700s CE eruption of *Sii Aks* (Tseax) volcano in NW British Columbia is the second most recent volcanic eruption in Canada and the *Adaawak* (oral histories) of the Nisga'a Nation suggest that it was responsible for the deaths of up to 2,000 people (Figure 1). The eruption also significantly changed the local

Wil Ksi Baxhl Míhl: Where the Fire Comes Out

Long ago two children were playing down by the river. One child caught a salmon and slit open its back. The child stuck sticks into the salmon's back, set them on fire, and returned the fish to the river. The children were amused to see the salmon swim erratically, smoke rising from its back. The other child caught a salmon and slit open its back, inserted a piece of shale, and put it back into the river. The salmon floated on its side, weighed down by the shale. The children laughed at the struggling fish.

An elder happened upon the scene and warned the children, "Take care what you do. The salmon will curse you and the Creator will respond in kind."

The ground began to tremble and shake. Nature's harmony had been upset. A scout was sent to investigate. From the top of *Gennu'axwt*, he saw smoke and flames and ran to warn the people of their fiery destiny. In panic, some villagers fled up the mountain. Others canoed to the far side of the river but were killed by the lava.

As the people watched the lava flow over their villages, *Gwaxts'agat* (a powerful supernatural being) suddenly emerged to block the lava's advance. For days, *Gwaxts'agat* fought back the lava by blowing on it with its great nose. Finally, the lava cooled and *Gwaxts'agat* retreated into the mountain where it remains to this day.



FIGURE 1

Nisga'a Volcano story - *Wil Ksi Baxhl Míhl: Where the Fire Comes Out* (Joint Nisga'a/BC Parks Committee, 1997; Nisga'a Nation, 2004). Text of one version of the Nisga'a volcano story, reproduced from Nisga'a Nation (2004) and an accompanying piece of Indigenous artwork, reproduced from Joint Nisga'a/BC Parks Committee (1997). See Table 2 for interpreted links to volcanological events and concepts.

environment; notably, *Sii Aks* is Nisga'a for new (*Sii*) water (*Aks*) and the eruption, *Wil Ksi Baxhl Míhl* or 'Where the fire comes out', led to the formation of a new lake (*Sii T'ax*) and displaced *Lisims* (the Nass River) (e.g., Jones et al., 2024; Le Moigne et al., 2022; Williams-Jones et al., 2020).

Given the significant cultural and environmental impact of the volcano, authors Jones and Williams-Jones have been involved in numerous volcanology studies aimed at better understanding the eruption history. During this research, discussions and meetings with members of the Nisga'a Lisims Government (NLG) and the Board of *Wilp Wilxooskwhl Nisga'a* Institute (Nisga'a House of Wisdom; WWNI) identified an interest and need for resource co-creation (Jones et al., 2024). The WWNI is an Indigenous Post-Secondary Institute with a mission to provide equitable access to quality educational programs, courses, and training for Nisga'a citizens (Robinson, 2023; Wilp Wilxooskwhl Nisga'a Institute, 2024). Of particular note, *Wahlin Sim'oogit Hleek*, the late Dr. Joseph Gosnell (a Nisga'a Hereditary Chief, first elected President of the Nisga'a Lisims Government, recipient of the Order of British Columbia, and Companion of the Order of Canada) requested that a course be developed "so students could learn about our history as well as the physical and chemical aspects of volcanology" (University of Northern British Columbia, 2023). Following this direction, starting in 2023 the authors of this study began to design and co-develop a 'Sii Aks Volcano' course, following the Nisga'a Research Protocol. This was done over a series of (online, video) meetings, to co-develop the curriculum with the core objective of teaching both Indigenous Knowledge and volcanology. The co-production of knowledge within the course was centred around

the Nisga'a Volcano story and for the course we ensured that all the relevant Knowledge Keepers and permissions for printed story versions (from school districts) were in place to allow for aspects of the stories to be shared and discussed while ensuring data sovereignty. For example, when one story version was shared orally, this was done by the relevant knowledge keeper, an Elder and member of the family to whom the story belongs. Here, in this publication the version of the story and accompanying artwork are reproduced from previously published government reports (Joint Nisga'a/BC Parks Committee, 1997; Nisga'a Nation, 2004), and thus already in the public domain.

2.3 Survey and interview methods

All students enrolled and auditing the course were asked to complete an anonymous online pre-course survey in the very first 30 min of class on the first day of teaching and similarly an anonymous online post-course survey in the last 30 min of the last class. The set of survey questions can be found in the online supplementary information. The pre-survey was designed to capture basic demographic data, student expectations about the course and motivations for enrolment. The post-survey was designed to capture the level of student satisfaction, the impact the course had on the students and ideas for future improvements. Additionally, one of three Elders who took part as students in the course volunteered to share his opinions about the course; quotes from this conversation are presented below with the Elder's permission.

TABLE 1 Outline of the *Sii Aks* Volcano course, showing the topics covered and the mixture of both Indigenous Knowledge and volcanology science that was distributed and integrated throughout the course.

Day	Topics covered	Indigenous knowledge	Volcanology science
1	Nisga'a Origins, <i>Ayuukhl</i> Nisga'a Volume I	✓	
2	Nisga'a volcano story	✓	✓
	Indigenous knowledge systems	✓	
3	Classifying volcanic eruptions and their landforms		✓
	<i>Sii Aks</i> eruption sequence [lecture]	✓	✓
4	<i>Sii Aks</i> eruption, and its impact on the local people, culture and the environment [field trip]	✓	✓
5	Canadian volcanoes, tectonic setting, magma reservoirs	✓	✓
	Lava flows		✓
6	Magma fragmentation and eruption columns		✓
	Monitoring volcanoes and their hazards		✓

3 Results

3.1 Course structure

The 6-day course ran from July 15 to 20, 2024 and was delivered as an intensive block course between the hours of 9:30 a.m. and 3:30 p.m. local time each day with a 30 min lunch and two 15 min breaks. It was taught equally by all three authors and the course syllabus (Table 1) was approved and formalised by WWNI and University of Northern British Columbia (UNBC) Department of Geography, Earth and Environmental Sciences for the designation 'GEOG 298: *Sii Aks* Volcano'. The course started by introducing students to Nisga'a Ontology, Nisga'a Epistemology, and the multifaceted elements of Nisga'a culture. A Nisga'a Volcano story was then shared orally in-class by an Elder and Knowledge Keeper (Figure 1; Table 2) followed by an introduction to Indigenous Knowledge systems aimed at introducing students to concepts such as Edge Walking and Two-Eyed Seeing, and discussing their strengths and limitations (e.g., Bartlett et al., 2012; Krebs, 1999; Macfarlane and Macfarlane, 2019). This started in-class discussions around bridging different knowledge systems. Following this, on day 3, some volcanology concepts were introduced, and we discussed the great diversity of volcanic eruptions that exist and how this is captured in different classifications and landforms. Drawing on aspects of the Nisga'a *Adaawak*, the *Sii Aks* (Tseax) eruption sequence was then presented in the classroom and on the following day (day 4) all the students participated in a field trip which investigated and discussed the eruption onset, the formation of the volcanic products and the impact on the local environment and resources, examining information and learnings from both the *Adaawak* and volcanology as Dr. Gosnell directed. Back in the classroom, *Sii Aks* was set in the Canadian context and compared with other North American volcanoes and fundamental volcanology science principles were taught on the topics of lava flows, explosive eruptions, monitoring

and hazards (Table 1). A full set of learning objectives can be found in the online supplementary information.

3.2 Nisga'a volcano story

Indigenous Elders have preserved knowledge by passing it down orally including allegorical teachings and cultural wisdom with practical observations, which often emphasise respect, especially for the natural environment (e.g., Mahuika, 2021; Nunn, 2018). The Nisga'a Volcano story is thus central to the co-teaching, co-production and braiding of knowledge systems in this course as these observations provide a framework along with critical information and data with which to interpret past events (Table 2). Through discussions of the volcanic eruption sequence in the classroom and during the field trip, links between the *Adaawak* and current volcanological understanding of the eruption chronology (e.g., Le Moigne et al., 2022) were noted, such as the fact that “the ground began to tremble and shake” possibly suggesting precursory earthquakes and likelihood that the eruption occurred in the mid-late summer due to the presence of pink salmon in *Lisims* and its pink salmon-producing tributaries (Table 2). Notably, all data, be they observational or experimental and collected in a Western science framework or Indigenous Knowledge system, have some level of uncertainty (e.g., Pérez-Díaz et al., 2020). However, these uncertainties can be constrained to enable meaningful and important interpretations.

The assessment for the course was co-created by all instructors and consisted of (i) a reading journal where the students documented and summarised learning from their out of class readings (10% of grade); (ii) take home short answer questions covering the material discussed in class (four in total of equal weighting each contributing 15% to the final course grade) and (iii) a final take home, open book exam contributing 30% to the final

TABLE 2 Mapping elements of the Volcano story *Adaawak* (Figure 1; Nisga'a Nation, 2004) with potential volcanological events. See Le Moigne et al. (2022) and Williams-Jones et al. (2020) for additional information on eruption chronology. Also note that only a select number of publicly available excerpts from one Volcano story are shared here to maintain Indigenous data sovereignty.

Wil Ksi Baxhl Muhl - Indigenous knowledge	Volcanology science
"Long ago two children were playing down by the river. One child caught a salmon and slit open its back"	Spawning season of the pink salmon in Lisims and its pink salmon-producing tributaries is between June and September
"The ground began to tremble and shake for days beforehand"	Earthquakes from magma intrusion preceding eruption
"he saw smoke and flames"	Convective eruption column several kilometres high visible from nearby peak
"Others canoed to the far side of the river but were killed by the lava"	Fatalities due to some people being trapped between the Nass River and the advancing lava
"For days, <i>Gwaxtsagat</i> fought back the lava by blowing on it with its great nose"	Vigorous lava-water interaction as the flow displaced the Nass River northwards

course grade and consisting of fifteen short answer questions and one long answer essay question. Importantly, in keeping with the course ethos, this final essay question, re-printed below, covered aspects of Indigenous Knowledge and volcanology which were continually interwoven into the course teaching material.

Final essay question: "Clearly citing and bridging evidence from the Nisga'a Volcano story (*Adaawak*), physical volcanology, and your field trip observations, discuss how the *Sii Aks* (Tseax) volcanic eruption started, progressed, and interacted with the local environment. The best answers will synthesise topics covered throughout the entire course."

3.3 Student population

A total of 17 students participated in the course, with 16 taking the course for credit and 1 auditing. Student ages were diverse, with students identifying across a spectrum ranging from 18–24 years to 65–74 years. Thirteen students identified as female, two as male, and two as gender diverse. In terms of ethnic or cultural origins, three students reported a North American and/or European origin whereas the majority of the students ($n = 14$) identify with Indigenous origins of which at least three students were Nisga'a Elders. Formal education ranged from current undergraduate students to graduate (Masters and Ph.D.) students and the majority of students (59%) reported as having no formal university-level training in the physical sciences (e.g., maths, engineering, physics, chemistry) and 71% reported as having no formal university-level training in Earth Science.

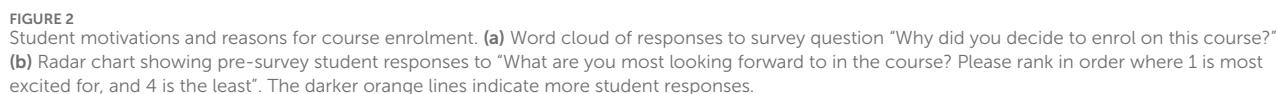
3.4 Student motivations for taking the course

In the pre-course survey, students reported a number of reasons for enrolling in the course with the majority mentioning an interest in learning more about the volcano because "I have never seen it" and "wanted to learn more about the volcano from a Nisga'a history and science lens" given that "my ancestors were part of the catastrophe" (Figure 2a). As a number of students were in the WWNI teacher education program, many noted that this new

information could be "something I can share in my future classroom". Further, students mentioned wanting "a better understanding of the impact to Nisga'a and how it affected our existence post eruption" and seeking to have a deeper "understanding of Nisga'a history and the cultural significance of the Nass Valley". In the pre-course survey, students were also asked to rank four course aspects in order from most excited for (score of 1) to least excited for (score of 4). These included, Indigenous studies/Knowledge (average score of 1.8), the mixture of and co-teaching of volcanology and Indigenous studies (average score of 1.9), fieldwork (average score of 2.9) and volcanology science (average score of 3.4). This shows that the majority of students were most looking forward to learning about Indigenous studies/Knowledge with volcanology co-taught components. However, the students were least looking forward to the pure volcanology science and the fieldwork component (Figure 2b).

3.5 Student course evaluations

In the post-course survey, the students were asked to evaluate the course against three statements: (i) The course met my expectations; (ii) The assessments/assignments were a fair test of my knowledge and ability; and (iii) Overall, I was satisfied by the course. In all cases the majority of students strongly or somewhat agreed with these statements (Figure 3), illustrating that the course delivery and assessments met expectations and were a success. Furthermore, the students were also asked to comment on any strengths of the course, and they noted that "the course did an extremely good job of balancing the two perspectives/worldviews of the indigenous and volcanological bodies of knowledge." Providing evidence that the way we drew on both Indigenous Knowledge and western science was well received, students commented that "Even beyond the split of first days social, later days science, the local perspectives were fluidly incorporated into the topics through the discussions in class." This complements our approach of co-teaching both knowledge systems and not simply dividing the course into two disconnected halves. Furthermore, "the additional knowledge of elders in the class was very powerful in how it complimented and encouraged the knowledge shared by the volcanologists". This highlights the value of local people and respected community members both



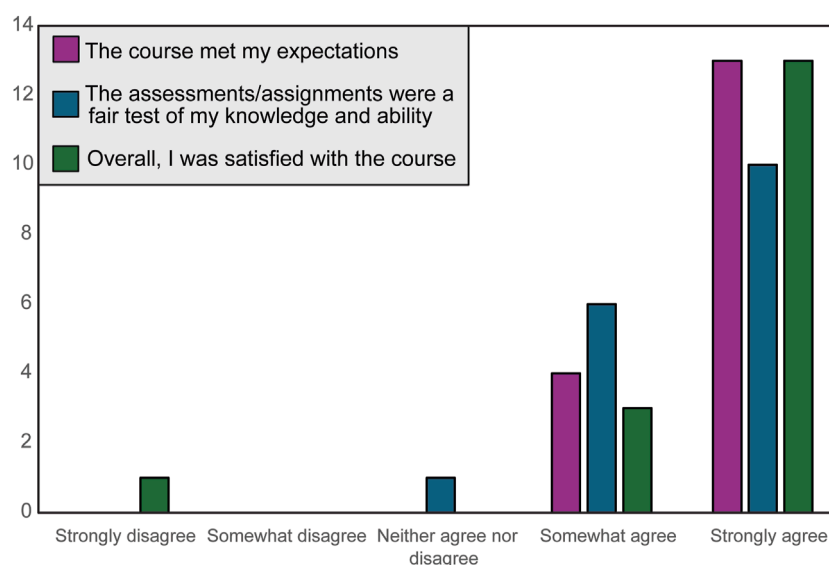


FIGURE 3
Student evaluations of the course. Bar chart of the post-course survey responses to three statements, shown by the three colours. For each question a total number of 17 responses were gathered (n = 17).

attending and contributing to the class and related discussions throughout.

3.6 Interview with Nisga'a elder

Following the course, we interviewed Chief Clifford Azak, an Elder and Knowledge keeper, Hereditary Chief, and former elected member of the Nisga'a Lisims Government. In the context of the impact of the course, Chief Azak stated that “it’s really exciting to think that researchers like yourselves in different fields are going to consider incorporating traditional knowledge and wisdom into research ...it needs to happen in a way that unites us, rather than divides us”. The blending of both science and Indigenous Knowledge was also seen to be able to help address “the gaslighting of the first missionaries that came to our land, who literally brainwashed some of our ancestors into believing that even the history of the lava and the way it’s been portrayed was wrong”. Further, by learning about the current scientific understanding of the volcanic eruption “I think there’s a lot of value there for the Nisga’a that’s going to be really important for them to understand what we all grew up knowing. What the impact was and how our ancestors interpreted that. How that unfolded and why?”

Chief Azak also spoke about the benefit he perceived in offering a course of this type as the co-produced knowledge could also help promote indigenous education since “the term ‘school’ has been [negative], because of the residential schools and day school events and the Canadian Government and how that impacted us, I think this will be able to start to show an exciting side to school and teaching and learning and going into the field and understanding that better” and that “I’d certainly like to see those teachings written in Nisga’a”. The discussion also highlighted the importance of Reconciliation (Truth and Reconciliation Commission of Canada,

2015) to Indigenous people, especially the fact that many modern historians continue to “write us out” by not including “indigenous values, perspectives and the impacts” whereas by studying both the *Adaawak* and volcano science of Sii Aks, “you’ve written us into history”. True reconciliation should include “writing us into history but also looking at the historical perspectives of who we are, and you know, as Indigenous people, we don’t live in the environment, we are the environment.” He also felt it was important to be aware that “Not all of our history is one of, I guess, misfortune. No, in order to exist here, we lived with all of the good and the bad, right, so now we’re going to see how we lived that way, how we existed and thrived in this area”. As a student and learner, but also one of the Knowledge Keepers of the Nisga’a Volcano story, Chief Azak noted that “Our first law is respect and the young people that were disrespecting our food sources caused us to be punished. The second law is to teach. So, I have an obligation to teach what I’ve learned [from the course] so, now I’m going to do that in my own way.”

4 Discussion

4.1 Decolonising or indigenising western science curriculum

The sciences, and particularly the geosciences, have deep-rooted connections to colonial practices disregarding Indigenous Knowledge systems, both historically and in contemporary contexts. The discipline of geoscience emerged and grew significantly during the height of European colonial expansion, when geological surveys and expeditions prioritised the identification and extraction of natural resources to increase colonial wealth (e.g., *Nature*, 1944), frequently at the expense of Indigenous populations and their environments. The legacy of this history continues to shape modern

geosciences, as much of the foundational knowledge accepted today was developed within this framework (e.g., Rogers et al., 2022; Scarlett, 2022). It is thus important to address this through educational initiatives, both within the geosciences and across the sciences more broadly (e.g., Aikenhead and Elliott, 2010). The *Sii Aks* volcano course accomplishes this through its co-creation and co-teaching, but especially with the emphasis placed on holding space for Indigenous Knowledge (e.g., Todd et al., 2023). Furthermore, co-teaching by an Indigenous educator can also provide a role model and mentor to students, potentially increasing student retention (Todd et al., 2023).

As noted earlier, many Indigenous communities use oral traditions to preserve and pass on cultural knowledge and teachings (e.g., Mahuika, 2021; Nunn, 2018) therefore the Nisga'a origins and volcano story (*Adaawak*) was intentionally placed first in the course structure (Table 1), followed by Western volcanology content. Students noted in the post-course survey that they particularly appreciated this structure and that it empowered "*Nisga'a to know their inherent history in a way that they can identify with (as Nisga'a/Indigenous) and within the 'westernized' academic setting*" and as noted by the Elder, Chief Clifford Azak, this presentation of both knowledge sets is "*a way that unites us, rather than divides us*" in our efforts towards Reconciliation. At the end of the course, many students (and Elders) also noted that this is another opportunity for local community members to further support Indigenous language and culture (e.g., Robinson, 2023), possibly by identifying existing words, or creating new ones, which reference meanings in both Western scientific terminology and the Nisga'a language.

4.2 Place and land-based experiential learning

Place-based education (PBE) and experiential learning, in which teaching and learning are centred in place, has long been a fundamental component of Earth and Environmental science education as well as Indigenous teaching practices (e.g., Boyle et al., 2007; Jones and Ehlers, 2021; Kawagley and Barnhardt, 1998; Semken et al., 2017; Wooltorton et al., 2020). As such, PBE is a mutually 'accepted' method that enables the bridging of Western science with Indigenous Knowledge. Further, it may often be the case that many community members have not had the opportunity to visit important cultural areas. In fact, pre-course survey results indicated that students were not overly interested in the proposed fieldwork component of the course (Figure 2b), however, post-survey results show that this was highly valued/appreciated and indeed a highlight of the course. Students noted that the visit to the volcano helped deepen connections to this emotionally sensitive event and enabled them "*to better understand what my ancestors went through, to learn about the history of the people and of the science of the volcano that I can use as part of a land-based learning lesson in my classroom*". More broadly, land- and place-based teaching, which incorporates Indigenous Knowledge, has been shown to empower both Indigenous and non-Indigenous students to further protect their local environment, a key component for future conservation and climate mitigation efforts (e.g., Franzolin et al., 2020; Todd et al., 2023).

4.3 Direct impacts on students

The co-creation and co-delivery of a course that draws on these different knowledge systems not only advances Indigenisation of curriculum and pedagogy, but also has a direct and meaningful impact on students at the individual level. For local Indigenous students, understanding the science associated with significant historical events can provide a stronger connection to their land and their histories. Specifically in our course, students commented that the course enables them to "*better appreciate our lava beds, volcano and history*" and also that the course is an example of a way to "*Empower Nisga'a to know their inherent history in a way that they can identify with (as Nisga'a/Indigenous) and within the 'westernized' academic setting*". Further, these co-produced courses provide local Indigenous students with the opportunity to take a 'physical science' course that may not currently be offered in the schooling system. This can allow students to see Indigenous Knowledge through a different lens and appreciate its unique, individual value, but also the value of braiding knowledge systems. For example, students commented that the course enabled them to "*see our lava beds through a different lens and have a deeper appreciation for the science behind volcanology*". For all students, Indigenous and non-Indigenous, courses that connect the land, science processes, and culture provide a wealth of opportunities for students to share their learnings with others outside of the classroom in their daily lives. Additionally, bringing diverse groups together, and holding safe space for discussions enables individuals to express and debate difficult issues and as one of the students commented "*Understanding our history is very important to moving forward to reconciliation*". Although these quotations and opinions are from the relatively small, predominantly Indigenous, student sample, we contend that the overarching themes apply to other courses that braid such knowledge systems.

4.4 Challenges and potential solutions

As with any new multidisciplinary initiative, the co-production, co-delivery and learning from a joint Indigenous Knowledge and Western science course does not come without challenges. Here, we highlight some of these key challenges and provide a series of actionable solutions. Firstly, for co-design and the weaving of respective knowledge systems to take place, trusting relationships need to be built, typically over long time periods (Jones et al., 2024). Once this relationship is established, mutual priorities for co-creation need to be clearly set (Jones et al., 2024). This ensures that the correct and respectful balance between the different knowledge systems is formed and avoids the Indigenous or the Western science component being effortlessly 'tacked on' to the end, or the formation of a course with two distinct, unconnected halves. Only after relationships are established and mutually agreed priorities set, can course co-design begin.

A course should be made as open and as accessible to all; however in doing this, enrolled students are likely to have a range of knowledge bases, backgrounds and expectations, for example. Further, as both knowledge systems have their own terminology, the rapid exposure to many new concepts and

vocabulary can be a challenge. One way to mitigate this is to impose a course prerequisite, however this can significantly reduce enrolment, especially when the courses are located in small, rural communities. Another solution is to provide extensive pre-course reading materials, ensuring that, where possible, texts are available openly, and not behind a pay-wall. Fieldwork and/or place-based learning, although an excellent pedagogic tool, can limit inclusivity; therefore established approaches such as multisensory engagement, financial support, providing flexibility in access and content delivery, should be implemented to reduce barriers (Giles et al., 2020; John and Khan, 2018; Lawrence and Dowey, 2022; Mol and Atchison, 2019; Stokes et al., 2019). Studies in the field need to address mobility issues of students to generate options for accessible place-based learning. Lastly, during course planning educators need to be mindful of data sovereignty. For example, different oral stories and traditions can belong to different families or houses and there is thus a need to engage with specific groups who have the right to present/share these. To expand the reach and geographical accessibility of a course, new large-scale initiatives, such as massive online open courses (MOOCs) could be considered, in which a recent example has demonstrated the success of braiding knowledge systems (Kennedy et al., 2024).

When bringing together information from different knowledge systems, tensions and concerns can arise. These include concerns that history and stories will be lost, overruled, or 'proved wrong' by science, or that Indigenous Knowledge is presented as the sole factual evidence to topics (Ahdar et al., 2024; Black and Tylianakis, 2024b; 2024a; Jones et al., 2024; Matzke, 2024). Understandably, the synthesising, merging, or integration of such knowledge systems to create a 'single story' is inappropriate and should not be done. Rather, information from each knowledge system should be viewed and treated as different sets of data, all viewed through different lenses/perspectives. All data thus have different uncertainties and these need to be contextualised before interpretations are made. Clearly explaining these expectations for all students and educators at the beginning of each course sets appropriate boundaries and forms a safe place for discussion when appropriately braiding or weaving knowledge.

For any course to build and increase its impact, it needs to be sustained (e.g., run for multiple years) and as such the delivery methods need to be sustainable in the long-term (Jones et al., 2024). This can be a challenge when a course relies on external factors, like the presence of Elders or external scientists/researchers. To bring these people together a short, intense block-style teaching course is best, rather than gradual delivery over weeks to months. However, this is juxtaposed with the time needed for students to learn new concepts and terminology outside of their normal education setting, to deal with the intensity of 'edge-walking' between the different knowledge systems (Beals et al., 2020; Krebs, 1999) and when the oral stories relate to catastrophic or culturally sensitive events, have the time to process related emotions. Thus, these braided courses should ideally be taught over a longer time frame (e.g., over months), and the reliance on external scientists could be reduced by Indigenous educators delivering the entire course. However, we recognise that not all Indigenous communities and institutions will have the capacity and resources to support such efforts. Diverse funding streams

could support these efforts, however, as outlined by Jones et al. (2024), the funding should ideally support long-term (i.e., multiple year) projects to allow team members to build relationships and trust. Furthermore, eligibility must extend to Indigenous scholars in the broadest sense and not be restricted to Western institutions.

5 Conclusion

In this study, we have shown that the co-design and co-delivery of an educational course can effectively, and equitably, teach Indigenous Knowledge with western science. Such an approach is needed to address global efforts to decolonise, Indigenise and refresh curricula; it is also a critically important step forward in efforts towards Reconciliation. Furthermore, co-designing and co-teaching a course aligns with the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP; United Nations, 2007) which imposes an obligation on educators to ensure that teaching and learning is conducted in a manner that is appropriate to Indigenous methods. Through our experience, we have shown that these co-produced courses and the processes of co-created curricula itself can foster mutual respect and understanding across different knowledge systems, empower Indigenous students and strengthen community connections to their history, protocol, and language. Lastly, we addressed the challenges that exist when co-creating and co-teaching a course and provide actionable solutions that can ensure long-term success, while retaining place-based learning, ensuring data sovereignty, and delivering meaningful educational outcomes.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Wilp Wilxooskwhl Nisga'a Institute Board. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

TJ: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review and editing. GW-J: Conceptualization, Data

curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review and editing. HN: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review and editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. Thomas J. Jones acknowledges funding from a United Kingdom Research and Innovation (UKRI) Future Leaders Fellowship (MR/W009781/1) and Lancaster University. Glyn Williams-Jones acknowledges funding from the Natural Sciences and Engineering Research Council of Canada Discovery program (RGPIN-2023-04284).

Acknowledgments

The authors thank all the participants of the 2024 *Sii Aks* Volcano course, the WWNI and the broader Nisga'a community for enthusiastically supporting research and project co-development over many years. We also thank the two reviewers whose constructive comments helped improve this paper.

References

- Adams, M. S., Carpenter, J., Housty, J. A., Neasloss, D., Paquet, P. C., Service, C., et al. (2014). Toward increased engagement between academic and indigenous community partners in ecological research. *Ecol. Soc.* 19 (3), art5. doi:10.5751/ES-06569-190305
- Ahdar, R., Boyd, B., Chaudhuri, A., Clements, K. D., Cooper, G., Elliffe, D., et al. (2024). World science and indigenous knowledge. *Science* 385 (6705), 151–152. doi:10.1126/science.ado6679
- Aikenhead, G. S., and Elliott, D. (2010). An emerging decolonizing science education in Canada. *Can. J. Sci. Math. Technol. Educ.* 10 (4), 321–338. doi:10.1080/14926156.2010.524967
- Anderson, J., and Christen, K. (2013). “Chuck a copyright on it”: dilemmas of digital return and the possibilities for traditional knowledge licenses and labels. *Mus. Anthropol. Rev.* 7 (1–2), 105–126.
- Anolani Alegado, R., Hintzen, K. D., Tamanaha, M., Asuncion, B., and Bottjer-Wilson, D. (2023). “Kūlana Noi'i: a kanaka 'ōiwi-centered indigenist axiology for conducting research with communities,” in *Ignite: a decolonial approach to higher education through space, place and culture*. Editors L. M. Pipe, and J. T. Stephens (Wilmington, MA: Vernon Press), 147–175.
- Bang, M., and Medin, D. (2010). Cultural processes in science education: supporting the navigation of multiple epistemologies. *Sci. Educ.* 94 (6), 1008–1026. doi:10.1002/sce.20392
- Bartlett, C., Marshall, M., and Marshall, A. (2012). Two-Eyed Seeing and other lessons learned within a co-learning journey of bringing together indigenous and mainstream knowledges and ways of knowing. *J. Environ. Stud. Sci.* 2 (4), 331–340. doi:10.1007/s13412-012-0086-8
- Beals, F., Kidman, J., and Funaki, H. (2020). Insider and outsider research: negotiating self at the edge of the emic/etic divide. *Qual. Inq.* 26 (6), 593–601. doi:10.1177/1077800419843950
- Black, A., and Tylaniakis, J. M. (2024a). Teach Indigenous knowledge alongside science. *Science* 383 (6683), 592–594. doi:10.1126/science.adi9606
- Black, A., and Tylaniakis, J. M. (2024b). Vitalism in New Zealand science education—response. *Science* 385 (6705), 152–153. doi:10.1126/science.ado9278
- Boyle, A., Maguire, S., Martin, A., Milsom, C., Nash, R., Rawlinson, S., et al. (2007). Fieldwork is good: the student perception and the affective domain. *J. Geogr. High. Educ.* 31 (2), 299–317. doi:10.1080/03098260601063628
- Cámara-Leret, R., and Dennehy, Z. (2019). Information gaps in indigenous and local knowledge for science-policy assessments. *Nat. Sustain.* 2 (8), 736–741. doi:10.1038/s41893-019-0324-0
- Cirkony, C., Kenny, J., and Zandvliet, D. (2023). A two-eyed seeing teaching and learning framework for science education. *Can. J. Sci. Math. Technol. Educ.* 23 (2), 340–364. doi:10.1007/s42330-023-00276-z
- Cronin, S. J., Gaylord, D. R., Charley, D., Alloway, B. V., Wallez, S., and Esau, J. W. (2004). Participatory methods of incorporating scientific with traditional knowledge for volcanic hazard management on Ambae Island, Vanuatu. *Bull. Volcanol.* 66 (7), 652–668. doi:10.1007/s00445-004-0347-9
- Cunningham, C., and Mercury, M. (2023). Coproducing health research with Indigenous peoples. *Nat. Med.* 29 (11), 2722–2730. doi:10.1038/s41591-023-02588-x
- Dalbotten, D., Ito, E., Myrbo, A., Pellerin, H., Greensky, L., Howes, T., et al. (2014). NSF-OEDG Manoomin Science Camp Project: a model for engaging American Indian students in science, technology, engineering, and mathematics. *J. Geoscience Educ.* 62 (2), 227–243. doi:10.5408/12-408.1
- David-Chavez, D. M., Valdez, S., Estevez, J. B., Meléndez Martínez, C., García, A. A., Josephs, K., et al. (2020). Community-based (rooted) research for regeneration: understanding benefits, barriers, and resources for Indigenous education and research. *AlterNative* 16 (3), 220–232. doi:10.1177/1177180120952896
- Franzolin, F., García, P. S., and Bizzo, N. (2020). Amazon conservation and students' interests for biodiversity: the need to boost science education in Brazil. *Sci. Adv.* 6 (35), eabb0110. doi:10.1126/sciadv.abb0110
- Giles, S., Jackson, C., and Stephen, N. (2020). Barriers to fieldwork in undergraduate geoscience degrees. *Nat. Rev. Earth Environ.* 1, 77–78. doi:10.1038/s43017-020-0022-5
- Gilio-Whitaker, D. (2019). *As long as grass grows: the indigenous fight for environmental justice, from colonization to standing rock*. Boston, MA: Beacon Press.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/feart.2025.1587092/full#supplementary-material>

- John, C. M., and Khan, S. B. (2018). Mental health in the field. *Nat. Geosci.* 11, 618–620. doi:10.1038/s41561-018-0219-0
- Joint Nisga'a/BC Parks Committee (1997). *Anhluut'ukwim La xmihl angwing'asankwhl Nisga'a Nisga'a memorial lava bed park master plan*.
- Jones, T. J., and Ehlers, T. A. (2021). Using benchtop experiments to teach dimensional analysis and analogue modeling to graduate geoscience students. *J. Geoscience Educ.* 69 (3), 313–322. doi:10.1080/10899995.2020.1855040
- Jones, T. J., Nyce, H., Le Moigne, Y., Williams-Jones, G., and Nyce, D. (2024). Rethinking natural hazards research and engagement to include co-creation with Indigenous communities. *NPJ Nat. Hazards* 1, 34. doi:10.1038/s44304-024-00034-7
- Karhulahti, V.-M. (2024). Positionality statements in science. *Open Res. Eur.* 4, 62. doi:10.12688/openreseurope.17058.2
- Kawagley, A. O., and Barnhardt, R. (1998). Education indigenous to place: western science meets native reality. *ERIC Clgh. Rural Educ. Small Sch.*
- Kennedy, B., Engel, K., Davidson, J., Tapuke, S., Hikuroa, D., Martin, T., et al. (2024). Incorporating science communication and bicultural knowledge in teaching a blended volcanology course. *EGU sphere*. doi:10.5194/egusphere-2024-2512
- Krebs, N. (1999). *Edgewalkers: defusing cultural boundaries on the new global frontier*. (Far Hills, NJ: New Horizon Press).
- Kukutai, T., and Taylor, J. (2016). "Indigenous data sovereignty," in *Indigenous data sovereignty*. Editors T. Kukutai, and J. Taylor (Canberra, Australia: Australian National University Press), 38. doi:10.22459/caep38.11.2016
- Kulana Noi'i Working Group (2021). *Kulana Noi'i v. 2*. Honolulu. Available online at: https://seagrant.soest.hawaii.edu/wp-content/uploads/2021/09/Kulana-Noi-i-2.0_LowRes.pdf.
- Lawrence, A., and Dowey, N. (2022). Six simple steps towards making GEES fieldwork more accessible and inclusive. *Area* 54 (1), 52–59. doi:10.1111/area.12747
- Le Moigne, Y., Williams-Jones, G., Vigouroux, N., and Russell, J. K. (2022). Chronology and eruption dynamics of the Historic~1700 CE eruption of Tseax volcano, British Columbia, Canada. *Front. Earth Sci.* 10. doi:10.3389/feart.2022.910451
- Macfarlane, A., and Macfarlane, S. (2019). Listen to culture: Māori scholars' plea to researchers. *J. R. Soc. N. Z.* 49, 48–57. doi:10.1080/03036758.2019.1661855
- Macfarlane, S., Macfarlane, A. H., and Gillon, G. (2015). "Sharing the food baskets of knowledge: creating space for a blending of streams," in *Sociocultural realities: exploring new horizons*. Editors A. H. Macfarlane, S. Macfarlane, and M. Webber (Christchurch, New Zealand: Canterbury University Press), 52–67.
- Mahuika, N. (2021). *Rethinking oral history and tradition: an indigenous perspective*. *Rethinking oral history and tradition: an indigenous perspective*. Oxford University Press. doi:10.1093/oso/9780190681685.001.0001
- Ma Rhea, Z., and Russell, L. (2012). The invisible hand of pedagogy in Australian Indigenous studies and Indigenous education. *Aust. J. Indig. Educ.* 41 (1), 18–25. doi:10.1017/jie.2012.4
- Martel, R., Shepherd, M., and Goodyear-Smith, F. (2022). He awa whiria—a "Braided River": an indigenous māori approach to mixed methods research. *J. Mix. Methods Res.* 16 (1), 17–33. doi:10.1177/1558689820984028
- Matzke, N. J. (2024). Vitalism in New Zealand science education. *Science* 385 (6705), 152. doi:10.1126/science.ad6728
- McKinley, C. C., Showalter, G. M., Crofoot, T. L., and Stone, K. K. (2023). Systematic evaluation of geoscience education programs that are designed for Indigenous students, or use Traditional Knowledge. *J. Geoscience Educ.* 71 (3), 428–441. doi:10.1080/10899995.2022.2112491
- Michie, M., Hogue, M., and Rioux, J. (2018). The application of both-ways and two-eyed seeing pedagogy: reflections on engaging and teaching science to post-secondary indigenous students. *Res. Sci. Educ.* 48 (6), 1205–1220. doi:10.1007/s11165-018-9775-y
- Mol, L., and Atchison, C. (2019). Image is everything: educator awareness of perceived barriers for students with physical disabilities in geoscience degree programs. *J. Geogr. High. Educ.* 43 (4), 544–567. doi:10.1080/03098265.2019.1660862
- Nature (1944). Colonial geological surveys. *Nature*, 153–582. doi:10.1038/153582b0
- Nisga'a Nation (2004). *Laxmihl - 2002/2003 annual report. Nisga'a final agreement implementation reports*. (New Aiyansh, BC). Available online at: <https://www.nisgaanation.ca/wp-content/uploads/2024/07/NLG2003AR.pdf>.
- Nunn, P. (2018). *The edge of memory: ancient stories, oral tradition and the post-glacial world*. London, United Kingdom: Bloomsbury Publishing.
- Ober, R., and Bat, M. (2007). Paper 1: both-ways: the philosophy. *Ngoonjook A J. Aust. Indig. Issues* 31, 64–86.
- Pérez-Díaz, L., Alcalde, J., and Bond, C. E. (2020). Introduction: handling uncertainty in the geosciences: identification, mitigation and communication. *Solid Earth*. 11 (3), 889–897. doi:10.5194/se-11-889-2020
- Reyes-García, V., and Benyei, P. (2019). Indigenous knowledge for conservation. *Nat. Sustain.* 2 (8), 657–658. doi:10.1038/s41893-019-0341-z
- Robinson, R. (2023). Indigenous post-secondary institutes in British Columbia, Canada: exemplars of indigenous control over indigenous education. *Can. J. Educ./Revue Can. de l'éducation* 46 (2), 386–411. doi:10.53967/cje-rce.5739
- Rogers, S. L., Lau, L., Dowey, N., Sheikh, H., and Williams, R. (2022). Geology uprooted! Decolonising the curriculum for geologists. *Geosci. Commun.* 5 (3), 189–204. doi:10.5194/gc-5-189-2022
- Scarlett, J. P. (2022). The harmful legacy of colonialism in natural hazard risk. *Nat. Commun.* 13 (1), 6945. doi:10.1038/s41467-022-34792-7
- Semken, S., Ward, E. G., Moosavi, S., and Chinn, P. W. U. (2017). Place-based education in geoscience: theory, research, practice, and assessment. *J. Geoscience Educ.* 65 (4), 542–562. doi:10.5408/17-276.1
- Smythe, W., Hugo, R. C., and McAllister, S. (2017). Incorporation of traditional knowledge into geoscience education: an effective method of Native American instruction. *J. Sustain. Educ.* 14. Available online at: https://www.susted.com/wordpress/content/incorporation-of-traditional-knowledge-into-geoscience-education-an-effective-method-of-native-american-instruction_2017_06/.
- Stokes, A., Feig, A. D., Atchison, C. L., and Gilley, B. (2019). Making geoscience fieldwork inclusive and accessible for students with disabilities. *Geosphere* 15 (6), 1809–1825. doi:10.1130/GES02006.1
- Te Mana Raraunga (2018). Principles of Māori data sovereignty (Brief #1). Available online at: <https://www.temanararaunga.maori.nz/s/TMR-Maori-Data-Sovereignty-Principles-Oct-2018.pdf> (Accessed November 6, 2024).
- Todd, W. F., Towne, C. E., and Clarke, J. B. (2023). Importance of centering traditional knowledge and Indigenous culture in geoscience education. *J. Geoscience Educ.* 71 (3), 403–414. doi:10.1080/10899995.2023.2172976
- Truth and Reconciliation Commission of Canada (2015). Honouring the truth, reconciling for the future - summary of the final report of the truth and reconciliation commission of Canada. Available online at: https://ehprnh2mwo3.exactdn.com/wp-content/uploads/2021/01/Executive_Summary_English_Web.pdf.
- United Nations (2002). *Report of the world summit on sustainable development*. Johannesburg, South Africa. Available online at: <https://digitallibrary.un.org/record/478154.pdf>.
- United Nations (General Assembly) (2007). United Nations declaration of the rights of indigenous peoples. Available online at: https://www.un.org/development/desa/indigenouspeoples/wp-content/uploads/sites/19/2018/11/UNDRIP_E_web.pdf.
- United States Indigenous Data Sovereignty Network (2024). United States indigenous data sovereignty network. Available online at: <https://usindigenousandatanetwork.org> (Accessed November 6, 2024).
- University of Northern British Columbia (2023). New volcano course advances Indigenous. Available online at: <https://www.unbc.ca/our-stories/story/new-volcano-course-advances-indigenization> (Accessed November 6, 2024).
- Venkatesan, A., Begay, D., Burgasser, A. J., Hawkins, I., Kimura, K., Maryboy, N., et al. (2019). Towards inclusive practices with indigenous knowledge. *Nat. Astron.* 3 (12), 1035–1037. doi:10.1038/s41550-019-0953-2
- Walter, M., and Suina, M. (2023). "Indigenous data, indigenous methodologies and indigenous data sovereignty," in *Educational research practice in southern contexts: recentring, reframing and reimagining methodological canons*. Editors S. Swartz, N. Singal, and M. Arnot (London: Taylor & Francis), 207–220.
- Wildcat, D. R. (2009). "Red alert!: saving the planet with indigenous knowledge," in *Lakewood*. (Lakewood, CO: Fulcrum Publishing). Available online at: <https://www.fulcrumbooks.com/product-page/red-alert>.
- Williams-Jones, G., Barendregt, R. W., Russell, J. K., Le Moigne, Y., Enkin, R. J., and Gallo, R. (2020). The age of the Tseax volcanic eruption, British Columbia, Canada. *Can. J. Earth Sci.* 57 (10), 1238–1253. doi:10.1139/cjes-2019-0240
- Wilp Wilxooskwhl Nisga'a Institute (2024). Wilp Wilxooskwhl Nisga'a Institute - mission statement. Available online at: <https://wni.bc.ca/about/mission-statement/> (Accessed November 6, 2014).
- Wooltorton, S., Collard, L., Horwitz, P., Poelina, A., and Palmer, D. (2020). Sharing a place-based indigenous methodology and learnings. *Environ. Educ. Res.* 26 (7), 917–934. doi:10.1080/13504622.2020.1773407