An Emerging Decolonizing Science Education in Canada

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Abstract

The article describes developments in science education since 2006 related to an agenda to decolonize the Pan-Canadian Science Framework by recognizing Indigenous knowledge as being foundational to understanding the physical world. Of particular interest is the Province of Saskatchewan's curriculum renewal that integrates Indigenous knowledge into school science, guided by continuous collaboration with Saskatchewan's Indigenous communities and with a textbook publisher to support a decolonizing, place-based, culturally responsive science instruction.

This article builds upon an earlier *CJSMTE* viewpoint piece "Towards Decolonizing the Pan-Canadian Science Framework" (Aikenhead, 2006b), which mapped out a rationale for an agenda to integrate Indigenous[1] ways of knowing nature into the school science curriculum. Significant developments have occurred since that publication, including a special issue of *CJSMTE*, "Indigenous Science Education from Place: Best Practices on Turtle Island" (Michell, 2009). Moreover, some regions in Canada and around the world have illustrated the success of a community-based decolonizing agenda for science education. The present article describes some of these significant developments and then presents the case of Saskatchewan where a decolonizing science curriculum has emerged.

Significant Developments

Background

There are challenges to creating an enhanced school science curriculum that recognizes Indigenous knowledge[2] as being foundational to understanding the physical world. Such an enhanced science curriculum is framed by a pluralist viewpoint on science: Many cultures worldwide have their own rational and empirical ways of describing and explaining nature. Thus, there are multiple sciences (Ogawa, 1995). School science conventionally teaches Eurocentric or

[1] The term 'Indigenous' encompasses worldwide the original inhabitants who have suffered colonization (McKinley, 2007). The term includes First Nations, Inuit, and Métis peoples of Canada, collectively referred to in the Canadian constitution as Aboriginal peoples.
[2] Indigenous knowledge is also known as Aboriginal knowledge, Indigenous science, traditional knowledge, traditional ecological knowledge, Native science, etc.

Western science. Ogawa's pluralist perspective should not be confused with a relativist perspective (McKinley, 2007).

The former *CJSMTE* article's agenda to decolonize school science (Aikenhead, 2006b) called for Indigenous communities and leaders to negotiate appropriate modifications to the provincial or territorial science curricula in order to maintain the integrity of Indigenous ontologies, epistemologies, axiologies, and political realities. Evidence shows that these types of integrated science curricula are indeed feasible and educationally sound (Herbert, 2008; Keane, 2008; Richards & Scott, 2009; Wood & Lewthwaite, 2008), whether or not these modifications were initiated by Indigenous communities.

Challenges to achieving a decolonized science curriculum were characterized in the *CJSMTE* article in terms of Bennett's (1986) model of intercultural sensitivity, a multi-stage continuum from highly ethno-centric to highly ethno-pluralistic. Ethno-pluralism evolves in three stages: acceptance, adaptation, and integration. "Decolonizing school science *begins* at the stage of 'acceptance' and succeeds at the stage of 'integration'" (Aikenhead, 2006b, p. 393, original emphasis). Specific challenges to achieving a decolonized curriculum included the articulation of Indigenous knowledge for school science, the allocation and production of resources to support teachers, and the development of teachers' professional capacities to teach the curriculum's Indigenous knowledge to all students.

The former article also pointed out that the expression "Indigenous knowledge" is problematic because the word "knowledge" is embedded in a Eurocentric epistemology and should be replaced by other expressions that more authentically capture an Indigenous worldview, such as "Indigenous ways of knowing, living, or being." Concomitantly, the Eurocentric meaning of "to learn" becomes "coming to know" in most Indigenous contexts, a meaning which signifies a personal, participatory, holistic journey towards gaining wisdom-in-action. The verb "to learn" fits a Eurocentric context, while the action "coming to know" assumes an Indigenous perspective. In the present article, we intend "Indigenous knowledge" in school science to mean "Indigenous ways of knowing or living in nature." These expressions will be interchangeable.

The remainder of this section continues to summarize the main points of the former article while presenting recent research findings that clarify three related topics: conventional school science, school science for Indigenous students, and cross-cultural school science for all students.

Conventional School Science

What is conventional school science (grades 6-12) to most students in industrial countries? School science usually attempts to enculturate all students into the culture of academic Eurocentric science, replete with its canonical knowledge, techniques, and values. Many science teachers want all their students to be able to think like a scientist, behave like a scientist, and believe what scientists are purported to believe (Eisenhart, Finkel, & Marion, 1996).

But teachers certainly fail to meet this goal; except for the small proportion of students who, like the authors, have worldviews that harmonize with the worldviews endemic to Eurocentric sciences. Most students' worldviews differ, to varying degrees, from the worldview conveyed by conventional school science (Cobern & Aikenhead, 1998). Forty years of research on this issue was synthesized as follows (Aikenhead, 2006a; supporting citations are omitted):

> Discordant worldviews create an incompatibility between, on the one hand, students' self-identities (e.g. who they are, where they have been, where they are going, and who they want to become) and, on the other hand:
>
> - students' views of [Eurocentric] science, school science, or their science teacher, and
> - students' views of the kind of person they think they must become in order to engage in science. (pp. 107-108)

Students who do not feel comfortable taking on a school science identity (i.e., being able to think, behave, and believe like a scientist) represent the vast majority of any student population.

A parallel conclusion was reached by Scott and his colleagues' (2007) when they reviewed research into students' learning science concepts. The researchers investigated (a) epistemological differences between scientists' ways of thinking and students' everyday ways of thinking (e.g., generalizable models versus context specific ideas), and (b) ontological differences (e.g., energy as a mathematical tool versus energy as a concrete entity). They concluded:

> Learning science involves coming to terms with the conceptual tools and associated epistemology and ontology of the scientific social language. If the differences between scientific and everyday ways of reasoning are great, then the topic in question appears difficult to learn (and to teach). (p. 49)

As a result, most students (about 90 percent[3]) tend to experience school science (grades 6-12) as a foreign culture to varying degrees, but their teachers do not treat it that way (Costa, 1995). To be successful, these students must, without teacher assistance, learn to cross a cultural border between their own everyday culture and the culture of academic school science (Aikenhead, 2006a). A majority of students end up feeling alienated simply by the foreign language of science (Brown & Spang, 2008). This happens in spite of supportive influences on student learning (Shanahan, 2009). Thus, teachers will certainly fail at enculturating *most* students into a Eurocentric science. When summarizing research in Europe, Osborne and Dillon (2008) lamented:

> The irony of the current situation is that somehow we have managed to transform a school subject which engages nearly all young people in primary schools, and which many would argue is the crowning intellectual achievement of European society, into one which the majority find alienating by the time they leave school. (p. 27)

Aikenhead (2006a) documented five key problems faced by conventional school science (grades 6-12).

1. Although students generally continue to value Eurocentric science in their world outside of school, there is an alarming and chronic decline of interest and enrolment in secondary and tertiary science education (Schreiner & Sjøberg, 2007).
2. School science tends to alienate students whose cultural identities differ from the culture of Eurocentric science (described above).

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[3] The phrase "most students" and the figure "90 percent" are clarified by a variety of qualitative and quantitative studies that have produced various ways of estimating the proportion of students who do not likely have a future in science or engineering fields (i.e., who are not potential scientists, as they do not have worldviews that harmonize with a worldview endemic to academic school science) and consequently do not value the meaningful engagement in academic school science expected by their science teachers. Here are a few examples. In her qualitative investigation, Costa (1995) found 35 of 43 Grade 11 California students (81 percent) were not potential scientists. This 81 percent figure was deflated from 84 or 86 percent, however, by a sample bias: almost all students alienated from school science "refused to be interviewed" (p. 324). Cobern's in-depth work exploring people's worldviews concerning nature (e.g., scientific, aesthetic, religious worldviews) indicated: (a) 94 percent (15 out of 16) of Grade 9 students in a suburban Arizona study were not potential scientists (Cobern, 2000); and (b) 93 percent (14 out of 15) of nursing students in an Arizona study were not potential scientists (Cobern, 1993). A confirming finding arises in Reiss's (2004) 6-year longitudinal study in England: "…for the *great majority of students*, science education played only a small part of their lives" (p. 108, emphasis added). Quantitative data in the United States based on high school students' enrolment in optional science courses show that "about 90 percent take no more science than is required to meet secondary-school graduation requirements" (Atkin & Helms, 1993, p. 2). But of the 10 percent who do, some were found to be motivated by university entrance standards rather than their interest in science or engineering (Carlone, 2004; Lyons, 2006); thus the proportion of potential scientists would actually be lower than 10 percent.

3. Although students grasp scientific ideas as needed in out-of-school settings (Albright, Towndrow, Kwek, & Tan, 2008; Rennie, 2007), they generally fail to learn academic science content meaningfully in school. For instance, a 10-year longitudinal study showed that only 20% of students achieved meaningful learning of the molecule concept (Löfgren & Helldén, 2009).
4. School science invariably encourages many students to pass science courses simply to acquire credentials rather than to engage in meaningful learning. "Empirical evidence demonstrates how students and many teachers react to being placed in the political position of having to play school games to make it appear as if significant science learning has occurred even though it has not" (Aikenhead, 2006a, p. 28).
5. Similar to the mass media, conventional school science conveys dishonest and mythical images of Eurocentric science and scientists, such as a positivistic ideology of technical rationality that supports "*the* scientific method."

Is it little wonder then that school science means so little to most junior and senior secondary students in industrial nations (Schreiner & Sjøberg, 2007)?

School Science for Indigenous Students

In countries with a history of colonial oppression, these problems of alienation are magnified for Indigenous students whose home culture often differs dramatically from the culture of school science. Indigenous ways of living in nature have not generally been welcomed in science classrooms, and Indigenous students must suppress such knowledge to meet the conventional goal of thinking, behaving, and believing like a scientist. Thus, school science overtly and covertly marginalizes Indigenous students by its ideology of neo-colonialism – a process that systemically undermines the cultural values of a formerly colonized group (Ryan, 2008). As a result, an alarming under representation of Indigenous students in senior sciences persists.

This issue is exacerbated for students whose first language is not English (or not French in Franco-phone schools). For example, Chigeza (2008) found that the concepts force and energy expressed in an English scientific genre were particularly difficult for junior high school Indigenous students to grasp (e.g., only 20 % succeeded), because their rich place-based, relational, holistic, functional concepts about nature differed dramatically from the abstract, generalized, "objective," reductionist, explanatory concepts of force and energy. More fundamental are the two knowledge systems' contrasting presuppositions, for example, sustainability as a responsibility to Mother Earth on the one hand, and on the other, anthropocentrism that has challenged sustainability (Aikenhead & Michell, 2011; Aikenhead & Ogawa, 2007).

Under representation in high school science enrolment causes several inequalities for Indigenous people: low participation in post-secondary science-related programs, low employment in science-related sectors of society (e.g., resource-based careers, technicians, medical practitioners, engineers, and scientists), and inadequate participation as citizens in the social fabric of their country (Richards & Scott, 2009). This in turn causes economic, social, and political disadvantages for Indigenous communities (McKinley, 2007). Moreover, the economic consequences alone of under representation could undermine the Canadian economy because successful educational outcomes for Indigenous students lead to increases in their incomes, increases in government tax revenue, and decreases in government program expenditures (Sharpe & Arsenault, 2009). Education – "the new buffalo" (Stonechild, 2007) – is seen as a major contributor to economic progress. Canada's Indigenous population recently surged past the million mark for the first time, a spike of 45 per cent from a decade earlier (Statistics Canada, 2008).

Many factors influence the under representation of Indigenous students in high school science, including: generations of colonial oppression (e.g., residential schools and the Indian Act), systemic poverty, chronic under funding by governments, and adverse living circumstances. These factors undermine a family's support for their children's success in school.

Although science educators have no influence over these factors, they do have jurisdiction over one crucial factor: the degree to which students experience marginalization or alienation in science classes. One way to understand this phenomenon is to appreciate the culture clashes and cultural border crossings that most Indigenous students face daily. Values, assumptions, and ideologies embedded in Eurocentric science content can conflict with values, assumptions, and ideologies of Indigenous ways of living in nature. For example:

- Conventional school science often conveys positivistic notions of Eurocentric science, combined with realism and Cartesian duality, to justify reductionistic and mechanistic practices that celebrate an ideology of power and dominion over nature (Aikenhead, 2006b).

As mentioned above, to participate in conventional school science, many Indigenous students are expected to set aside or devalue their Indigenous ways of knowing nature; that is, their journeys towards wisdom-in-action:

- Indigenous ways of knowing nature combine the ontology of monism and spirituality with the epistemology of place-based, holistic, relational, and empirical practices in order to celebrate an ideology of harmony with nature for the purpose of community survival (Aikenhead, 2006b).

Knowledge in Eurocentric science expresses an *intellectual tradition* of thinking, while Indigenous knowledge expresses a *wisdom tradition* of thinking, living, and being (Aikenhead & Michell, 2011). Broadly speaking, an intellectual tradition emphasizes individual cognition, while a wisdom tradition emphasizes group-oriented ways of being as practised by living in harmony with Mother Earth for the purpose of survival.

The distinction between an intellectual tradition and a wisdom tradition is mirrored in Aristotle's dichotomy "thought directed toward *understanding* how the world works and thought directed toward *taking action* in the world" (Atkin, 2007, p. 68, original emphasis). The respective Greek terms are 'episteme' and 'phronesis.' In the realm of phronesis, thought and action are somewhat dialogically related: "Not only is action sometimes derived from thought, but practical thought is generated *through* action" (p. 69, original emphasis). Phronesis is not practical knowledge, but instead practical *wisdom*, which is associated with practical reasoning – "what is prudent, what is obligatory, what is moral and what is appropriate for the particular situation" (Atkin, 2007, p. 69).

Practical wisdom (phronesis) tends to resonate with wisdom-in-action, which indicates a way of knowing the world embraced by most Indigenous peoples (Aikenhead & Michell, 2011). The Nehiyawak (Plains Cree Nation) of Canada, for instance, would easily translate 'phronesis' as 'yipwakawatisiwin' ("wisdom in practice;" Beaudet, 1995). Phronesis and yipwakawatisiwin, it would seem, represent common ground between a Greek-based Eurocentric perspective and a Nehiyaw (Plains Cree) perspective. Sharing common ground, however, does not mean the two words are identical. Much will be lost in translation between the two because the cultural context of each word differs (Aikenhead & Ogawa, 2007).

Although Indigenous and scientific knowledge systems share some fundamental features (e.g., both are culture-based, empirical, experimental, rational, communal, and dynamic), and although both embrace common values (e.g., honesty, perseverance, open-mindedness, curiosity, aesthetic beauty, repeatability, and precision), their worldviews tend to be ontologically, epistemologically, and axiologically incommensurate (Aikenhead & Michell, 2011). Metaphorically, scientists *see* the world while Indigenous Elders *inhabit* the world.

When school science fails to nurture students' Indigenous identities (Chinn, 2006) or fails to strengthen their resiliency (Sutherland, 2005), most students resist their science teacher's instruction and thus become marginalized or alienated in school science. School science that excludes Indigenous knowledge from the curriculum is a neo-colonialist school science. On the other hand, an inclusive school science teaches Indigenous knowledge in culturally responsive ways to all students, a topic to which we now turn.

Cross-Cultural School Science

A cross-cultural science curriculum promotes the decolonization of school science. Indigenous students learn to master and utilize Eurocentric science and technology without, in the process, sacrificing their own cultural ways of knowing nature. Cross-cultural school science nurtures walking in both worlds – Indigenous and Eurocentric. In the Mi'kmaw Nation, some Elders talk about two-eyed seeing that emphasizes the strengths of both knowledge systems (Hatcher, Bartlett, Marshall, & Marshall, 2009). By walking in both worlds or by two-eyed seeing, Indigenous students (rural and urban) gain cultural capital essential for accessing power as citizens in a Eurocentric dominated world while maintaining their roots in an Indigenous wisdom tradition.

For *non-Indigenous* students, cross-cultural school science can nurture a richer understanding of the physical world. Their Eurocentric dominated world can be an impoverished mono-cultural world that stifles diversity. By learning to walk in both worlds or by two-eyed seeing, non-Indigenous students gain insight into their own culturally constructed Eurocentric world, and they can gain access to Indigenous cultural capital essential for wisdom-in-action for their country's sustainable growth (Glasson, Mhango, Phiri, & Lanier, 2010).

Just as biodiversity is crucial to the biological world's survival, cultural diversity within society will be crucial to humankind's survival in the 21st century (Sillitoe, 2007). Mi'kmaw scholar Marie Battiste wrote, "Indigenous knowledge fills the ethical and knowledge gaps in Eurocentric education, research, and scholarship" (2002, p. 5). Thus, future scientists and engineers need a foundation in a rich, culturally diverse, science education because if they continue to try to solve today's problems with the same kind of thinking that caused the problems in the first place, the quality of life on this planet is in jeopardy (Cajete, 2000; Suzuki, 1997).

When Indigenous cultures influence the culture of Eurocentric science, an Indigenous wisdom tradition will help ensure wise environmental decisions and sustainable progress (Lyver, Jones, & Moller, 2009; Snively & Corsiglia, 2001). The two knowledge systems are complementary; they co-exist. Scientists and engineers can expand their perspectives on nature and augment their problem-solving repertoire by learning from the wisdom held by Knowledge Keepers[4] of an Indigenous culture.

The success of cross-cultural science education will be measured, in part, by the number of students who have learned to appropriate the tools of Eurocentric science and technology for their everyday lives, while strengthening their Indigenous self-identities. Success will also be indicated by a greater proportion of Indigenous students' selecting, and achieving in, high school science courses and postsecondary programs while forming stronger cultural self-identities.

Successful cross-cultural school science avoids tokenism and neo-colonialism. The aim is to nurture Indigenous students' scientific literacies (the plural is intended) so they can, if they wish, successfully participate in their local community's Indigenous culture and in the global community's culture of Eurocentric science. Cross-cultural school science anticipates that all students will *understand* how scientists think, behave, and believe without students being expected to think, behave, and believe that way themselves (Aikenhead & Michell, 2011; Cobern, 1996).

When teaching cross-cultural school science, teachers learn to build cultural bridges between their own Eurocentric science culture and their students' local Indigenous culture (Aikenhead & Michell, 2011; Belczewski, 2009; Cajete, 1999, Ch. 7; Herbert, 2008). Teachers also learn to shift their perspective from treating the two cultural ways of knowing nature as mutually exclusive, to treating them as complementary (Chinn, 2007; Ogunniyi, 2007).

A review of research concerning 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

[4] A Knowledge Keeper is a respected Indigenous person to whom people go to gain help or understanding related to a specific issue or event (e.g., using plants for healing purposes). They are expected to pass this understanding on to the next generation.

academically at higher rates" (Brayboy & Castagno, 2008, p. 733). In Alaska, cross-cultural school science resulted in Indigenous students' standardized science test scores uniformly improving over four years to meet national averages (Barnhart, Kawagley, & Hill, 2000). Classroom teacher/researcher Medina-Jerez (2008, p. 209) maintains that what matters most is "the acknowledgement of cultural differences in the classroom that provides the needed attention to each student in coping with his/her strengths and weaknesses as they feel integrated into the cross-cultural scenario of the classroom."

A five-year study with 366 public schools in British Columbia found that Indigenous students increased their achievement when Indigenous content was incorporated into the curriculum (Richards, Hove, & Afolabi, 2008). This research also resulted in "improving relations with Aboriginal families and community members, and transforming expectations in schools" (p. 14).

Indigenous student interest and achievement in school science increased whenever African communities collaborated with science educators to create a locally produced cross-cultural school science (Jegede & Okebukola, 1991; Lubben & Campbell, 1996). As a result, post-apartheid South Africa established the goal of teaching Indigenous African knowledge in science classrooms, which has led to community involvement in developing activities that combine Eurocentric science and Indigenous knowledge, such as agriculture practices (Keane, 2008). Similarly, a project in Malawi demonstrated "how merging worldviews and hybridized knowledge and languages can be leveraged to create a third space for dialogue and curriculum development" (Glasson et al., 2010, p.125).

"Third-space" is metaphorically where conversations occur between people of two diverse communities (e.g., Indigenous Knowledge Keepers and science educators) to negotiate new understandings or hybrid meanings that result in a mutual coming to know the other through dialogue (Wallace, 2004). In the context of Indigenous peoples on Turtle Island, Vickers (2007) calls such spaces "camping spots," while to Brandt (2008) they are a "location of possibilities."

Chinn (2008) drew upon Indigenous Hawaiian ways of knowing nature to develop an environmental literacy program for K-12 science curricula that met the standards-based expectations of the Hawaiian Ministry of Education. Its success was attributed, in part, to the in-depth professional development program for science teachers that combined place-based experiential learning (cultural immersion) with formal study at the University of Hawai'i. At the University of Victoria, Canada, a major professional development project supports teachers' coming to know Indigenous knowledge and supports teaching it in their classrooms (Snively & Williams, 2008).

The most advanced country in developing a cross-cultural school science is Aotearoa New Zealand, where a Mäori version of the science curriculum ("pütaiao") is taught in a network of Mäori bilingual and immersion classrooms in elementary and high schools (McKinley, 2007; Stewart, 2005; Wood & Lewthwaite, 2008). Teacher professional development and student achievement have been documented and analysed (McKinley, Stewart, & Richards, 2004).

In the Canadian territory of Nunavut, Inuit ways of knowing nature are compiled in the document *Inuti Qaujimajatuqangit*, developed conjointly by the Nunavut government and its citizens. It promotes combining Eurocentric science with Inuit ways of living in nature (Lewthwaite & McMillan, 2007; Lewthwaite & Renaud, 2009). On Canada's west coast, the *Forests and Oceans for the Future* project (Menzies, 2003) helps incorporate Tsimshian core community values and knowledge in local sustainable forest and natural resource management. It designs cross-cultural school science materials to facilitate mutual respect and knowledge sharing between First Nations and others. The *Rekindling Traditions* project in Saskatchewan demonstrated how collaboration between a science teacher and a Nehiyaw (Cree), Dëne, or Métis community's Knowledge Keepers and Elders can produce cross-cultural science units (Aikenhead, 2000, 2002).

On a much larger scale, the *Learning Indigenous Science from Place* project investigated how educators might integrate place-based Indigenous knowledge into Saskatchewan's science curriculum (Michell, Vizina, Augustus, & Sawyer, 2008). A broad literature review and an extensive interviewing process gave voice to First Nations and Métis perspectives on learning Indigenous knowledge from place – the location of an Indigenous community. Elders, traditional land users, teachers, and teacher candidates participated. The project documented a wide array of Indigenous approaches, processes, and content that the participants believed worthwhile for school science (e.g., "We are all connected and we have to live in harmony with each other;" p. 62). This encyclopaedia of ideas also highlighted barriers, challenges, and supports needed for science teachers in First Nations and Métis contexts. For example, "As a support to school systems and individual educators, having cultural liaison personnel available to go out and meet with traditional land users or Elders is necessary to take the time needed to honour traditional protocols properly and effectively" (p. 128). Teachers valued "a process that begins with professional development and learning directly from the Elders" (p. 128). In turn, many community members looked forward to providing individualized professional development experiences for teachers at their local level.

What are the components to successful cross-cultural school science programs for Indigenous students? Sutherland and Henning (2009) in Manitoba carried out a literature analysis study and then an interactive action-research project with 50 cross-cultural science educators from schools. Sutherland and Hemming's literature analysis led to four components to successful programs:

C1. coming to know
C2. cross-cultural pedagogy (culturally responsive ways of teaching)
C3. social and ecological justice (including the power relationships and social dynamics in science education)
C4. ecological literacy (a field more related to Indigenous knowledge than most other fields in science education)

By engaging school personnel experienced in Indigenous science education, Sutherland and Hemming facilitated a series of discussions that began with the participants' reaction to the four components above, and ended with four key themes they distilled from their discussions about what makes cross-cultural school science programs at their schools successful for Indigenous students. Their four themes were: (T1) Elders, (T2) culture, (T3) language, and (T4) experiential learning. Each of these is defined by a list of attributes generated by the participants (Sutherland & Hemming, 2009, p. 183). Finally, the researchers synthesized these components and themes into a two-dimensional grid (C1-C4 on the vertical axis, T1-T4 on the horizontal axis) as a framework for a cross-cultural science education strategy (a "life long learning model;" p. 187).

Although the *educational* value of integrating Indigenous knowledge into the school science curriculum is supported by empirical evidence, the *political* value of Indigenous knowledge in school science goes against global interests that assert a narrowly defined, mono-cultural, Eurocentric science curriculum (Ryan, 2008; Sillitoe, 2007).

The Case of Saskatchewan

The political will to ignore global pressures and to implement cross-cultural school science is being accomplished in several provinces in Canada, especially in the Province of Saskatchewan. The Ministry of Education embarked upon a renewal of its learning program beginning in 2005. One of the five foundations for renewal was the integration of First Nations, Métis, and Inuit content, perspectives, and ways of knowing into all curricula to encourage the engagement and success of Indigenous students, and at the same time, to enhance the quality of school science for non-Indigenous students.

Renewed Science Curriculum Framework

Based on the Pan-Canadian Science Framework (CMEC, 1997), the renewed K-12 science curriculum[5] was designed for students to achieve scientific literacy within a context that embraces Euro-Canadian and Indigenous heritages, both of which have developed an empirical and rational knowledge of nature. The Saskatchewan vision of scientific literacy is articulated through a framework that includes four foundations of scientific literacy: STSE,[6] attitudes, skills, and knowledge. Student learning outcomes, based on these four foundations, are organized into four units of study at each grade; a life science unit, two physical science units, and an Earth or space science unit. The breadth and depth of each outcome is shown through a representative list of indicators. Unlike other provinces at this time, the knowledge foundation includes *Indigenous knowledge*. In other words, Indigenous knowledge is recognized along with Eurocentric science's conventional disciplines as a legitimate way to understand the physical world. This knowledge is not addressed as a stand-alone unit of study or an add-on to a unit of study, but is integral to each of the four units of study at each grade in an attempt to avoid tokenism.

Another key aspect of the renewed curriculum (represented by the four inner terms in Figure 1) is the four learning contexts: scientific inquiry, technological problem solving, STSE decision making, and cultural perspectives. These learning contexts reflect different ways of engaging students in inquiry within a unit of study. In many ways, the learning contexts are the "how" of the curriculum whereas the four foundations of scientific literacy are the "what."

Figure 1 fits here.

The *cultural perspectives* learning context reflects a humanistic perspective that views teaching and learning as cultural transmission and acquisition (Aikenhead, 2006a). It conveys the fact that Eurocentric science is culturally anchored in paradigmatic communities of practice, most of which are Eurocentric in character, just as Indigenous knowledge is anchored in local,

[5] Saskatchewan's curriculum is on-line at www.curriculum.gov.sk.ca.

[6] STSE refers to a science-technology-society-environment approach to science education. It has been a major feature of Saskatchewan's science curriculum since 1989.

placed-based Indigenous cultures. Both knowledge systems are culture-based. To successfully engage students in developing scientific literacy through the learning context of cultural perspectives, teachers need to honour protocols for obtaining knowledge from a Knowledge Keeper, and to take responsibility for learning that knowledge. For example, a teacher may learn a story related to seasons, but may only be granted permission to tell this story at a particular time of year, and in a particular context. This learning context emphasizes experiential learning which begins with observation of phenomena in the natural world. In Grade 6, students may begin their study of flight by observing the flight patterns of birds and insects in collaboration with a Knowledge Keeper, as opposed to an instructional approach wherein the teacher begins by teaching about the four forces that act on flying objects.

Science Curriculum Renewal

The process of renewing Saskatchewan's science curriculum began with Grades 6-9 in 2008. A key element of this process involved consultation with several stakeholders, including an advisory committee representing teachers, directors of education, the Federation of Saskatchewan Indian Nations, the Northern Teacher Education Program and both science and science education professors from the province's three universities, including the First Nations University of Canada. The role of this committee was to provide feedback to the Ministry of Education on drafts of the Science 6-9 curriculum throughout the renewal process.

A second key element was piloting of draft curriculum in schools across the province, including First Nations band schools and rural and urban schools with Aboriginal teachers. During this two-year piloting process, teachers provided specific feedback about the individual outcomes and indicators. In some cases feedback focused on First Nations and Métis ways of knowing, such as the recommendation to change one outcome from "Examine First Nations and Métis lifestyles and worldviews as they relate to ecosystems" to "Relate key aspects of Indigenous knowledge to their understanding of ecosystems." In this change, the word "their" was being purposefully chosen to reflect the breadth of an Indigenous perspective on ecosystems. Other recommendations included adding indicators such as "Show how First Nations and Métis art and storytelling highlight understanding of and respect for birds" to signify both the oral nature of Indigenous culture and the ways in which art is used to convey understanding.

Indigenous knowledge content was introduced in ways that relate to the required science topics at each grade. For example, the Indigenous presupposition that everything in the universe is imbued with living Spirit is introduced in a life science unit when the concepts of living and non-living are taught. The two knowledge systems are contrasted (e.g., a holistic monist unity compared with a reductionist dualist dichotomy, respectively). Another example tells of the tragic social disruptions to Indigenous communities caused by some hydro-electric dams built in Saskatchewan; stories introduced when scientific concepts of electricity are taught.

While the curriculum renewal was underway, a separate committee was formed to examine how educators and the education system might take up place-based Indigenous science and apply it within the established school curriculum. Committee members included many of the representatives from the Ministry's advisory committee, along with Aboriginal teachers and educators representing other institutions such as the Gabriel Dumont Institute and the Aboriginal Education Research Centre at the University of Saskatchewan. Along with providing recommendations about outcomes and indicators, this group conducted research into the importance of place-based learning in Indigenous science (e.g., Michell, 2005; Michell et al., 2008). This research provided an opportunity for Saskatchewan First Nations and Métis communities to share their stories of learning from place and to give voice to essential elements of Indigenous worldviews. These results informed a re-write of the philosophical underpinnings of the foundations of scientific literacy in the overview to Science 6-9, particularly the section on science, technology, society, and the environment (STSE) interrelationships. Although few wording changes were made from the original source of the curriculum framework (CMEC, 1997), these represent important changes in thinking.

A major challenge for the Ministry was to name and succinctly describe each knowledge system. Following the lead of the International Council for Science (ICSU, 2002), "traditional knowledge" was defined as:

> a cumulative body of knowledge, know-how, practices and representations maintained and developed by [Indigenous] peoples with extended histories of interaction with the natural environment. These sophisticated sets of understandings, interpretations and meanings are part and parcel of a cultural complex that encompasses language, naming and classification systems, resource use practices, ritual, spirituality and worldview. (p. 9)

This general description helps teachers understand its essence. Later, a consensus among Indigenous advisors in the Ministry of Education formed around using the name "Indigenous knowledge." A new section was added to the curriculum overview that briefly explained the importance of Indigenous knowledge.

In keeping with the Pan-Canadian Framework (CMEC, 1997), the conventional name "science" was continued, rather than introducing a new term such as "Eurocentric science." Its description was decided upon by recognizing an extraordinarily strong parallel between the scientific enterprise (as understood from a humanistic perspective) and the ICSU's definition of traditional knowledge. One essential difference between the two knowledge systems is the centrality of spirit in Indigenous worldviews whereas this concept is not present in the definition of "science."

Curriculum documents respect the integrity of Indigenous knowledge as being different from, yet complementary to, science. Both knowledge systems have similarities, differences, strengths, and limitations. Validation of one knowledge system by the other is avoided, but common ground between the two systems is emphasized, for example, their very similar general descriptions, mentioned just above.

The curriculum renewal process required collaboration with Indigenous groups to ensure cultural and political validity of Indigenous knowledge included in the curriculum. Given the reality that the four units of study at each grade level were pre-determined by the Pan-Canadian Science Framework established by all of the provinces and territories (CMEC, 1997), Indigenous groups in Saskatchewan were asked to find connections, if possible, between a scientific topic and Indigenous knowledge that could be associated with those pre-determined topics. In this way, Indigenous people in Saskatchewan negotiated what Indigenous knowledge would be appropriate for the renewed science curriculum.

Because Indigenous knowledge is place-based, specific Indigenous content in the curriculum is valid only for the place from which it came. Therefore, a teacher might teach specific curriculum details as Indigenous knowledge belonging to a specific region or nation. Or even better (as urged by the Ministry of Education), a teacher will develop a relationship with an Elder or other Knowledge Keepers in the community, show them the Indigenous knowledge in the science curriculum, and enlist their help in determining what local knowledge should be taught instead, and how it should be taught. For instance, if Plains Cree information about the physical elements of Mother Earth (earth, water, wind, and fire) appears in the curriculum, and if a science teacher has Dëne students, then the teacher will need to collaborate with a Dëne Elder or Knowledge Keeper to determine what equivalent Dëne content might be added to the curriculum's Plains Cree content. Many Indigenous communities in Saskatchewan are ready to support science teachers this way (Michell et al., 2008). In other words, responsibility for teacher professional learning will be shared in large measure by local Knowledge Keepers.

Customized Science Textbooks

Science textbooks have been developed to support teachers' enactment of this cross-cultural curriculum. Pearson Education Canada (the textbook publisher) and the Ministry of Education collaborated to form an advisory council consisting of Cree, Dëne, Dakota, and Nakawē (Saulteaux) Elders and Knowledge Keepers. Given that the majority of this group had not worked with each other in the past, initial meetings focused on developing a rapport and trust among the parties with a specific commitment that knowledge shared would not be misappropriated. Once these ground rules were established, the advisory council provided the teacher-authors with an overview of some Indigenous knowledge that was related to each of the curricular topics.

The teacher-authors also conducted their own research into Indigenous knowledge related to certain Eurocentric science topics. Some teachers relied on the internet while others enlisted the help of local Knowledge Keepers, in a manner described above. In addition, one teacher who had extensive prior experience working with Indigenous people agreed to serve as a liaison between the groups throughout the process. He began by visiting all the Elders and Knowledge Keepers in advance of the first advisory council meeting, in order to follow traditional protocols for asking for their guidance. Once the writing process began he shared rough drafts of textbook chapters with the Elders and Knowledge Keepers so they could provide more detailed feedback.

This liaison teacher also interviewed one Elder or Knowledge Keeper about the content related to each unit in the textbook. The interviews were summarized, and each summary appears in a section entitled "Ask an Elder" or "Ask a Traditional Knowledge Keeper." An Elder's ideas were reinforced by integrating those ideas with Eurocentric science topics where appropriate, always making clear that both the Elders' ideas and scientific ideas are complementary. Precise wording became important. The statement "Things are either living or non-living" could be rewritten as: "In the world of science, things are either living or non-living." And the expression "Elders believe that all things are alive" could be rewritten as: "Elders know that everything in Mother Earth is alive with Spirit." The rewrites are sometimes subtle, but they have powerful consequences for an inclusive cross-cultural classroom environment.

Before the textbook manuscripts were considered ready for editing by the publisher, they were vetted by the Elders in a day-long face-to-face discussion with the authors and publisher, on two separate occasions. This process ensured Indigenous validity to what is printed as Indigenous knowledge. Consequently the resulting textbooks tend to avoid typical neo-colonial problems (e.g., tokenism) discovered in other science textbooks (Ninnes, 2000).

The Saskatchewan science textbooks emphasize knowledge *about* Indigenous perspectives on nature because specific Indigenous knowledge is mostly gained experientially on a holistic pathway towards wisdom-in-action – the process or journey known as coming to know (Cajete, 1999, 2000). The wisdom tradition of coming to know contrasts with Eurocentric science's intellectual tradition in which knowledge is fragmented and can be passively learned, accumulated, and assessed by written examinations. The experiential process of coming to know is possible in school science but only when local Knowledge Keepers initially help the science teacher with the content and pedagogy.

The grades 6 and 7 textbooks (Brockman, Doepker, Stephenson, Wallace, & View, 2009; Johanson, Mohr, Treptau, Wallace, & View, 2009) became available in schools by mid 2009, in time for September implementation of the curriculum. The Grade 8 textbook (Boulton, Grockman, Johanson, Wallace, & View, 2010) was published in May 2010. The Grade 9 textbook is in development and is expected to be published in January 2011. Similar innovative publications may occur for other grades in the near future.

Conclusion

A most significant development in science education since 2006 has been the substantial beginning towards decolonizing a provincial science curriculum through collaboration and negotiation with the province's Indigenous communities. Saskatchewan chose to integrate Indigenous and scientific ways of knowing nature in school science for two reasons: (1) both knowledge systems are foundational to understanding the 21st century's natural and constructed worlds that all students inhabit, and (2) economic progress and social justice cannot abide the current under representation of Indigenous students in secondary and tertiary science-related programs.

The decision to implement a decolonizing science curriculum requires a significant commitment to providing suitable resources and professional learning for all teachers. Customized science textbooks, developed in partnership with the province's Indigenous communities, provide practical examples of Indigenous knowledge, perspectives, and ways of knowing as a starting point for teachers. Elders and Knowledge Keepers provide another layer of support through sharing their place-based knowledge as it relates to the topics in the science curriculum and issues of importance to the local community.

Most science educators who have undertaken culturally responsive science teaching for Indigenous students talk about the improved science instruction for their non-Indigenous students. A teacher's culturally responsive instruction, while maintaining the same high expectations of academic success, turns out to be an improvement for most Indigenous and non-Indigenous students alike. Cross-cultural school science with a decolonizing curriculum is about improving the scientific literacy of all students.

By exploring the new territory of cross-cultural science education, much has been learned yet much more remains to be accomplished by Saskatchewan's Ministry of Education. Hopefully more case studies of developing and implementing a decolonizing science curriculum will soon be published in the spirit of cooperation among education authorities. The experiences of other educational jurisdictions can help pave the way for a pan-Canadian consensus on the decolonization of the school science curriculum. Its educational soundness is well established; the political will is emerging with increased momentum.

References

Aikenhead, G.S. (2000). *Rekindling Traditions: Cross-cultural science & technology units*. Retrieved March 10, 2010, from http://www.usask.ca/education/ccstu/.

Aikenhead, G.S. (2002). Cross-cultural science teaching: *Rekindling Traditions* for Aboriginal students. *Canadian Journal of Science, Mathematics and Technology Education*, *2*, 287-304.

Aikenhead, G.S. (2006a). *Science education for everyday life: Evidence-based practice*. New York: Teachers College Press.

Aikenhead, G.S. (2006b). Towards decolonizing the pan-Canadian science framework. *Canadian Journal of Science, Mathematics and Technology Education*, *6*, 387-399.

Aikenhead, G.S., & Michell, H. (2011). *Bridging cultures: Indigenous and scientific ways of knowing nature*. Toronto: Pearson Education Canada.

Aikenhead, G.S., & Ogawa, M. (2007). Indigenous knowledge and science revisited. *Cultural Studies of Science Education*, *2*, 539-620.

Albright, J., Towndrow, P.A., Kwek, D., & Tan, A-L. (2008). Identity and agency in science education: Reflections from the far side of the world. *Cultural Studies of Science Education*, *3*, 145-156.

Atkin, J.M. (2007). What role for the humanities in science education research? *Studies in Science Education*, *43*, 62-87.

Atkin, M., & Helms, J. (1993). Getting serious about priorities in science education. *Studies in Science Education*, *2I*, 1-20.

Barnhardt, R., Kawagley, A.O., & Hill, F. (2000). Cultural standards and test scores. *Sharing Our Pathways*, *5*(4), 1-4.

Battiste, M. (2002). *Indigenous knowledge and pedagogy in First Nations education: A literature review with recommendations*. Ottawa: Indian and Northern Affairs Canada.

Beaudet, G. (1995). *Nehiyawe mina Akayasimo, Akayasimo mina Nehiyawe ayamiwini masinahigan* (Cree – English Dictionary). Winnipeg, Canada: Wuerz Plublishing.

Belczewski, A. (2009). Decolonizing science education and the science teacher: A White teacher's perspective. *Canadian Journal of Science, Mathematics and Technology Education*, *9*, 191-202.

Bennett, M. (1986). A developmental approach to training for intercultural sensitivity. *International Journal of Intercultural Relating*, *10*, 179-195.

Boulton, J., Brockman, A., Johanson, T., Wallace, M., & View, T. (2010). *Saskatchewan science 8.* Toronto: Pearson Education Canada.

Brandt, C.B. (2008). Discursive geographies in science: Space, identity, and scientific discourse among Indigenous women in higher education. *Cultural Studies of Science Education*, *3*, 703-720.

Brayboy, B.M.J., & Castagno, A.E. (2008). How might Native science inform "informal science learning? *Cultural Studies of Science Education*, *3*, 731-750.

Brockman, A., Doepker, C., Stephenson, E., Wallace, M., & View, T. (2009). *Saskatchewan science 7*. Toronto: Pearson Education Canada.

Brown, B.A., & Spang, E. (2008). Double talk: Synthesizing everyday and science language in the classroom. *Science Education*, *92*, 708-732.

Cajete, G.A. (1999). *Igniting the sparkle: An Indigenous science education model*. Skyand, NC: Kivaki Press.

Cajete, G.A. (2000). *Native science: Natural laws of interdependence*. Santa Fe, NM: Clear Light.

Carlone, H.B. (2004). The cultural production of science in reform-based physics: Girls' access, participation and resistance. *Journal of Research in Science Teaching*, *41*, 392-414.

Chigeza, P. (2008). Language negotiations Indigenous students navigate when learning science. *Australian Journal of Indigenous Education*, *37*, 91-97.

Chinn, P.W.U. (2006). Preparing science teachers for culturally diverse students: Developing cultural literacy through cultural immersion, cultural translators and communities of practice. *Cultural Studies of Science Education*, *1*, 367-402.

Chinn, P.W.U. (2007). Decolonizing methodologies and Indigenous knowledge: The role of culture, place and personal experience in professional development. *Journal of Research in Science Teaching*, *44*, 1247-1268.

Chinn, P.W.U. (2008). *Malama I Ka 'Aina: Sustainability through Traditional Hawaiian Practices*. Honolulu, HI: University of Hawai'i at Mānoa. Retrieved January 3, 2009, from http://malama.hawaii.edu/.

CMEC (Council of Ministers of Education, Canada). (1997). *Common framework of science learning outcomes K to 12*. Toronto, ON: Author.

Cobern, W.W. (1993). College students' conceptualizations of nature: An interpretive world view analysis. *Journal of Research in Science Teaching*, *30*, 935-951.

Cobern, W.W. (1996). Worldview theory and conceptual change in science education. *Science Education*, *80*, 579-610.

Cobern, W.W. (2000). *Everyday thoughts about nature*. Boston: Kluwer Academic.

Cobern, W.W., & Aikenhead, G.S. (1998). Cultural aspects of learning science. In B.J. Fraser & K.G. Tobin (Eds.), *International handbook of science education* (pp. 39-52). Dordrecht, The Netherlands: Kluwer Academic.

Costa, V.B. (1995). When science is "another world": Relationships between worlds of family, friends, school, and science. *Science Education*, *79*, 313-333.

Eisenhart, M., Finkel, E., & Marion, S. (1996). Creating the conditions for scientific literacy: A re-examination. *American Educational Research Journal*, *33*, 261-295.

Glasson, G.E., Mhango, B.A, Phiri, A.D., & Lanier, M. (2010). Sustainability science education in Africa: Negotiating indigenous ways of living with nature in the third space. *International Journal of Science Education*, *32*, 125-141.

Hatcher, A., Bartlett, C., Marshall, A., & Marshall, M. (2009). Two-Eyed Seeing in the classroom environment: Concepts, approaches, and challenges. *Canadian Journal of Science, Mathematics and Technology Education*, *9*, 141-153.

Herbert, S. (2008). Collateral learning in science: Students' responses to a cross-cultural unit of work. *International Journal of Science Education*, *30*, 979-993.

ICSU (International Council for Science). (2002). *Science, traditional knowledge and sustainable Development*. Paris, France: Author.

Jegede, O.J., & Okebukola, P.A. (1991). The relationship between African traditional cosmology and students' acquisition of a science process skill. *International Journal of Science Education*, *13*, 37-47.

Johanson, R, Mohr, P., Treptau, C., Wallace, C., & View, T. (2009). *Saskatchewan science 6*. Toronto: Pearson Education Canada.

Keane, M. (2008). Science education and worldview. *Cultural Studies of Science Education*, *3*, 587-613.

Lewthwaite, G., & McMillan, B. (2007). Combing the views of both worlds: Perceived constraints and contributors to achieving aspirations for science education in Qikiqtani. *Canadian Journal of Science, Mathematics and Technology Education*, *7*, 355-376.

Lewthwaite, G., & Renaud, F. (2009). *Pilimmaksarniq*: Working together for the common good in science curriculum development and delivery in Nunavut. *Canadian Journal of Science, Mathematics and Technology Education*, 9, 154-172.

Löfgren, L., & Helldén, G. (2009). A longitudinal study showing how students use a molecule concept when explaining everyday situations. *International Journal of Science Education*, *31*, 1631-1655.

Lubben, F., & Campbell, B. (1996). Contextualizing science teaching in Swaziland: Some student reactions. *International Journal of Science Education*, *18*, 311-320.

Lyons, T.S. (2006). The puzzle of falling enrolments in physics and chemistry courses: Putting some pieces together. *Research in Science Education*, *36*, 285-311.

Lyver, P.O'B., Jones, C., & Moller, H. (2009). Looking past the wallpaper: Considerate evaluation of traditional environmental knowledge by science. *Journal of the Royal Society of New Zealand*, *39*, 219-223.

McKinley, E. (2007). Postcolonialism, indigenous students, and science education. In S.K. Abell & N.G. Lederman (Eds.), *Handbook of research on science education* (pp. 199-226). Mahwah, NJ: Lawrence Erlbaum.

McKinley, E., Stewart, G., & Richards, P. (2004). *Mäori knowledge, language and participation in mathematics and science education*. (Final Report). Hamilton, Aotearoa New Zealand: University of Waikato, School of Education.

Medina-Jerez, W. (2008). Between local culture and school science: The case of provincial and urban students from eastern Colombia. *Research in Science Education*, 38, 189-212.

Menzies, C.R. (Project Leader) (2003). *Forests and oceans for the future*. Vancouver, Canada: Department of Anthropology, University of British Columbia. Retrieved February 27, 2010, from http://www.ecoknow.ca.

Michell, H. (2009). Introduction to the special issue on Indigenous science education from place: Best practices on Turtle Island. *Canadian Journal of Science, Mathematics and Technology Education*, *9*, 137-140.

Michell, H., Vizina, Y., Augustus, C., & Sawyer, J. (2008). *Learning Indigenous science from place: Research study examining Indigenous-based science perspectives in Saskatchewan First Nations and Métis community contexts*. Ottawa, Canada: Canadian Council on Learning. Retrieved March 10, 2010, from http://www.ccl-cca.ca/pdfs/FundedResearch/Michell-FinalReport-14Nov2008-AbL2006.pdf

Ogawa, M. (1995). Science education in a multi-science perspective. *Science Education*, *79*, 583-593.

Ogunniyi, M.B. (2007). Teachers' stances and practical arguments regarding a science-Indigenous knowledge curriculum. *International Journal of Science Education*, *29*, 963-986.

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections*. London: The Nuffield Foundation.

Reiss, M.J. (2004). Students' attitudes towards science: A long-term perspective. *Canadian Journal of Science, Mathematics and Technology Education*, *4*, 97-109.

Rennie, L.J. (2007). Learning science outside of school. In S.K. Abell & N.G. Lederman (Eds.), *Handbook of research on science education* (pp. 125-167.). Mahwah, NJ: Lawrence Erlbaum.

Richards, J., Hove, J., & Afolabi, K. (2008). *Understanding the Aboriginal/Non-Aboriginal gap in student performance: Lessons from British Columbia* (Commentary No. 276). Toronto: C.D. Howe Institute.

Richards, J., & Scott, M. (2009). *Aboriginal education: Strengthening the foundations* (CPRN Research Report). Ottawa, Canada: Canadian Policy Research Networks. Retrieved March 6, 2010, from http://www.cprn.org/documents/51984_EN.pdf.

Ryan, A. (2008). Indigenous knowledge in the science curriculum: Avoiding neo-colonialism. *Cultural Studies of Science Education*, *3*, 663-683.

Schreiner, C., & Sjøberg, S. (2007). Science education and youth's identity construction: Two incompatible projects? In D. Corrigan, J. Dillon, & R. Gunstone (Eds.), *The re-emergence of values in science education* (pp. 231-247). Rotterdam: Sense Publishers.

Scott, P., Asoko, H., & Leach, J. (2007). Student conceptions and conceptual learning in science. In S.K. Abell & N.G. Lederman (Eds.), *Handbook of research on science education* (pp. 31-56.). Mahwah, NJ: Lawrence Erlbaum.

Shanahan, M-C. (2009). Identity in science learning: Exploring the attention given to agency and structure in studies of identity. *Studies in Science Education*, *45*, 43-64.

Sharpe, A., & Arsenault, J-F. (2009). *Investing in Aboriginal education in Canada: An economic perspective* (CPRN Research Report). Ottawa, Canada: Canadian Policy Research Networks. Retrieved March 6, 2010, from http://www.cprn.org/documents/51980_EN.pdf.

Sillitoe, P. (Ed.) (2007). *Local science vs. global science: Approaches to Indigenous knowledge in international development*. New York: Berghan Books.

Snively, G., & Corsiglia, J. (2001). Discovering indigenous science: Implications for science education. *Science Education*, *85*, 6-34.

Snively, G.J., & Williams, L.B. (2008). "Coming to know": Weaving aboriginal and Western science knowledge, language, and literacy into the science classroom. *L1 – Educational Studies in Language and Literature, 8*(1), 109-133.

Statistics Canada (2008). *Aboriginal peoples in Canada in 2006: Inuit, Métis and First Nations census* (Release no. 5: January 15). Retrieved January 18, 2008, from http://www12.statcan.ca/english/census06/release/aboriginal.cfm.

Stewart, G. (2005). Mäori in the science curriculum: Developments and possibilities. *Educational Philosophy and Theory*, *37*, 851-870.

Stonechild, B. (2007). *The new buffalo: The struggle for Aboriginal post-secondary education in Canada*. Winnipeg, Canada: University of Manitoba Press.

Sutherland, D.L. (2005). Resiliency and collateral learning in science in some students of Cree ancestry. *Science Education*, *89*, 595-613.

Sutherland, D.L., & Henning, D. (2009). Ininiwi-Kiskānītamowin: A framework for long-term science education. *Canadian Journal of Science, Mathematics and Technology Education*, *9*, 173-190.

Suzuki, D. (1997). *The sacred balance: Rediscovering our place in nature*. Vancouver, Canada: Greystone Books.

Vickers, P. (2007). Ayaawx: In the path of our ancestors. *Cultural Studies of Science Education*, *2*, 592-598.

Wallace, C. S. (2004). Framing new research in science literacy and language use: Authenticity, multiple discourses, and the "third space." *Science Education*, 88, 901-914.

Wood, A., & Lewthwaite, B. (2008). Mäori science education in Aotearoa New Zealand: He pütea whakarawe: Aspirations and realities. *Cultural Studies of Science Education*, *3*, 625-654.

Figure 1. The Renewed Saskatchewan Science Curriculum Framework