A Synthesis of Research into Outcomes Arising from
Enhancing School Science with Indigenous Understandings

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Indigenous Worldviews in Informal Science Education conference
Albuquerque, New Mexico, September 3-5, 2015

It is expected that Indigenous students will understand a curriculum's scientific content, processes, and values while simultaneously strengthening their own cultural self-identities, rather than hiding, rejecting, or replacing them with a Eurocentric or scientific identity. Strong cultural self-identities and values are foundational to significant increases in Indigenous students' academic achievement (Aikenhead & Michell, 2011; Barnhardt, Kawagley, & Hill, 2000; Brayboy & Castagno, 2008; Richards, Hove, & Afolabi, 2008).

Underlying these findings is a fundamental presupposition: each major culture worldwide have developed their own set of ways for investigating, describing, and explaining natural phenomena; in short, they each have developed a science. Schools and universities in the USA and Canada teach a science primarily anchored in Euro-American cultures. This Euro-American science (EAS) is found internationally due to past colonization, current globalization, and EAS's powerful success in promoting economic, social, political and military progress. Conventionally, school science introduces students to EAS only. But there is also Indigenous science, Japanese science, Islamic science, etc. (Aikenhead & Ogawa, 2007). These cultural knowledge systems have similarities, differences, assets, and limitations. This paper synthesizes research on the outcomes of students going from their Indigenous culture with its Indigenous knowledge (IK) into the culture of EAS taught in schools. Students usually find this to be a cross-cultural experience. Their success at learning EAS has been augmented by science teachers who not only acknowledge and respect the students' IK, but enrich school science instruction by including IK from time to time. Both Indigenous and non-Indigenous students benefit, as evidenced by the research synthesized here. Within Euro-American cultures, EAS is normally referred to as "science," which masks the existence other sciences worldwide.

A review of research concerning Indigenous cross-cultural school science in the United States concluded: "Efforts at culturally responsive schooling for Indigenous youth result in students who have enhanced self-esteem, develop healthy [cultural identities], are more self-

directed and politically active, give more respect to tribal elders, have a positive influence in their tribal communities, exhibit more positive classroom behaviour and engagement, and achieve academically at higher rates" (Brayboy & Castagno, 2008, p. 733). The Alaska Native Knowledge Network (ANKN, 1996) produced cross-cultural teaching materials for Yup'ik students. In classrooms where teachers implemented the ANKN science modules, the standardized science test scores of Yup'ik students uniformly improved over four years to match the national averages in the United States (Barnhardt, Kawagley, & Hill, 2000). Elementary science classes similarly experience success (Matthews & Smith, 1994); a result that is also observed in multicultural classrooms (Lee, 2002).

When science and social studies curricula were enhanced with Indigenous knowledge, increased student interest and achievement in those and other school subjects have been documented (Kanu, 2011; Snively, 1990). In Canada's far north, the Inuit Subject Advisory Committee (1996) published *Inuuqatigiit: The Curriculum from the Inuit Perspective*, which conveys Inuit Elders' ideas to be included in school science. A case study in a Grade 7 science classroom identified limited advantageous outcomes as well as challenges when integration was solely the responsibility of the teacher (DeMerchant, 2002).

A five-year study with 366 provincial schools (as opposed to reserve schools) in British Columbia, Canada, found that Indigenous students significantly increased their achievement when Indigenous content was incorporated into the curriculum (Richards, Hove, & Afolabi, 2008). This project also resulted in "improving relations with Aboriginal families and community members, and transforming expectations in schools" (p. 14). This unexpected outcome itself suggests a powerful consequence that will certainly encourage student achievement.

The project *Rekindling Traditions* integrated Eurocentric science into the local Indigenous knowledge by collaborating with Indigenous communities (Aikenhead, 2000, 2002) in order to develop Indigenous cross-cultural science teaching units. The teachers observed that the units engaged Indigenous students who might otherwise resist school science. Similarly, Woodlands Cree teachers in northern Manitoba, Canada, developed their own culturally responsive science lessons with good results (Sutherland & Tays, 2004). On the basis of several years of work, Sutherland and Dennick (2002, p. 21) concluded, "A greater emphasis on understanding the epistemological differences between traditional and Western scientific

knowledge systems should be explored in the middle years' (Grades 5 to 9) science programme, especially in schools with high Aboriginal populations."

Culturally responsive teaching in school science and social studies led to many positive consequences for Indigenous students (Barnhardt et al., 2000; Kanu, 2011), including a serious consideration science-related careers or occupations. In turn, more Indigenous students tend to choose post-secondary STEM-related programs. Other positive consequences observed were Indigenous students' stronger cultural self-identities and their desire to become voices of conscience for sustainability. Positive consequences for non-Indigenous students in those same classrooms have also been documented (Kanu, 2011).

For many years Aotearoa New Zealand has had a Māori language version (Pūtaiao) of their country's standard science curriculum. It was developed in 1992 through negotiations between Māori Elders and science educators (McKinley, 1996, 2007; Stewart, 2005). Pūtaiao was then introduced into a network of Māori bilingual and immersion classrooms in both elementary and secondary schools (Wood & Lewthwaite, 2008). A thorough evaluation of these programs documented various advantages for Māori students (McKinley, Stewart, & Richards, 2004). Aotearoa New Zealand is the most advanced country for Indigenous cross-cultural science teaching.

Cultural validity of the Indigenous content of school science is a necessity. This is gained by having Indigenous groups decide the Indigenous content of the local science curriculum; not the internet. Collaboration, not consultation, with an Indigenous community leads to positive outcomes (Aikenhead & Elliott, 2010). On the other hand, little progress can be expected in educational jurisdictions that emphasize standardization and accountability (Castagno & Brayboy, 2008).

There are exceptions, of course. Chinn (2007, 2008) drew on Indigenous Hawaiian knowledge to develop an environmental literacy program for K–12 science curricula that met the standards-based expectations of the Hawaiian Ministry of Education. The program's success at meeting this objective was partially attributed to in-depth professional development for science teachers that combined cultural immersion with formal study at the University of Hawai'i. (The topic of teacher professional development is considered in more detail below.)

When culturally responsive instruction includes outdoor, hands-on science instruction with group activities, instead of using textbook-based indoor instruction, the research showed

that standardized science test scores of Indigenous students improved significantly, reaching par with the scores of their non-Indigenous counterparts (Chinn, 2008; James, 2001; Zwick & Miller, 1996). Similarly, Riggs (2005) concluded that "successful Earth science curricula for Indigenous learners share in common an explicit emphasis on outdoor education, a place-based and problem-based structure, and the explicit inclusion of traditional Indigenous knowledge in the instruction" (p. 296). Student success also increases whenever an Indigenous community becomes involved with enhancing its school science program (Reyhner, 2006).

The results of two Indigenous cross-cultural research studies were each summarized by constructing a model of best practices. In the first study, a group of science teachers in Saskatoon, Canada, took part in a year-long professional development project that focussed on developing their capacity in cross-cultural competencies (Aikenhead et al., 2014). Eight of the teachers wrote stories about their experiences. These stories are replete with positive student outcomes that account for higher achievement for their Indigenous and non-Indigenous students. Besides a better understanding of Indigenous perspectives, non-Indigenous students tended to gain a much deeper understanding of their Euro-Canadian culture's scientific way of knowing nature. By learning the similarities, differences, strengths and limitations of both knowledge systems, non-Indigenous and Indigenous students alike tended to identify hidden or taken-for-granted assumptions found in the science they were learning. This research produced a holistic placed-based Model of Culturally Responsive Science Teaching, inspired by the Plains Cree First Nation's medicine wheel.

A very different research project focused on Indigenizing and decolonizing school subjects (Goulet & Goulet, 2014). In-depth case studies of seven experienced Indigenous teachers (Grades 3-9) were synthesized into a holistic "Model of Effective Teaching for Indigenous Students" (p. 87 and Appendix 2). A fascinating feature of their book is its introduction to selected Woodlands Cree words in order to animate a Woodlands Cree worldview. By learning some of the intricacies of the Cree language and the translations from key English words such as "learning," a reader gains an appreciation of the sophistication of Cree education that reflects best practices. Attempts to translate between any Indigenous language and English reveals how much gets lost in translation. More importantly, European language speakers and researchers can learn from Linda and Keith Goulet how easy it is for an English expression to misrepresent or corrupt an Indigenous idea whose richness is diluted by

using an English expression. Ultimately, many English words and expressions act like a Trojan Horse by subtly forcing Indigenous people to use the colonizer's language, thereby marginalizing a culturally valid Indigenous perspective.

Cultural validity and a reduction of what is "lost in translation" can often be achieved with the use of back translations. Back translation is the process of translating a word, phrase, or even a document that has already been translated into a non-English language, back into English by an independent translator. Here are three examples. The English word 'knowledge' back translated from Canadian First Nations Cree becomes 'ways of thinking, doing, being, and living'. The word 'language' becomes 'taking something apart from the female body that has life of the wind'. It is not a coincidence that an English noun becomes an Indigenous verb. English tends to be noun-based, unlike verb-based features of most Indigenous languages. And as a last example of lost in translation, our English distinction between teaching and learning is not shared by the Māori word 'oka', which makes no such distinction—teaching and learning are one concept, a fact that speaks volumes about a Māori perspective on education.

As mentioned above, positive outcomes for Indigenous students can rarely accrue unless their teachers are sufficiently prepared and supported in their journey to enhance school science with Indigenous perspectives. As evidenced by Chinn's (2007, 2008) research into professional development programs, teachers must engage in some type of cultural immersion experiences before they can augment their own cross-cultural competencies. Aikenhead and colleagues (2014) confirmed Chinn's findings, and noted a key causal relationship: "The brain needs the heart." Before teachers can adequately prepare lessons (an intellectual process, by and large) to engage their Indigenous and non-Indigenous students in learning Indigenous ways of describing and explaining the physical universe (IK), teachers must first experience heartfelt emotional feelings about those Indigenous ways; feelings that invariably arise from: (a) hearing the emotional cadence of Indigenous people's voices recount firsthand the painful colonizing history of social alienation, economic deprivation, and endemic racism that they and their ancestors have survived; (b) participating in Indigenous ceremonies that help a person connect with their own spiritual self, non-Indigenous or Indigenous; and (c) hearing some ancient Indigenous stories and contemporary commentaries that reveal aspects of Indigenous people's worldviews. These three items comprise the main agenda for most cultural immersions.

What usually emerges from a cultural immersion experience is a grounded respect for Indigenous ways of knowing and an informed acknowledgement of the coexistence of two ways of knowing – Indigenous and Euro-American—not to be misconstrued as a dichotomy. Integrating Indigenous knowledge into school science does work, if adequate preparation and support for teachers are provided. This is a significant, trustworthy, evidence-based conclusion.

Noteworthy, however, is the warning from McKinley (2001) about science educators masking their non-Indigenous privilege and power by embracing the unfounded objectivity of EAS, along with its myth that EAS is value- and culture-free. Castagno and Brayboy's (2008) review of the literature concerning culturally responsive schooling in general (CRS) gives depth to the phrase "support for teachers." Their findings are also a cautionary note to avoid taking the research synthesized above out of context; specifically out of the context of political power wielded by American and Canadian institutions that systemically subjugate Indigenous people and, in some cases, continue to breathe life into an outdated belief in the 1452 Doctrine of Discovery, a.k.a. the Doctrine of Christian Nations. This belief, for instance, explains the written *minority* view of a 5-4 decision by the U.S. Supreme Court case *State of Michigan* v. *Bay Mills Indian Community*, on May 27, 2014. This minority view argued for the "subjugation" of American Indians. On the other hand, support for teachers is reflected in the Supreme Court's *majority* view in favour of the Bay Mills Indian Community. This view is reflected in Castagno and Brayboy's advice to educators (2008, p. 941, emphasis added):

> The authors suggest that although the plethora of writing on CRS reviewed here is insightful, it has had little impact on what teachers do because it is too easily reduced to essentializations, meaningless generalizations or trivial anecdotes—none of which result in systemic, institutional, or lasting changes to schools serving Indigenous youth. The authors argue for *a more central and explicit focus on sovereignty and self-determination, racism, and Indigenous epistemologies* in future work on CRS.

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