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A Two-Eyed Seeing Teaching and Learning Framework for Science Education

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Abstract Worldwide, education jurisdictions are looking for authentic ways to address First Nations perspectives in the K-12 curriculum, including science education. At the same time, there have been ongoing efforts to integrate authentic and engaging approaches to teaching science, including those that are student-centred, inquiry-based, multimodal, and linked to meaningful contexts. Both goals may be realised through the principle of Two-Eyed Seeing (TES), which seeks to integrate the strengths of Indigenous ways of knowing with one eye, and Western ways of knowing with the other eye, for the benefit of all students. This theoretical paper presents a Two-Eyed Seeing for Science Education (TESSE) Framework, which brings together two pedagogical models. One is from a contemporary science perspective, the *5Es* representation-rich inquiry approach, which scaffolds authentic student-centred conceptually focused learning experiences. The other is from an Indigenous perspective, the *8 Aboriginal Ways of Learning, which* illustrates different ways of knowing—many of which are familiar with First Peoples across the world (e.g., place-based, visual, holistic). The TESSE Framework aims to act as a strengths-based interface between the two knowledge systems to support a culturally responsive approach to teaching and learning science. It is designed to support meaningful connections through curriculum and pedagogy in ways that are contextually relevant to place. Through empirical investigation and in collaboration with local communities, the Framework has the potential to inform current approaches to science education in schools and universities and provide a pathway towards decolonisation and reconciliation.

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Résumé Partout dans le monde, les instances éducatives cherchent des moyens concrets pour inclure les perspectives des Premières Nations dans le programme d'études de la maternelle à la 12e année, y compris dans l'enseignement des sciences. Parallèlement, des efforts sont faits pour intégrer des approches authentiques et attrayantes à l'enseignement des sciences, notamment celles qui sont centrées sur l'élève, qui sont fondées sur l'enquête, qui sont plurimodales et qui sont mises en œuvre dans des contextes enrichissants. Ensemble, ces deux objectifs peuvent être atteints par le biais de l'approche à double perspective (« Two Eyed Seeing » en anglais), qui vise à intégrer les forces des modes de savoir autochtones « perçus avec un œil », et les meilleurs aspects des systèmes de connaissance occidentaux « discernés avec l'autre œil », et ce, dans l'intérêt de tous les élèves. Cet article théorique présente un cadre fondé sur une approche à double perspective pour l'enseignement des sciences (ADPES), qui réunit deux modèles pédagogiques. D'une perspective scientifique contemporaine, l'approche fondée sur l'enquête des 5E (entreprendre, explorer, expliquer, élaborer, évaluer), riche en représentations, permet d'échafauder des expériences d'apprentissage véritables centrées sur l'élève et axées sur les concepts. D'un point de vue autochtone, les huit modes d'apprentissage autochtones montrent différentes façons d'acquérir le savoir, dont plusieurs sont familières aux premiers peuples du monde entier (par exemple, celles fondées sur le lieu, la manière visuelle, globale, etc.). Le cadre basé sur l'ADPES a pour but de servir d'interface entre les différents systèmes de connaissances, en s'appuyant sur les points forts, afin de soutenir une approche de l'enseignement et de l'apprentissage des sciences qui tient compte des spécificités culturelles. Il est conçu pour favoriser l'établissement de liens valables par le biais du programme d'études et de la pédagogie, selon des modalités pertinentes au milieu. Grâce à des recherches empiriques et à la collaboration avec les collectivités locales, le cadre peut orienter les approches actuelles de l'enseignement des sciences dans les écoles et les universités et fournir une voie vers la décolonisation et la réconciliation.

Keywords Culturally responsive science education · Two-Eyed Seeing · Indigenous sciences · Nature of science · Inquiry-based learning and teaching · Representations

Introduction

Worldwide, there is an increasing call to incorporate First Nations perspectives in K-12 school curriculum. This is in part due to the influence of the UN Declaration of the Rights of Indigenous Peoples, where educators have a professional obligation to ensure the rights of all Indigenous peoples, which can be achieved by including First Nations perspectives into their teaching (United Nations General Assembly (UNGS), 2007). This rights-based agenda requires the transition from colonial education systems to postcolonial and globalised approaches that recognise the importance of the knowledges and wisdoms of Indigenous peoples and local communities within education (Anderson & Rhea, 2018). Countries such as Australia, Canada, and New Zealand have enacted policies through their teacher qualification standards and curricula that require educators to understand and include First Nations ways of knowing and being to support reconciliation (e.g., Australian Institute for Teaching and School Leadership, 2022; British Columbia Teacher's Council, 2019).

In science education, the inclusion of First Nations perspectives raises concerns, two of which we highlight in this paper:

1. The perception that Eurocentric school science approaches to teaching and learning are at odds with Indigenous ways of teaching and learning.

2. The fact that most science educators at all levels, primary, secondary, and tertiary are typically educated through the Eurocentric science perspective. Moreover, most do not have an Indigenous background so are uncertain of how to teach in this space respectfully and meaningfully (Anderson & Rhea, 2018).

In regard to the first concern, the authors argue that the teacher-centred, textbook-driven, and transmissive approaches to science education are not only at odds with First Nations approaches, but also with those espoused by contemporary science education research (e.g., Harlen & Bell, 2010; Lyons, 2006; Osborne & Dillon, 2010). Such transmissive approaches have remained largely unchanged since the 1950s (Harlen & Bell, 2010). Consequently, students generally associate science with memorising disconnected and irrelevant facts and terminology, and as a single method for understanding the world (American Association for the Advancement of Science [AAAS], 1989; Lyons, 2006; Schweingruber et al., 2012).

The impact is profound. It contributes to students' disengagement, their lack of understanding of the nature of science and scientific concepts, and their inability to understand how science relates to their lives or their futures (AAAS, 1989; Harlen & Bell, 2010; Lyons, 2006). Governments have reported for decades a consistent decline in student engagement with Science, Technology, Engineering, and Mathematics (STEM) during their transition from primary to secondary school (AAAS, 1989; European Commission, 2007; Freeman et al., 2015). This impact is more pronounced for students from nondominant communities who do not identify or engage with STEM disciplines (Kayumova & Dou, 2022). Osborne and Dillon (2010) state that the overwhelming conclusion is that school science, as described above, has failed.

Over the last few decades, there have been ongoing efforts to integrate more authentic and engaging approaches to teaching and learning school science, including those that are student-centred, inquiry based, multimodal, and explore meaningful contexts (e.g., Blades & McIvor, 2017; Cirkony et al., 2022; Duschl & Grandy, 2013). Globally, current policy directions in science education focus on scientific literacy, which emphasises students as reflective citizens who act through high-level engagement with ideas of science and science-related issues (Organisation for Economic Cooperation and Development [OECD], 2019). Future directions elaborate on the idea of *science identity*, with:

> …young people achieving a meaningful connection with science, feeling that science is 'for me', finding science to be useful and relevant to their everyday life, experiencing science as valuing and inclusive of diverse people and experiences and using science to challenge social and environmental inequalities (OECD, 2020, p. 12).

According to the OECD (2020), science identity is strongly linked to social justice, and is considered to be fundamental to science learning and achievement, and as important as acquiring knowledge and competencies.

These directions are reflective of diverse humanistic approaches to science education over the past few decades (e.g., science-technology-society-environment, teaching through socio-scientific issues, culturally responsive science education) (Klopfer & Aikenhead, 2022). These approaches engage more students, particularly those who would otherwise avoid science, by demonstrating how science is relevant to their lives and to society in general (Klopfer & Aikenhead, 2022). These directions illustrate that "(c)ontemporary science is moving towards a more holistic vision of nature, in accordance with Indigenous thought" (First Nations Education Steering Committee [FNESC], 2016, p. 7). Therefore, in response to the first concern, we argue that these reforms in science education are consistent with Indigenous ways of teaching and learning.

The second, long-standing concern stems from the question: "How can science teachers enable all students to study a Western scientific way of knowing and, at the same time, respect and access the ideas, beliefs, and values of non-Western cultures?" (Snively & Corsiglia, 2001, p. 24). Addressing this question requires the recognition that "[a]ll science learning can be understood as cultural" (National Research Council, 2012, p. 284), where culture is reflected in peoples' and communities' identities through their ways of being, knowing, and relating to the world (i.e., onto-epistemology) (Kayumova & Dou, 2022).

Educators, therefore, need to unpack the cultural philosophies underpinning Western science and challenge the assumption that there is a single universal way of knowing and doing science. In short, there is a need to decolonise science education.

The second concern is further confounded by the fact that most students, both Indigenous and non-Indigenous, understanding of the world is often at odds with scientific thinking (Aikenhead & Elliott, 2010). However, for Indigenous students, scientific concepts may also be at odds with cultural practices at home or in their communities. Thus, the role of the teacher is not only crucial in learning science (Osborne & Dillon, 2010), but also in addressing other perspectives in constructive and respectful ways (Rhea & Russell, 2012). Teachers must develop appropriate content knowledge and pedagogical practices (Aikenhead & Elliott, 2010; Anderson & Rhea, 2018) relevant to their local contexts and communities (Ogawa, 1995). They need to understand and support their students to engage in and through multiple ways of knowing (Bang & Medin, 2010), while recognising common ground. To do this well, teachers need guidance to avoid knowledge dominance or assimilation in their efforts to decolonise and indigenise school science (Hatcher et al., 2009; Reid et al., 2021).

Therefore, in response to the second concern, we argue the need for significant guidance and resources to support educators not only to integrate appropriate content, but also to understand the processes and purposes of different knowledge systems and how they might be brought together to improve the teaching and learning of science.

While there are several frameworks discussed in the literature designed to bring together Indigenous and Eurocentric knowledge systems or *ways of coming to know* (e.g., Both Ways, Kaupapa Māori, Two-Eyed Seeing) (Hatcher et al., 2009; Levac et al., 2018; Ober & Bat, 2007), advice and support for teachers on how to implement these practices remains limited (Rhea & Russell, 2012). Moreover, there are few contextually relevant resources designed specifically for science educators. According to Aikenhead and Elliott (2010), specific challenges are associated with the articulation of Indigenous knowledges for school science, the production and distribution of resources to support teachers, and the development of teachers' professional capacities to teach the curriculum's Indigenous knowledge to all students.

Given the long-standing calls for guided inquiry-based approaches in science education (e.g., Dewey, 1910/1990; Deboer, 2006; Eberback & Hmelo-Silver, 2015; Harlen & Bell, 2010), some jurisdictions have adapted the *5Es* constructivist model to support teachers and learners of science. First introduced in the USA in the 1980s, Bybee et al.'s (2006) 5Es has since been adopted around the globe. The model scaffolds teaching and learning through five iterative phases: Engage, Explore, Explain, Elaborate, and Evaluate. Each phase builds on the other to support students to gradually build their understanding with the guidance of the teacher, in contrast to transmissive approaches.

The 5Es model has been adapted to accommodate First Nations perspectives. For example, the Canadian 7Es model is an extension of the 5Es, by inclusion of *Environment* and *Elders* (FNESC, 2016). This ensures lessons relate to the local environment to build an appreciation of connectedness and a sense of place, with direct engagement with Community members. The 7Es model promotes traditional ways of teaching and learning (e.g., guest speakers, guided-labs, field-trips, formative assessment), and provides guidance for the development of lessons and units (FNESC p. 19). It is further supported by a framework for designing Indigenous science resources, which foregrounds: Indigenous voices, languages, and diversity, protocols, relationships with the land, and ways of teaching and learning (FNESC, 2016).

In Australia, the Primary Connections project has developed an Indigenous Perspective Framework to support the 5Es inquiry approach (Primary Connections, n.d.). The framework is guided by six key concepts: cultural diversity, relationships and partnerships, quality teaching and learning, students' and teachers' worldviews, and curriculum. Through these concepts, primary science units were developed in collaboration with Aboriginal and Torres Strait Islander groups, cultural consultants, Indigenous education and linguistic experts, and other stakeholders.

Both these examples involve consultation with Elders and other knowledgeable community members to connect science activities and traditional knowledge. Both also emphasise the need for educators to connect with other knowledgeable community members, and draw on authentic and place appropriate cultural resources. Notably, while these two examples support the inclusion of First Nations perspectives in science education and provide a practical entry point for science educators, neither consider the *common ground* between contemporary science approaches and First Nations approaches to teaching and learning science, nor the 'complementarity' of both perspectives in understanding the natural world.

In this article, we focus on both common ground and complementarity through a framework designed to guide science educators to bring together the strengths of contemporary and Indigenous sciences to support teaching and learning in ways that are contextually relevant to place.

Throughout this article, the terms *Aboriginal*, *First Nations*, and *Indigenous* are considered synonymous, and are used as they appear in the literature. The terms *Western science*, *modern science*, *Western modern science*, and *Eurocentric science* are also considered synonymous and are used as they appear in the literature and are meant to reflect the global scientific system in practice today. The term *contemporary science* is also used synonymously, with the intent of acknowledging the global scientific system in practice today. *Western science* is considered the dominant science in the world, and *Indigenous sciences* are understood as interpretations of nature from a particular cultural perspective (Ogawa, 1995; Snively & Corsiglia, 2001).

Purpose

In this article, we draw on the principle of Two-Eyed Seeing (Bartlett et al., 2012; Hatcher et al., 2009) to propose a Two-Eyed Seeing for Science Education (TESSE) Framework. The TESSE Framework brings together pedagogical models for teaching and learning that acknowledges the strengths of both First Nations and contemporary science perspectives.

From a contemporary science perspective, the TESSE Framework adapts the 5Es model (Bybee et al., 2006) to support conceptual learning through the explicit use of student-generated multimodal representations (Kenny & Cirkony, 2018a, b). From a First Nations perspective, we draw on the *8 Aboriginal Ways of Learning* (Regional Aboriginal Education Team [RAET], 2019; Yunkaporta, 2009), which introduces Indigenous ways of teaching and learning, many which are familiar across the globe.

We argue that, by integrating the strengths of both perspectives, the TESSE Framework acts as an interface between two types of knowledge systems to support a culturally responsive approach to teaching and learning school science. The Framework aims to strengthen the links between contemporary science and Indigenous sciences, and support teachers to make meaningful connections through pedagogy and content in ways that are contextually relevant to place—while providing a pathway towards reconciliation.

Following this introduction and purpose, the remainder of this paper is structured into five sections. We provide some background on culturally responsive science education, outline the principle of Two-Eyed Seeing, and describe the two teaching models representing the contemporary and Indigenous perspective. We then introduce the TESSE Framework and consider its theoretical potential to inform current approaches to teaching science in schools and universities. We conclude with some considerations for further research on and validation of TESSE in classrooms through its implementation, co-design, and refinement in different education jurisdictions.

Background

Culturally Responsive Science Education

One of the impacts of colonialism is that Eurocentric ways of generating knowledge dominated over Indigenous ones (Cajete, 2000; Shipley & Williams, 2019). Since the nineteenth century, when science first became embedded in school curriculum (Deboer, 2006), most jurisdictions focused on Eurocentric science (Aikenhead & Elliot, 2010). However, Ogawa (1995) proposed that "multisciences" (p. 584) exist in cultures across the world, each with their own rational and empirical ways of describing and explaining nature. While the number of resources available for educators to include First Nations content is increasing (e.g., bush foods, fire management), understanding ways of knowing and being requires a deeper engagement with culture(s):

> Cross-cultural science education is not merely throwing in an Aboriginal story, putting together a diorama of Aboriginal fishing methods, or even acknowledging the contributions Aboriginal peoples have made to medicine. Most importantly, cross-cultural science education is not an anti-Western science. Its purpose is not to silence voices, but to give voice to cultures not usually heard to recognize and celebrate all ideas and contributions. It is as concerned with how we teach as with what we teach (Snively, 2009, p. 38).

The field of education about Indigenous knowledges has grown rapidly in the last decades, led by noted scholar Cajete (1999a). Following these developments, Lowan-Trudeau (2013) outlined an *indigenous environmental education* noting that its emergence has paralleled a growing trend in North America and other parts of the world of "programs teaching Indigenous knowledge and philosophies for the benefit of both indigenous and nonindigenous students" (Lowan-Trudeau, 2013, p. 404).

> Employing Indigenous ways of teaching and learning, including ceremonies, dreams, visions and visioning, fasting, storytelling, learning-by-doing, observation reflecting, and creating, not only allows students to share and learn in culturally inherent manner, but also reinforces the concept that Indigenous knowledge is not only content but also process (Simpson 2002, p. 18).

Following this is the point that Indigenous ways of *coming to know*, learning, and teaching are inherently tied to the land, sea, and sky, where humans, other living beings, and the non-living are interconnected (Battiste, 2002; Cajete, 2000; Hatcher et al., 2009). The notion of coming to know goes beyond acquiring knowledge. According to Cajete (2000, p. 66), it is considered a "journey, a process, a quest for knowledge and understanding" involving all relations, along with the responsibilities that come with the application and sharing of this understanding. Such knowledge systems are unique to peoples and places. According to the Royal Commission on Aboriginal Peoples [RCAP] in Canada (1996, p. 488):

> Each nation also has its own body of knowledge that encompasses language, belief systems, ways of thinking and behaving, ceremonies, stories, dances and history. Through thousands of years in the Americas, nations have evolved intricate relationships with their lands and resources.

Teaching and learning take place through sharing circles, dialogues, observation, experiential learning, and storytelling—all emphasising authentic experiences (Battiste, 2002; Hatcher et al., 2009). This body of evidence-based local knowledge and skills are acquired over thousands of years, have stood the test of time, and offer insights into how people make sense of the world, including those of a scientific nature (FNESC, 2016, p. 12). These insights are reflected throughout Indigenous agriculture, astronomy, ecology, engineering, navigation, mathematics, and medical practices, among others (Snively & Corsiglia, 2001).

While the authors acknowledge there are debates associated with different knowledge systems and worldviews (e.g., Aikenhead & Elliott, 2010; Brigg, 2016; Rigney, 1999; Snively & Corsiglia, 2001; Shipley & Williams, 2019), we seek to find a way forward that is respectful of different cultures, reflective of place, and feasible in education settings. We acknowledge that, although contemporary science provides strong contributions, other knowledge systems have not been considered in such depth, even though they may share similarities and potential benefits to the natural and constructed world (Aikenhead & Elliot, 2010; Shipley & Williams, 2019). Rather than being viewed as irreconcilable, different knowledge systems can be viewed in terms of "entanglements, synergies, and the shared conversations that can occur around the common interests explored through them" (Nakata, 2010, p. 55).

Nakata (2007) believes harnessing two systems to create new knowledge provides opportunities for creative and innovative meaning making. This includes approaches to knowledge creation and problem solving in science and technology (Durie, 2005). Further, Indigenous perspectives are thought to fill the ethical knowledge gaps not addressed through Eurocentric approaches (Battiste, 2002; Nakata, 2010). "Indigenous Science, then, would be recognized as an equal but different source of knowledge, not measurable through a Western worldview" (Cajete, 2000, p. 291).

In classroom settings, the inclusion of First Nations perspectives supports students' development of scientific thinking and grounds their learning within their local contexts (Snively & Corsiglia, 2001). Indigenous students learn science ways that do not compromise their cultural ways of knowing the natural world (Aikenhead & Elliott, 2010). Non-Indigenous students gain insights into their own "culturally constructed Eurocentric world" and through "Indigenous cultural capital" (Aikenhead & Elliott, 2010, p. 326). Thus, First Nations perspective are not just beneficial for Indigenous students, but can engage all students (Aikenhead, 2001; Blades & McIvor, 2017). These ideas are consistent with culturally responsive pedagogies, which actively draw on the perspectives and resources that diverse students bring to the learning experience, for the benefit of all (Morrison et al., 2019).

Most science educators who have undertaken culturally responsive science teaching while maintaining the same high expectations of academic success, report improvement for most Indigenous and non-Indigenous students alike (Aikenhead & Elliott, 2010). Moreover, a culturally diverse science education is critical in addressing the increasingly complex challenges of our time: "Just as biodiversity is crucial to the biological world's survival, cultural diversity within society will be crucial to humankind's survival in the twenty-first century" (Aikenhead & Elliott, 2010, p. 326).

To support a strengths-based culturally responsive approach to contemporary and Indigenous sciences, we draw on the principle of Two-Eyed Seeing.

Two-Eyed Seeing

The concept of *Etuaptmumk* or Two-Eyed Seeing (TES) is based on the principle that Indigenous and Western scientific ways of knowing are valuable, achievable, and inform how we live in the world (Bartlett et al., 2012; Hatcher et al., 2009). It originated from Atlantic Canada, the traditional territory of the Mi'kma'ki people who have the longest history of living with colonisers, providing their Elders with a unique understanding of Western perspectives (Hatcher et al., 2009). The Mi'kma'ki word *Etuaptmumk* means *the gift of multiple perspectives*. In 2004, the phrase *Two-Eyed Seeing* (TES) was coined by the Mi'kma'ki Elders Albert and Murdena Marshall, while working in collaboration with Professor Cheryl Bartlett (Bartlett et al., 2012). As explained by Elder Albert Marshall, *Etuaptmumk* or TES is about:

> …learning to see from one eye with the strengths of Indigenous knowledges and ways of knowing, and from the other eye with the strengths of Western knowledges and ways of knowing, and to using both these eyes together, for the benefit of all (Bartlett et al., 2012, p. 335).

TES is based on knowledge coexistence, the complementarity of knowledge generation (Reid et al., 2021), and a recognition that both Indigenous and Western knowledge systems are whole and distinct in and of themselves (Roher et al., 2021). Knowledge holders do not have to relinquish either position: instead, they work collaboratively across knowledge systems on a common problem to understand perspectives of both (Berkes, 2017; Reid et al., 2021). As opposed to a dichotomous comparison, it assumes both systems contribute in parallel to co-produce a more pluralistic understanding that informs context-specific decisions to add to our understanding of the world (Bang & Medin, 2010; Cajete, 2000). These ideas are illustrated in Fig. 1, with two eyes positioned behind two connected pieces of a jig-saw puzzle.

To explain the significance of this graphic, Elder Albert Marshall wrote: "the two jig-saw puzzle pieces help remind us that, with respect to [traditional knowledge], no one person ever has more than one small piece of the knowledge" (Bartlett et al., 2012, p. 336). The graphic was designed such that the puzzle pieces do not fit together perfectly (Cheryl Bartlett, personal conversation, July 7, 2022). Further, that other pieces of the puzzle include perspectives of different cultures, other living beings, and kin. The binocular view supports a "wider, deeper, and more generative field of view" than could be achieved by either perspective or knowledge system in isolation (Iwama et al., 2009) and results in a richer, though still partial, understanding of the world (Roher et al., 2021).

Together, both systems offer valid and different understandings that can act in tandem to offer unique knowledge and innovations (Cajete, 2000; Mistry & Berardi, 2016; Reid et al., 2021). TES also considers common ground, so "time-tested Indigenous knowledge systems can be paired with revelatory Western scientific insights" (Mistry & Berardi, 2016; Reid et al., 2021, p. 245). Importantly, TES acknowledges the changing nature of knowledge systems from within our own perspectives. As Elders Murdena and Albert Marshall explained: "The advantage of Two-Eyed Seeing is that you are always fine tuning your mind into different places at once, you are always looking for another perspective and better way of doing things" (Bartlett et al., 2012, p. 336).

At Cape Breton University in Canada (formerly known as the University College of Cape Breton), TES was applied to guide the development and implementation of an *Integrative Science* concentration within a four-year Bachelor of Science Community Studies degree program for Indigenous tertiary students (Hatcher et al., 2009). The term *integrative* denotes the bringing together of knowledges and emphasises an ongoing process (i.e., knowledges travelling together) (Cheryl Bartlett, personal conversation, November 16, 2022). As a guiding principle, TES sought to avoid knowledge domination and assimilation by recognizing the best from both worlds (Hatcher et al., 2009; Reid et al., 2021). Rather than "unified knowledges" being a goal unto itself, context-specific knowledges are applied in practice, preserving the integrity, authenticity, and sacredness of each knowledge system (Cheryl Bartlett, personal communication, November 16, 2022; Reid et al., 2021, p. 249).

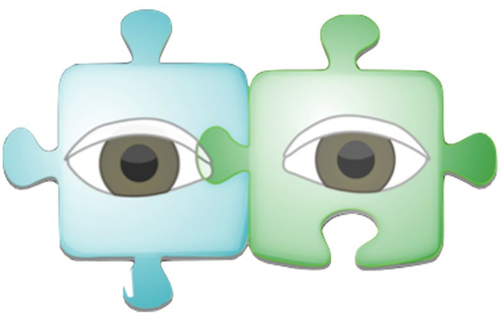

Fig. 1 *Etuaptmumk* or Two-Eyed Seeing. Image credit: Team of the Canada Research Chair in Integrative Science in collaboration with Mi'kmaw Elders in Unama'ki/Cape Breton

Key philosophies that informed this program are found in Indigenous knowledges across the globe, particularly that all beings and natural elements are interconnected and interdependent (Cajete, 2000; Hatcher et al., 2009; Levac et al., 2018; Stephens, 2003). Rather than being separate, humans are considered part of the natural world, albeit a very small part (Hatcher et al., 2009). Moreover, knowledge and the knowers are interconnected, and the knowers bear a responsibility to act on their knowledge (Hatcher et al., 2009). This ethic of responsibility is extended to all beings—now and for future generations (Bartlett et al., 2012; Hatcher et al., 2009). There are a growing number of examples where TES has been applied in fields such as Education for Sustainable Development (e.g., Zeyer, 2022), fisheries (e.g., Reid et al., 2021), medicine (e.g., Hall et al., 2015), and wildlife health (e.g., Kutz & Tomaselli, 2019). TES presents authentic and compelling possibilities for school science education.

We applied the guiding principle of TES to bring together two well-known teaching and learning approaches: the 5Es model, with a representation-rich approach, complemented by the *8 Aboriginal Ways of Learning*.

The 5Es Guided Inquiry Approach

The 5Es model supports teaching and learning through guided inquiry. While inquiry-based teaching and learning is thought to better reflect the practice of scientific inquiry, further refinements to this model have integrated additional discipline-specific approaches where students engage directly in scientific knowledge construction processes (Kenny & Cirkony, 2018a, b). These involve teachers guiding their students to create their own representations of phenomena (e.g., diagrams, gestures, models) and use them to illustrate their ideas and justify their claims based on evidence (Tytler et al., 2013). The ongoing creation and refinement of representations to develop, evaluate, and communicate ideas and claims reflects authentic scientific practice (Latour, 1999; Tytler et al. 2018). However, the interactive nature of this learning places demands on teachers. It takes more time, is difficult to assess, and requires a high level of expertise (Cirkony & Kenny, 2022).

Kenny and Cirkony (2018b) have developed a planner for teachers combining the 5Es model (Bybee et al. 2006) with the IF-SO framework (Waldrip et al., 2010) to support teachers to plan representation-rich learning experiences. This involves the following: Identifying key concepts (I); Focusing on form and function of multimodal representations (F); Sequencing lessons and activities (S); and Ongoing evaluation (O). The planner emphasises conceptual learning and student-generated representations across each of the five phases (see Appendix).

The *engage* phase is intended for students to tune-in to the topic and make connections with their current knowledge. The teacher provides experiences to probe students' ideas about a given phenomenon. Students express and share their ideas through multimodal representations (e.g., diagrams, models, role plays) in combination with simple texts or verbal explanations. In the *explore* phase, the teacher prompts deeper and more scientific thinking though additional hands-on activities, by posing follow-up questions to prompt students to link their explanations to evidence, and/or compare different explanations to refine their thinking.

In the *explain* phase, the teacher provides more scientific information to the students. In practice, the *explore* and *explain* phases often overlap. The teacher provides a range of common experiences and builds students' reasoning and inquiry skills. This involves facilitating discussion and debate between students, follow-up exploratory activities to address points of contention, and students' integrating scientific ideas by refining their representations. Importantly, the teacher must avoid moving to a formal scientific explanation too soon. To support the development of conceptual learning, the teacher must gradually introduce new ideas, to ensure students are not just memorising content. The teacher needs to judge when students are ready, drawing clear connections between students' earlier experiences. Alternatively, the teacher may pose questions or make suggestions that extend students' ideas.

After some further work to consolidate students' understanding, the process shifts to the *elaborate* phase where they apply their new knowledge to solve a problem or conduct an investigation. Again, students share their ideas through a range of representations and challenges. This process helps to build their inquiry skills and reasoning abilities as a transferrable skill (Cirkony & Kenny, 2022). The *explain* and *elaborate* phases focus on a deeper development of skills and conceptual understanding.

The *evaluation* phase starts at the beginning. As students share their ideas verbally and visually, teachers receive ongoing feedback about students' learning as formative assessment. At the end of a learning sequence, students demonstrate what they have learned as summative assessment. This may involve representation-rich tasks as well as more traditional testing methods.

Where the 5Es provides guidance for representation-rich inquiry-based teaching and learning, the *8 Aboriginal Ways of Learning* provides guidance for ways of knowing—many of which are observed across the globe (RAET, 2019; Yunkaporta, 2009).

Aboriginal Ways of Learning

The *8 Aboriginal Ways of Learning* (8 ways) guides teachers to engage with Aboriginal knowledge through Aboriginal pedagogies (RAET, 2019; Yunkaporta, 2009). The 8 ways was developed by the New South Wales Department of Education Western Regional Aboriginal Education Team in Australia, in collaboration with local Aboriginal communities and their schools, who shared their cultural knowledge. It was further refined by comparing with other models of Aboriginal pedagogy in the literature, alongside Western models of pedagogy also used in the region (RAET, 2019; Yunkaporta, 2009). As

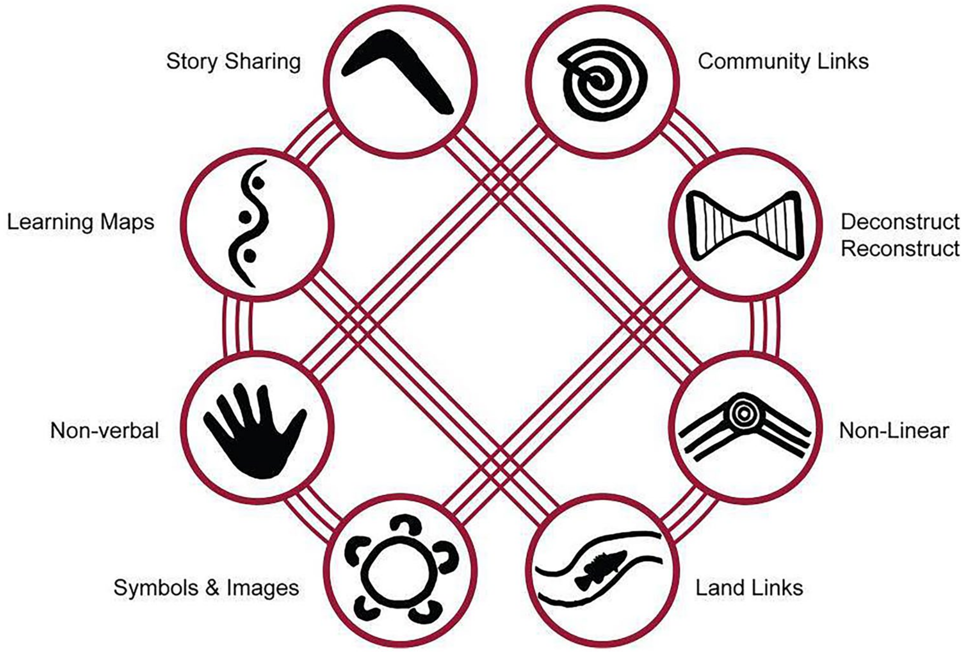

Fig. 2 The 8 Ways of Aboriginal Learning. Image used with permission by Tyson Yunkaporta and the New South Wales Department of Education, Western Regional Aboriginal Education Team

metaphors for Aboriginal knowledge, each approach is represented as culturally significant symbols to provide a meaningful context (see Fig. 2).

According to Yunkaporta (2009), combining these approaches is the most productive way to understand how Aboriginal knowledge is constructed, particular through the paired elements. For example, story sharing is directly connected to non-linear and learning maps, which are then connected to land links. These connections are further enhanced through the diagonal lines at the centre, which represent protocols, processes, systems, and values. Importantly, these connections highlight the relationship between learners, teachers, and place—and how all elements, people, variables, and materials are interconnected (Bilton et al., 2020). Table 1 elaborates on the 8 ways of learning.

Together, these interconnected elements and the meaningful spaces between them carry the underlying concept of *learning through* Aboriginal pedagogies, as explained by Tyson Yunkaporta:

> The core concept, the gamechanger of all my research into Aboriginal pedagogies, is the idea of learning through culture rather than about culture (Bilton et al., 2020, p. 88).

In other words "[p]erspectives are not in the content, but the process" (Bilton et al. 2020, p. 88). The application of the 8 ways involves teaching all Aboriginal content through an Aboriginal way of knowing, providing a more holistic and meaningful engagement with Aboriginal perspectives.

The 5Es and 8 ways models form the basis of the TESSE Framework for teaching and learning science.

Table 1 Elaborating on the 8 ways of learning (adapted from Bilton et al., 2020; RAET, 2019; Yunkaporta, 2009)

	**Story Sharing:** This is about teaching and learning through narrative. Personal narratives (i.e., stories) are central. We connect through the stories we share.
	**Learning Maps:** This is about making learning pathways and processes visually explicit. We picture our pathways of knowledge.
	**Non-verbal:** This is about hands-on learning, critical reflection, and least-intrusive management strategies. Ancestral/spiritual knowledge also comes through this way of learning. We see, think, act, make, and share without words.
	**Symbols and Images:** This is about exploring content through imagery and using visual cues and signals. We keep and share knowledge through art and objects.
	**Land Links:** This is about place-based pedagogy, linking content to local land and environment. We work with lessons from land and nature.
	**Non-linear:** This is about indirect management strategies, lateral thinking, comparing and synthesising diverse cultural viewpoints and knowledge systems, innovating, adapting, working within cycles, and working with holistic knowledge. We put different ideas together and create new knowledge.
	**Deconstruct/Reconstruct:** This is about modelling and scaffolding, balancing teacher instruction with independent learning. We work from wholes to parts, watching and then doing.
	**Community Links:** This is about grounding learning content and values in community knowledge, working on community projects and using or displaying knowledge products publicly for local benefit. We bring new knowledge home to help our mob.

Table 2 The Two-Eyed Seeing for Science Education (TESSE) Framework

Two-Eyed Seeing Framework for Teaching and Learning Science	
Representation-rich 5Es Inquiry	**8 ways**
Engage: • Engage students' interest • Elicit their prior knowledge about a concept	**Story sharing + land links:** • Students and other community members (e.g., Elders) share their experiences with the local environment, associated with a concept
Explore: • Teachers plan a range of activities where students create, compare, critique, and refine their ideas through multimodal representations	**Non-verbal + symbols & images:** • Students represent their ideas through a variety of symbols and images to explain, compare, and refine their ideas • Students participate in hands-on activities and practical investigations
Explain: • Teachers guide students towards conceptual understanding through an interplay between their representations and scientific ideas • Teachers introduce scientific ideas	**Learning maps + deconstruct/reconstruct:** • Teachers and students make learning pathways and processes visible • Teachers and students link concepts with other concepts and to broader contexts
Elaborate: • Teachers plan activities where students apply and extend their knowledge to a new problem or context	**Non-linear + community links:** • Teachers and students consider diverse perspectives to understand and address problems • Students apply knowledge to innovate and/or solve real-world problems
Evaluate: Ongoing formative evaluation through dialogue and representations; summative evaluation in relevant contexts for a purpose	

Two-Eyed Seeing for Science Education (TESSE) Framework

Using principle of Two-Eyed Seeing, the proposed TESSE Framework brings together a contemporary guided-inquiry approach with an example of Aboriginal ways of knowing (Table 2).

Following the principle of TES, both approaches have value and offer guidance for teaching and learning science. Where the 5Es representation-rich approach provides broad guidance for a contemporary inquiry-based approaches, 8 ways provides specific examples of Aboriginal teaching and learning methods that may be introduced throughout the inquiry cycle. In bringing together these approaches, there is a need for educators to (re)consider three key aspects of science education: pedagogy, curricula, and the nature of science itself.

Pedagogy

As previously mentioned, there has been long-standing critique of transmissive, teacher-centred approaches that are reliant on textbooks (Harlen & Bell, 2010; Lyons, 2006; Osborne & Dillon, 2010). Over a century ago, Dewey (1910/1990) advocated for student-centred scientific inquiry. Researchers still argue for science education to become more interactive, inquiry- and place-based (Blades & McIvor, 2017; Duschl & Grandy, 2013). Teaching methods should include open-ended questions, class discussions, and activities (Eberback & Hmelo-Silver, 2015). Students should have direct experience with skills and methods of inquiry such as observation, collecting data, creating multimodal representations of their ideas, and collaboration (e.g., Duschl & Grandy, 2013; Tytler et al., 2018). Many of these contemporary inquiry approaches have a strong congruence with traditional Indigenous teaching approaches.

Table 3 Potential similarities between traditional teaching and learning and strategies for teaching inquiry-based science (adapted from Stephens, 2003, p. 28)

Traditional teaching	Inquiry teaching	Compatible strategies
Elders, family, community and peers	Teacher as facilitator of learning; science as a social endeavor	Community involvement, cooperative groups, peer tutoring; multiple teachers as facilitators of learning
Learning connected to life, seasons, and environment	Investigate fundamental science questions of interest to students	Investigate fundamental science questions related to life, seasons, and environment; investigate questions from multiple perspectives and disciplines
Learn by watching, listening, and doing; Elder is expert	Active and extended inquiry over time; use of print and electronic sources to help interpret or revise explanations	Learn by active and extended inquiry; use multiple sources of expert knowledge including cultural experts
Emphasize skills and practical application of knowledge	Focus on student understanding and use of scientific knowledge, ideas and inquiry skills	Integrate skill development, understanding, and application of knowledge
Knowledge shared through modeling, story-telling, and innovation	Classroom communication and debate of understandings	Diverse representations and communication of student ideas and work to classmates and community

As part of a culturally responsive science curriculum developed in the USA, Stephens (2003) compared traditional teaching with inquiry teaching (Table 3).

Where traditional teaching approaches involved diverse expert knowledge placed alongside relevant and practical contexts, inquiry teaching places teachers as facilitators of learning and emphasises student-centred methods. Together, these offer several compatible strategies, highlighting the opportunity to integrate diverse expertise and perspectives, learn across the disciplines, and connect learning to relevant contexts.

Both approaches are consistent with the guidelines provided by the RCAP (1996), where the teacher is a facilitator who guides the educational process and learners are active creators of knowledge rather than passive recipients. According to the guidelines, teaching methods include experiential learning, storytelling, observations, visualisations, movement, students use of trial-and-error, and student-directed research projects. Importantly, educators establish learning communities through learning circles, cooperative problem-solving, and knowledge sharing with no competitive ranking of performance. Similar approaches have also been recommended for use with the 7Es model (FNESC, 2016), where activities often take place on the land with Elders (e.g., videos, guest speakers, field trips). In both cases, learning and assessment ideally take place at the same time with an emphasis on formative approaches over summative.

Curricula

In contrast to pedagogies, curricula is more challenging to adapt. Policy for school science tends to prescribe curricula irrespective of culture or place. Curricula are typically organised into disciplinary strands (e.g., biology, chemistry, physics), *covering* a broad range of unrelated topics (Schweingruber et al., 2012). Science textbooks also tend to present a collection of information as an "encyclopedic curriculum" in response to committee-influenced development teams (Schwartz et al., 2009, p. 799). Thus, science is presented as a series of disconnected facts and skills (Duschl & Grandy, 2013). Consequently, school science has been described as a "rhetoric of conclusions" (Schwab, 1962, p. 24), with content that is considered largely irrelevant to everyday life (Aikenhead, 2006; Zidny et al., 2020). Even hands-on experiments and other activities do not guarantee meaningfulness (Crawford, 2014) or enable students to investigate topics in which they are interested (Lyons, 2006).

In contrast, First Nations approaches offer possibilities for contextually relevant curriculum integration (i.e. interdisciplinarity) where curriculum works alongside pedagogy and context as part of teaching and learning. As Elder Albert Marshall, explained:

> Two-Eyed Seeing is hard to convey to academics as it does not fit into any particular subject area or discipline. Rather, it is about life: what you do, what kind of responsibilities you have, how you should live while on Earth (Bartlett et al., 2012, p. 336).

Indigenous thought does not separate knowledge into disciplines such as science, art, religion, philosophy, or aesthetics (Battiste & Henderson, 2005). For example, the curriculum for the Integrative Science program went beyond the disciplinary siloes, following a transdisciplinary design that related to complex and socially relevant issues (Bartlett et al., 2012; Hatcher et al., 2009). Academic disciplines and traditional knowledge were connected through the visual arts, and the body and mind through movement and dance.

Moreover, both curriculum and pedagogy were strongly place-based, and followed a holistic education model involving the integration of communities within the classroom (Hatcher et al., 2009). Students' learning was also connected with activities outside school and in communities, consistent with the need to connect to the larger world of learning and understanding (RCAP, 1996). Finally, students were connected to nature. This involved focusing on the senses and the powers of observations as ways to help them re-establish themselves as part of nature rather than separate from it (Hatcher et al., 2009). By designing pedagogy and curriculum in context, students in the program developed an understanding that knowing is relational and dynamic (Hatcher et al., 2009). This *place-based science* offers rich and authentic contexts for science learning (Blades & McIvor, 2017; Hatcher et al., 2009; Zidny et al., 2020).

The Nature of Science

Most science education programs have taken a Eurocentric perspective on the scientific method (Aikenhead & Elliot, 2010), presenting it as the dominant or exclusive method for understanding the world (AAAS, 1989). If all science learning is to be understood as cultural (National Research Council, 2012), then there is need to unpack the philosophies and assumptions underpinning Eurocentric science, and challenge it as a single universal way of knowing and doing science (Kayumova & Dou, 2022). Both teachers and their students need to put their "values and actions and knowledges in front of [themselves], like an object, for examination and discussion" (Bartlett et al., 2012, p. 334). Again, we draw on Stephens (2003), to compare the purpose, methods, and skills for Indigenous knowledge creation and Western modern science (see Table 4).

Table 4 was adapted from its original representation as a Venn diagram, emphasising the complementarity between the systems, and the common ground in the centre. The Integrative Science program drew on these ideas to illustrate how each knowledge system offers valuable scientific knowledges through differences in ontologies, epistemologies, and methodologies (Bartlett, 2011).

Bartlett (2011) explained how the *organizing principles* (i.e., ontologies) are concerned with the need for knowledge to provide understanding about how the world works. While Indigenous science focuses on beings, *interconnectiveness*, spirit, and change within balance and wholeness, Western science focuses on parts building to understanding wholes and systems. The *habits of mind* (i.e., epistemologies) link knowledge and values to *ways of coming to know* in the natural world. Indigenous science focuses on respect, relationship, reverence, reciprocity, ritual, repetition, and responsibility (Archibald, 2001). Western science focuses on hypothesis (making and testing), data collection, data analysis, and model and theory construction.

Skills and procedures link languages and the methodologies that inform ways of knowing. Both Indigenous and Western science have knowledge systems that are changeable (i.e., not static) (Hatcher et al., 2009). Indigenous sciences focuses on patterns within nature through creative relationships and reciprocities. It is concerned with collective, living knowledge to enable an interconnective and place-based life journey, with the view of long-term sustainability for the people and natural environment as reinforced by Aboriginal languages. In contrast, Western science focuses on the analysis of nature's patterns through mathematical language and computer models. It is concerned with dynamic, testable, publishable knowledge, independent of personal experience, that can enable prediction and control, towards an understanding of how the cosmos works.

The complementarity and common ground outlined by Stephens (2003) and elaborated by Bartlett (2011) illustrate how we might respectfully reconcile different philosophies. Where the purpose of Western scientific knowledge is to understand the natural world, Indigenous science focuses place-based ways of way of living in the natural world, through respect, responsibility, and reciprocity within nature's relationships (Aikenhead & Ogawa, 2007; Hatcher et al., 2009; Snively & Corsiglia 2001). Indigenous sciences emphasise humans as participants in the natural world as well as the knowledge system. In doing so, "the acquisition of scientific knowledge is essential to human survival—it is a practical engagement with the real world, or put another way, it is about our interactions with and within nature"

Table 4 Similarities, differences, and common ground between Indigenous knowledge and Western modern science (adapted from Stephens, 2003, p. 11)

Themes	Indigenous knowledge	Common ground	Western modern science
Organizing principles	• Holistic • Includes physical and metaphysical worldviews linked to moral codes • Emphasise practical application of skills and knowledge	• Universe is unified • Body of knowledge is stable but subject to modification	• Parts to whole • Limited to evidence and explanations within the physical world • Emphasis on understanding how
Habits of mind	• Trust for inherited wisdom • Respect for all things	• Honesty, inquisitiveness • Perseverance • Open-mindedness	• Skepticism
Skills and procedures	• Practical experimentation • Qualitative oral record in natural settings • Local verification • Communication of metaphors and stories connected to life, values, and proper behavior	• Empirical observation in natural settings • Pattern recognition • Verification through repetition • Inference and prediction	• Tools expand scale of direct procedures and indirect observation and measurement • Hypothesis falsification • Global verification • Quantitative written record • Communication of procedures, evidence, and theory
Knowledge	• Integrated and applied to daily living and traditional subsistence practices	• Plant and animal behavior, cycles, habitat needs, interdependence • Properties of objects and materials • Position and motion of objects • Cycles and changes in earth and sky	Discipline-based • Macro vs (sub-) micro representations (e.g., cell biology, particle, and atomic theory) • Mathematical models

(Institute for Integrative Science and Health [IISH], n.d.-a). The bringing together of both knowledge systems "allows the Indigenous Sciences sense of the whole 'to dance with' the Western Science sense of the parts" (Hatcher et al., 2009, p. 146).

Unpacking knowledge systems and coming to understand multiscience perspectives (Ogawa, 1995) requires both teachers and their students participating in ongoing reflection and being open to continuous development in ways of knowing, valuing, and doing (Hatcher et al. 2009). Given that the idea of *holding space* for multiple perspectives is a feature of many Indigenous knowledge systems (Berkes, 2017), Indigenous students may be more open to this multi-perspectival approach than non-Indigenous students (Bartlett et al., 2012; Shahjahan et al., 2022).

On the other hand, First Nations students may have a different starting point to understanding Western science, experiencing what is described as a 'culture shock' in science education (Cajete, 1999b, p. 153). This is attributed to the idea that there are three types of science: personal science (based on personal beliefs and experiences); Indigenous science (cultural beliefs and experiences); and Western modern science (Ogawa, 1995). First Nations students may need to recognise their own conflicting schema. In science education, this might be considered as an extra dimension of students' prior ideas, so the teacher needs to be mindful to ensure a culturally responsive approach.

Though the (re)consideration of pedagogy, curricula, and nature of science may seem daunting, Yunkaporta (2009, p. 163) emphasizes that both Aboriginal and non-Aboriginal teachers are equally able to come to Aboriginal knowledge and pedagogies:

> Applications of Aboriginal pedagogy at the Cultural Interface define a safe yet challenging ground in which teachers and students can engage with Aboriginal knowledge from perspectives that are multicultural, inclusive, intellectually rigorous, connected to curriculum and connected to community.

The (re)consideration of pedagogy, curricula, and the nature of science indicate areas of compatibility, complementarity, and common ground between two knowledge systems, illustrating how the principle of *Etuaptmumk* or TES has been applied in learning environments. The following highlights two consideration to support the respectful and meaningful implementation of the TESSE Framework.

Implementation

The proposed TESSE Framework is presented as a way to guide the teaching and learning of science in schools and universities. Though there is no "uniform pedagogical approach can be applied to all students, both Aboriginal and non-Aboriginal" (Lloyd et al., 2015, p. 13), the TESSE Framework provides a starting point for those exploring culturally responsive pedagogies. The Framework is based on the assumption that many science educators will already be familiar using the 5Es approach. The following outlines implications for implementation, based on the lessons learned from the Integrative Science program (Hatcher et al., 2009), along with advice associated with the 8 ways pedagogies (Yunkaporta, 2009).

The first implication is about the need to focus on common ground while understanding and respecting and preserving ideas but avoiding knowledge domination (Hatcher et al., 2009). This requires the teacher to consciously "(w)eave back and forth between our worldviews" (Bartlett et al., 2012, p. 334). At the same time, teachers must avoid situations where Indigenous knowledges become tokenistic, trivialized, romanticized, co-opted, or undertaken without co-learning (Marshall et al., 2015); or are assimilated such that they become invisible, or cultural differences are denied (Levac et al., 2018). Levac and colleagues (2018, p. 4) advocated for the complementarity of these approaches:

> Despite the differences between them, and the risks posed by integration, several scholars and wisdom keepers argue that we can and should try to learn from bringing together Indigenous and Western ways of knowing. Their complementarity will allow us to gain new ways of thinking about and approaching existing problems.

These ideas are consistent with Nakata's (2007) notion of a *cultural interface*, which encourages the explorations between Aboriginal and Western cultures as a source of innovation, critical thinking, and problem-solving in ways that are relevant for learners of all cultures.

The second implication is about the co-learning journey. To implement both knowledge systems, educators and First Nations communities need to walk and work together as each undertake their journeys (Hatcher et al., 2009). Given the context-specific nature of Indigenous knowledges, integrating First Nations perspectives into the classroom requires collaborating with local communities and focusing on meaningful cultural content (Yunkaporta, 2009). This involves positioning educators, students, and community as co-learners, focusing on big picture understandings and project-based learning around issues of common interest (Hatcher et al., 2009). Importantly, co-learning journeys must also involve ongoing relationship-building, guided by the process of conversation rather than focusing only on the outcomes (Roher et al., 2021). These connections have potential to grow into long-term partnerships between schools and the local Indigenous community (Anderson & Rhea, 2018).

A functioning partnership is built on relationships based on trust, mutual respect, and effective communication (Kenny et al., 2018). It involves mutual benefit and negotiation for goal setting, planning, implementation, and evaluation (Kenny et al., 2018; Kenny & Cirkony, 2022). This involves educators identifying local First Nations communities and the appropriate agencies, as well as understanding and practicing the local protocols (FNESC, 2016). Researchers have argued for partnerships in education to improve educational outcomes and to better link theory to practice, especially in teacher education (e.g., Jones et al., 2016).

To ensure First Nations perspectives are introduced respectfully, educators need to collaborate with local Elders or other Knowledge Keepers to determine what appropriate knowledge should be taught and how it should be taught (Aikenhead & Elliott, 2010; FNESC 2016; RAET, 2019). Educators may also consider developing an advisory council of willing, knowledgeable stakeholders, with individuals from their own educational institution(s) as well as local First Nations communities (Bartlett et al., 2012; FNESC, 2016). Such collaborations can lead to the co-development of local inquiry-based science resources, lessons, and units, which can also be used for the benefit of the Aboriginal community (FNESC 2016). Through these trusted collaborations, "teachers will be able to develop their professional practice in a culturally appropriate manner and be able to create a powerful teaching and learning environment for all of their students" (Anderson & Rhea, 2018, p. 212).

In the final section, we highlight how a Two-Eyed Seeing approach benefits all students.

Benefits of a Multisciences Perspective

Cultural responsive approaches enrich learning environments by unpacking worldviews, appreciating other perspectives, and engaging with learning in productive ways. The inclusion of multiple perspectives in science enables students to reflect on the nature of knowledge and what it means to know, developing a 'meta-awareness' about different ways of learning, knowing, and doing (Nakata, 2010, p. 56). They have an opportunity to develop a deeper understanding of the nature of science, as well as balanced and holistic worldviews, intercultural understanding, and an ethic of sustainability (e.g., Aikenhead & Ogawa 2007; Blades & McIvor, 2017; Shipley & Williams, 2019; Zeyer, 2022; Zidny et al., 2020).

As students learn through different knowledge systems, they come to understand that the practice of science is influenced by cultures and worldviews. They learn that Indigenous and Eurocentric sciences have different ontologies, epistemologies, methodologies, and goals—which influence ways of living and frame societal decisions (IISH, n.d.-b; Shipley & Williams, 2019). This cultural interface facilitates a dialogical exchange between Indigenous and non-Indigenous knowledge systems and provides a pathway towards reconciliation (Nakata, 2007). Such exchanges enable students to recognise the tacit assumptions underlying histories, politics, economics, discourses, social practices, and how they influence sense-making in our everyday world (Nakata, 2007). These discussions are particularly salient for non-Indigenous students, given that Indigenous learners are already familiar with complexities of the cultural interface due to the predominance of Eurocentric science on culture and in classrooms (Nakata, 2011).

All students benefit from learning about the rich, complex, and effective knowledges about medicine and natural systems that existed prior to the notion of Western science, along with the ways in which these were transmitted through teaching and learning across the generations (Bartlett, 2011). Students also benefit by learning through a more holistic mindset that is transcultural, multidisciplinary, multidirectional, and multisensory, with the total environment as the laboratory (Hatcher et al, 2009). As stated by Nakata (2011, p. 8), "by considering the education of all students as a task at the cultural interface, we can harness Indigenous content and the knowledge, language and skills of all the discipline areas to assist in the education of all students." Importantly, Nakata (2011) also emphasises that there is no need to discard Western ways of knowing that are working, or to impose an imagined ideal past into a more traditional future that is separated from global perspectives—reflective of the value of engaging in both knowledge systems.

Culturally responsive approaches also align with a global call to reorient education systems to enable student agency in contributing to the well-being of their communities and the planet (OECD, 2019). These approaches also align with future directions for school science education, which include a focus on *Socio-environmental Systems and Sustainability*—addressing the complexities and interconnections of problems young people will face in their lifetime (e.g., climate change, pandemics, food security). Moreover, young people themselves are looking to participate more constructively in addressing these challenges (Han & Ahn, 2020). The recent focus on the *development of scientific knowledge and its misuse* renews an emphasis on ethics, requiring students to develop the competencies for decision-making and action (OECD, 2020). These directions are particularly salient for Indigenous students and their continued engagement in STEM education and careers (Bartlett et al., 2011).

According to Blades and McIvor (2017, p. 473), "science education would better serve humanity if respect for nature and being part of nature were a fundamental part of all science curricula." Reforms would orient "science for society instead of science for economy" (Avraamidou & Bryan, 2018, p. 415). In school science settings, Indigenous perspectives can open up new possibilities for scientific inquiries and explanations of natural systems (Bartlett et al., 2011). For example, pairing both knowledge systems can assist with forming new questions to explore, or reinforce discoveries in science that are closely connected with human experience (Blades & McIvor, 2017). Thus, scientific inquiry is not just a method, "it is a way of knowing that involves awareness and wonder, creativity and curiosity, dreaming and awe, along with logical and critical thinking" (IISH, n.d.-a). According to Blades and McIvor (2017, p. 476) "[g]enuine contributions from both Indigenous and Western scientific worldviews provide greater understandings of the world" and can increase scientific literacy for all students.

Conclusion, Implications, and Next Steps

The Two-Eyed Seeing for Science Education (TESSE) Framework aims to act as an interface between contemporary and Indigenous pedagogies to support a culturally responsive approach to teaching and learning science by combining the strengths of both. From a contemporary science perspective, the 5Es representation-rich approach scaffolds guided-inquiry (Bybee et al., 2006; Kenny & Cirkony, 2018a, b), drawing on active knowledge constructions methods that share common ground with traditional First Nations methods (Lloyd et al., 2015; Stephens, 2003). Complementing this with a First Nations perspective, the 8 ways illustrates how Aboriginal content can be learned through Aboriginal ways of knowing in a manner that is accessible to all (RAET, 2019; Yunkaporta, 2009). Common ground is evident in that both approaches:

- highlight the role of the teacher as facilitator who scaffolds the learning process;
- emphasise interactive learning approaches (e.g., discussions, experiential learning);
- involve the use of representations (e.g., diagrams, symbols);
- provide opportunities for students to share knowledge through collaboration and cooperative problem-solving; and
- emphasise formative assessment.

The First Nations perspectives offers additional complementary methods, including:

- a role for community Elders and Knowledge Keepers;
- the use of learning circles to build learning communities;
- the use of storytelling (e.g., story sharing);
- the need to consider diverse perspectives and methods for knowledge creation and adaptation (e.g., non-linear);
- the interdisciplinary nature of knowledge and knowledge creation;
- the *interconnectiveness* of knowledge, knower, and place;
- knowledge that is relevant, meaningful to the student, and connected to local environments (e.g., place-based, land-links), including the communities outside the school;
- knowledge to benefit people and place (e.g., community links), now and into the future.

In light of the common ground and complementarities across pedagogies, assessment, purpose, and place, we now discuss implications and next steps in the development of TESSE. We consider the implications for improving current approaches to science education in schools and universities. These involve the need for educators to willingly embark on this co-learning journey, challenge their own personal and professional beliefs about science, and develop their confidence to teach with culturally responsive approaches. In turn, institutions must undergo systemic reform including policy changes in curricula and assessment, co-designed training, and relationship-building between schools and communities (Kenny & Cirkony, 2022) to support educators in their decolonising journeys. Importantly, education systems must address persistent issues such as institutional racism and colonialist attitudes that are entrenched at all levels (Lloyd et al., 2015).

Further refinement of the TESSE Framework involves exploring how it might be adapted to local First Nations ways of knowing. It also involves developing meaningful connections with curriculum and place, as well as thoughtful implementation in schools and universities. These activities will necessarily involve science educators and their students working alongside First Nations educators and their communities. These activities will also involve ongoing reflection on personal knowledge systems and how they align with localised cultural knowledge systems as an integral part of what it means to walk together in a journey towards reconciliation.

Appendix: Representation-rich 5Es inquiry approach for science education (adapted from Kenny & Cirkony, 2018b)

Unit title			**Year level**	
I: Identify key concepts	Prior knowledge: Possible alternative conceptions: Science Understanding(s):			
	Engage	**Explore**	**Explain**	**Elaborate**
F: Focus on form and function of different representations	• Engage students' interest • Elicit prior knowledge about a concept • Identify any alternative conceptions	• Plan a range of activities where students represent their ideas through a range of representations (e.g., drawings, role-plays) • Focus on what each representation shows and hides	• Students compare and refine their representations with scientific ideas (e.g., interplay, two-way mapping) • Gradual development of conceptual understanding	• Students apply their knowledge to novel situations
S: Sequence lessons with representational challenges/activities	1 or 2 lessons	As appropriate, based on students' learning	2–3 lessons	
O: Ongoing assessment	**Evaluate:** • Ongoing formative (including diagnostic) evaluation, summative evaluation • Students reflect on communicate their learning through a range of representations			

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Author Contribution Cirkony and Kenny elaborated on the 5Es model, presenting these ideas at a science education conference and published the representational 5Es version in 2018. At the same conference in 2018, Cirkony also presented ideas exploring the interface of representations-focused inquiry with the 8 ways pedagogy. In 2022, Cirkony revisited these ideas and in discussions with Zandvliet, and brought in the principle of Two-eyed Seeing. Cirkony and Zandvliet presented these ideas at a science conference in 2022. Cirkony then led the development of the paper, with all authors contributing different sections, and reviewing the draft manuscript.

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