Science, Culture and[1] Citizenship: Cross-Cultural Science Education

Ciência, Cultura e Cidadania:
Educação em Ciências Transcultural.

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Abstract

My paper has three purposes: (1) to explore an alternative to the conventional mono-cultural science curriculum in schools narrowly defined by Eurocentric science; (2) to consider the benefits that accrue from a school science curriculum that recognizes the knowledge of nature held by an Indigenous culture as being foundational to understanding the physical world; and (3) to illustrate this cross-cultural school science by what we are accomplishing in Saskatchewan, Canada. From an anthropological perspective, science can be seen as anchored in Euro-American cultures (i.e., Eurocentric science), regardless of the cultural identities of non-Euro-American professional scientists. The vast majority of students experience school science as a foreign culture, but their teachers do not treat it that way. Culture clashes for socially marginalized students in society (e.g., Indigenous students) are particularly pronounced. Conventional school science discriminates against their culture's way of knowing nature and alienates many of them in science classrooms. A cross-cultural school science, on the other hand, does not accept the hegemony of Eurocentrism, but instead seeks ethical, social, ecological, and economic rewards for all students and citizens as a consequence to implementing a cross-cultural curriculum that recognizes Indigenous knowledge as being foundational to understanding nature.In the province of Saskatchewan, Canada, we are implementing a science curriculum that introduces some

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Indigenous knowledge of nature into conventional school science. The provincial school science curriculum is now a pluralistic curriculum that stipulates content to be studied from two knowledge systems (Eurocentric and Indigenous). Eurocentric-Indigenous, cross-cultural, science curricula need to be developed in countries with a history of colonization. Implementation involves science teachers who build cultural bridges between their Eurocentric science culture and a local Indigenous culture.

key words: cross-cultural, Indigenous, school science

Resumo

Meu trabalho possui três objetivos: (1) explorar uma alternativa para o currículo de ciências convencionais mono-cultural nas escolas estritamente definidas pela ciência eurocêntrica, (2) considerar os benefícios que se obtêm a partir de um currículo escolar que reconhece o conhecimento da natureza realizada por uma cultura indígena como sendo fundamental para a compreensão do mundo físico, e (3) ilustrar esta ciência escolar transcultural, que estamos realizando em Saskatchewan, Canadá. De uma perspectiva antropológica, a ciência pode ser vista como ancorada nas culturas euro-americana (ou seja, a ciência eurocêntrica), independentemente da identidade cultural não-euro-americana dos cientistas profissionais. A grande maioria dos estudantes experienciam a ciência escolar como uma cultura estrangeira, mas os professores não a tratam dessa maneira. Confrontos Culturais para estudantes socialmente marginalizados (por exemplo, os estudantes indígenas) são particularmente pronunciadas. A ciência escolar convencional discrimina sua cultura de conhecer a natureza e afasta muitos deles nas aulas de ciências. A ciência escolar transcultural, por outro lado, não aceita a hegemonia do eurocentrismo, mas sim se preocupa com recompensas ético, social, ecológica e econômica para todos os alunos e cidadãos, como consequência da implementação de um currículo multicultural, que reconhece conhecimento indígena como sendo fundamental para a compreensão da natureza. Na província de Saskatchewan, no Canadá, estamos a implementar um currículo de ciências, que introduz alguns conhecimentos indígenas sobre a natureza da ciência em escolas convencionais. O currículo de ciências da escola provincial agora é um currículo plural que determina o conteúdo a ser estudado a partir de dois sistemas de conhecimento (eurocêntrica e indígenas). Eurocêntrica indígenas, currículos transculturais de ciências, precisam ser desenvolvidos em países com uma história de colonização. A implementação envolve os professores de ciências para construir pontes culturais entre a sua cultura eurocêntrica e a cultura indígena local.

Palavras-chave: transcultura, indígena, ciência escolar.

Introduction

My paper has three purposes: (1) to explore an alternative to the conventional science curriculum in schools narrowly defined by the mono-culture of science; (2) to describe the benefits of a *cross-cultural* school science curriculum that recognizes and respects the knowledge held by Indigenous cultures as being foundational to understanding the physical world; and (3) to illustrate such a cross-cultural school program by what we are accomplishing in Canada. I speak from a cultural perspective on science education because it offers insights into enhancing all students' preparation for citizenship, for both Indigenous[2] and non-Indigenous students (Aikenhead 2006, 2009a,b; Hammond & Brandt, 2004).

One insight is the realization that science itself is shaped by its Eurocentric origins and Euro-American evolution (Aikenhead, 2006, Ch. 2; 2009b). Thus, this knowledge system can be identified by the phrase *Eurocentric sciences* (plural) to capture its ethnicity and heterogeneity. Eurocentric sciences are first and foremost anchored in culture, especially in the culture of colonizing nations that advance globalization today (Sillitoe, 2007).

Another insight concerns the meaning of the word 'science' itself. I draw upon Ogawa (1995) to define 'science,' not from the usual Universalist stance but from a Pluralist (multi-science) stance. Science is *a rational, empirically based way of describing or explaining nature*. This definition recognizes that most world cultures have a science. For example, there are Eurocentric sciences, Indigenous sciences, neo-indigenous sciences[3], and personal sciences that students often bring into the classroom as preconceptions (Aikenhead & Ogawa, 2007). A Pluralist perspective should not be confused with relativism (McKinley, 2007).

The word 'science' in the Anglophone world has privileged a very narrow meaning: Science is what scientists do, which is usually assumed to be the canonical science programs at universities. When did this meaning come into use? In 1831, a few British natural philosophers deliberately invented a new meaning for the word 'science' for very political reasons when they founded the British Association for the Advancement of Science (BAAS) (MacLeod & Collins, 1981). Their new social institution needed a new brand (as we would say today) to distinguish itself from natural philosophers of the Royal Society and from technologists who saw natural philosophers as handmaidens to future industrial revolutions (Aikenhead, 2006, Ch. 2). The BAAS's political manoeuvre to create a new meaning for the word 'science' transformed what was natural philosophy into professionalized science. 'Science' translates into Portuguese as 'ciência,' but I am unsure if the meanings are identical. In 1867, the BAAC defined the structure of school science by formulating a science curriculum for the Anglophone world. We have lived with that structure ever since.

Equally political to the BAAS innovation of 1867, I expand its mono-cultural meaning of 'school science' to include at least two cultural ways of knowing nature – Eurocentric and Indigenous – for the 21st century.

Conventional School Science

First, I want to quickly review what conventional school science means to most students in Brazil and Canada. School science attempts to enculturate all students into the culture of Eurocentric science disciplines, replete with their canonical knowledge, techniques, and values. In other words, many science teachers want all students to think like a scientist, behave like a scientist, and believe what scientists are purported to believe (Eisenhart et al., 1996).

But teachers will certainly fail; except for the small proportion of students who, like ourselves, have worldviews that harmonize with the worldviews endemic to Eurocentric sciences.

[2] The term 'Indigenous' encompasses worldwide the original inhabitants of a place who have suffered colonization. Indigenous peoples include, for instance, Canada's First Nations peoples and the *Povos Indígenas no Brasil*.

[3] The term 'neo-indigenous' refers to original inhabitants of a place who have not, by and large, experienced colonization, for instance, Islamic science, Chinese science, a Japanese way of knowing nature, and the intimate ecological knowledge of long-standing inhabitants such as farmers (Aikenhead & Ogawa, 2007). In Brazilian Portuguese, this is more like the word "*Nativa*."

However, most students' worldviews differ, to varying degrees, from the worldview conveyed by conventional school science (Cobern & Aikenhead, 1998). The research on this issue was synthesized as follows (Aikenhead, 2006; 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 in Scott and colleagues' (2007) review of research into learning science concepts. These 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 tend to experience school science as a foreign culture, but their teachers do not treat it that way. To be successful, these students must, without teacher assistance, learn to cross a cultural border between their own culture and the culture of academic school science. A majority of students end up feeling alienated (Costa, 1995). This happens in spite of supportive influences on student learning (Shanahan, 2009). Therefore, teachers will certainly fail if they try to enculturate *all* students into a Eurocentric science.

The culture of conventional school science has failed in five ways (Aikenhead, 2006).

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.
2. School science tends to alienate students whose cultural identities differ from the culture of school science (mentioned above); and those students who live outside the cultural power structures that sustain schooling and traditional school science, for instance, visible minorities, women, and economically depressed groups.
3. Although students grasp scientific ideas as needed in out-of-school settings (Rennie, 2007), they generally fail to learn academic science content meaningfully in school. This was recently illustrated by a 10-year longitudinal study in which only 20% of the participants 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), or to achieve on international tests to make their country look good. "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, 2006, 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.

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

School Science for Indigenous Students

In countries with a history of colonial oppression, such as Canada and Brazil, these five failures are magnified for Indigenous students whose home culture differs dramatically from the culture of school science (Aikenhead, 1997, 2009a,b; Cajete, 2000; McKinley, 2005). School science overtly and covertly marginalizes them by its ideology of neo-colonialism – a process that systemically undermines the cultural values of a formerly colonized group (Ryan, 2008). This causes several inequalities: in high school enrolment, in participation in post-secondary science-related programs, in employment in science-related sectors of society (e.g., resource-based careers, medical practitioners, engineers, and scientists), and in their participation as citizens in the social fabric of their country. This in turn causes economic, social, and political disadvantages for Indigenous communities (McKinley, 2007). The issue is complex because many factors influence under representation, including: generations of colonial oppression, systemic poverty, chronic under funding by governments, and adverse living circumstances. These factors undermine a family's support for their children's success in education.

Although science educators do not have influence over these factors, they do have jurisdiction over the degree to which students are forced to experience marginalization or alienation in science classes. One way to understand this phenomenon is to appreciate the culture clashes and border crossings that most Indigenous students face daily.

Comparing Eurocentric Science and Indigenous Knowledge

Eurocentric sciences are not value neutral. They encompass values, presuppositions, and ideologies. These are subtly embedded in Eurocentric sciences to varying degrees and can conflict with values, presuppositions, and ideologies of Indigenous ways of knowing nature (Aikenhead, 2006, 2009c; Aikenhead & Ogawa, 2007; Aikenhead & Michell, 2010; Cajete, 1999). For instance, conventional school science often conveys notions of Cartesian duality to justify reductionistic and mechanistic practices that celebrate *power and dominion over nature*. To participate in this culture, Indigenous students are expected to set aside or devalue their Indigenous ways of knowing nature. Their ways are "coming to know" wisdom, rather than the Eurocentric accumulation of knowledge (Cajete, 1999, 2000). Indigenous knowledge combines the ontology of monism and spirituality with the epistemology of place-based, holistic, relational, and empirical practices in order to celebrate *harmony with nature* for the purpose of survival (Aikenhead & Michell, 2010; Aikenhead & Ogawa, 2007; Michell, 2005).

Eurocentric science knowledge expresses a more narrow *intellectual tradition* of thinking, while Indigenous knowledge expresses a *wisdom tradition* of thinking, living, and being (Aikenhead & Michell, 2010). Broadly speaking, an intellectual tradition emphasizes individual cognition exemplified by Descartes' famous dictum 'I think; therefore I am.' On the other hand, a wisdom tradition emphasizes group-oriented ways of being, exemplified by 'We are, therefore I am,' and practised by living in harmony with Mother Earth.

The two worldviews are ontologically and epistemologically incommensurate, although they share some fundamental epistemological features, such as being culture-based, empirical, experimental, rational, metaphorical, communal, and dynamic over time. The two perspectives share common ground with some fundamental values, such as honesty, perseverance, inquisitiveness, open-mindedness, logic, aesthetic beauty, creativity, intuitiveness, and precision (Aikenhead, & Michell, 2010; Cajete, 2000).

This common ground, however, is contextualized by each group's respective culture. For example, both knowledge systems are rational, but their rationality is culture-laden; that is, Indigenous rationality and Eurocentric rationality. The two knowledge systems differ in several other ways to varying degrees, as summarized in Table1 (Aikenhead & Michell, 2010). The categories in Table1 interrelate with each other; they do not represent separate isolated ideas. Thus, some repetition occurs because some ideas belong in two or more of the arbitrary categories. The table emphasizes the complementary ways Indigenous knowledge and scientific knowledge deal with nature. They need not conflict with each other. In addition, the differences shown in Table1 can either highlight strengths or they can acknowledge limitations in a knowledge system, depending upon one's point of view and upon the specific situation in which the knowledge is used. For example, in the category "Association with human action," the characteristic of Indigenous knowledge may have an advantage over Eurocentric sciences in many resource management deliberations, but in the category "Type of validity," the characteristic of scientific knowledge will certainly have an advantage over Indigenous knowledge in determining energy flow in an industrial system.

In summary, different cultures have diverse ways of describing and explaining nature, and they often have unique ways of designing artefacts and processes for human use (Semali & Kincheloe, 1999). Euro-American cultures have privileged Eurocentric science and have exported it worldwide as an icon of prestige, power, and progress within the ideologies of colonialism and globalization (Sillitoe, 2007). Eurocentric science is indeed a powerful predictor in several contexts of natural phenomena, which makes it an attractive tool for medical, industrial, corporate, and military interests. But at the same time, Euro-American nations have had a habit of colonizing the world and appropriating or obliterating Indigenous knowledge systems for the purpose of advancing a European ideology of human power and dominion over nature (Mendelsohn & Elkana, 1981). These nations have held an ideology that equated materialistic growth with progress (Suzuki, 1997). Their cognitive imperialism continues today as neo-colonialism in school science (Ryan, 2008; Sillitoe, 2007) and threatens a country's move towards sustainability.

* Based on Aikenhead & Michell (2010).

General perspective	Monist, spiritual, relational, and intuitive descriptions/explanations of nature, *compared with* dualist, materialist, non-relational, and often mechanistic descriptions/explanations of nature
Social goals	Communal wisdom-in-action for the survival of the group, family, or community, *compared with* an individual's scientific credibility; and many other social goals defined by the context of the scientific work, such as medical advances and progress in a Western capitalist society
Assumptions	Mother Earth is mysterious and is in continual flux, *compared with* nature is knowable and constant, but changes in consistently knowable patterns
Intellectual goals	Co-existence with the mysteries of Mother Earth by celebrating mystery through the maintenance of a host of interrelationships, *compared with* eradication of mystery by describing and explaining nature in ways acceptable to a community of scientists
Fundamental value	Harmony with Mother Earth by balancing a web of interrelationships for survival, *compared with* power and dominion over nature
Association with human action	Intimately, subjectively, morally, and ethically related to human action with respect to seven generations to come, *compared with* formally and objectively refrains from normative prescriptions of human action
Notion of time	Cyclical – there is no beginning and no ending, *compared with* rectilinear
Concepts of knowledge	Holistic, relational, and place-based, *compared with* reductionism, anthropocentrism, and the goal of generalizability
Type of validity	Content validity as defined by Aristotle's notion of intelligible essences, and supported by tens of thousands of years of survival based on that content, *compared with* predictive validity as anticipating observations accurately; the cornerstone of natural philosophy and Eurocentric sciences since the 16^{th} century
Learning goals	Learning to become whole and complete (mentally, spiritually, emotionally, and physically), *compared with* learning a repository of knowledge (mentally and physically).

Table1. Differences between Indigenous Knowledge and Scientific Knowledge, Respectively *

Cross-Cultural School Science

As established above, differences between Indigenous and scientific knowledge systems often create a severe culture clash for Indigenous students whose worldview, culture, and home language differ from those in their science classes. Many feel unwelcome in school science.

When school science fails to nurture students' Indigenous identities or fails to strengthen their resiliency, most Indigenous students resist their science teacher's instruction, no matter how relevant that instruction may be to non-Indigenous students. When we try to force a solely Eurocentric science curriculum on all Indigenous students, we engage in neo-colonialism. To end that practice, science educators become involved in issues of equity, social justice, and sustainable economic growth; all of which speak to the sovereignty and cultural survival of Indigenous peoples as citizens fully participating in their country.

A neo-colonial school science curriculum excludes Indigenous knowledge of nature. But an inclusive school science for Indigenous students teaches Indigenous knowledge in culturally responsive ways, as we are currently undertaking in Canada (described in detail below). This requires a *cross-cultural* school science curriculum that promotes postcolonialism[4] (Aikenhead, 1997, 2001, 2006, 2009a; McKinley, 2007). Indigenous students learn to master and critique Eurocentric ways of knowing nature without, in the process, sacrificing their own culturally constructed ways of knowing.

A culturally responsive curriculum nurtures "walking in both worlds" – Indigenous and Eurocentric (Cajete, 1999). Similarly, in the Mi'kmaw nation of Canada some Elders talk about "two-eyed seeing" that emphasizes the strengths of both knowledge systems (Hatcher et al., 2009). By walking in both worlds or by two-eyed seeing, Indigenous students gain cultural capital essential for accessing power as citizens in a Eurocentric dominated world (e.g., the capability to appropriate knowledge from Eurocentric science and technology, as needed) 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 is 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.

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. 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, their wisdom tradition will help ensure sustainable progress if government, business, industry, resource management, and health sectors embrace a Pluralist perspective on science (Snively & Corsiglia, 2001). The

[4] The term 'postcolonism' does not mean that colonialism has ended; but rather, it means that colonialism is explicitly recognized and efforts are made to diminish and extinguish its power. A postcolonial attitude helps teachers avoid misunderstandings when including Indigenous knowledge in school science (Barnhardt, 2006).

two knowledge systems are complementary. Scientists and engineers can expand their perspectives on nature and augment their problem solving skills by learning from the knowledge of nature held by an Indigenous culture. In addition, they will come to appreciate the ontology, epistemology, and axiology of their own Eurocentric science when they contrast it with an Indigenous knowledge system of another culture, as in Table 1.

The success of cross-cultural science education will be measured, in part, by the number of students who have avoided indoctrination or assimilation into a Eurocentric way of thinking, but who have learned to appropriate the tools of Eurocentric science for their everyday lives (Aikenhead, 2006). Students' cultural self-identities will be strengthened as they learn to master and critique Eurocentric scientific ways of knowing. Success will come when we avoid tokenism, indoctrination, and neo-colonialism. Our aim is to nurture students' scientific literacies (the plural is intended) so students can successfully walk in at least two worlds: their community's Indigenous culture and the global community's Eurocentric science. In other words, cross-cultural school science can aim to have all students *understand* how scientists think, behave, and believe without being expected to think, behave, and believe that way themselves (Aikenhead, 2009b).

Related Research

One key educational issue worldwide is whether or not Indigenous knowledge is recognized and valued in the science curriculum. Research studies have empirically demonstrated the educational soundness of cross-cultural school science (Aikenhead, 2000, 2001, 2006, 2009a; Barnhardt et al., 2000; Herbert, 2008; Keane, 2008; McKinley et al., 2004). Worldwide, these decolonizing projects recognize, respect, and explicitly include Indigenous knowledge in school science. Their cultural and political validity is assured by having Indigenous groups decide what content should appear in the local science curriculum, and by following appropriate local protocols.

There are alternatives to alienating students in science classrooms. Medina-Jerez's (2008, p. 209) research in Columbia, for instance, concluded 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." In Canada, the *Rekindling Traditions* project (Aikenhead, 2000) developed a community-based process for producing cross-cultural science units. Science teaching that ignores cultural alienation and does not acknowledge cultural differences (including epistemological, ontological, and axiological differences) will fail most students.

What are the components to successful cross-cultural school science programs for Indigenous students? To answer this question, researchers Sutherland and Hemming (2009) in Canada carried out a literature analysis study and then an interactive action-research project with 50 cross-cultural science educators from schools. Their results are of interest to Brazilian researchers who can repeat the second part of the study with Brazilian communities. Sutherland and Hemming's literature analysis led to four components to successful programs:

C1. coming to know (signifies a personal, participatory, constructive, and holistic process towards gaining wisdom-in-action – an Indigenous alternative to Eurocentric learning.)

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 Canadian Indigenous science education, Sutherland and Hemming facilitated a series of discussions that began with the participants' reaction to the four points 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 table (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).

When teaching cross-cultural school science, teachers learn to build bridges between their own Eurocentric science culture and their students' local Indigenous culture (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).

Although the *educational* value of Indigenous knowledge in cross-cultural school science is supported by empirical evidence, the *political* value of Indigenous knowledge in school science goes against global interests the assert a narrowly defined, mono-cultural, Eurocentric science curriculum (Aikenhead, 2006; 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[5]. To reduce the culture clashes for Indigenous students, and at the same time, to enhance the quality of school science for non-Indigenous students, the science curriculum was changed in 2008. The Ministry of Education renewed its K-12 curriculum to include four components: STSE,[6] attitudes, skills, and knowledge. Unlike other provinces at this time, the knowledge component comprises life science, physical science, earth/space science, and *Indigenous knowledge*; that is, Indigenous knowledge is recognized along with Eurocentric sciences' conventional disciplines.

This renewed curriculum also defined four contexts in which instruction of these components is to take place: scientific inquiry, technological problem solving, STSE decision making, and cultural perspectives. The context "cultural perspectives" conveys the fact that science is culturally anchored in paradigmatic communities of practice, most of which are Eurocentric in

[5] In Canada, education is a provincial responsibility and our 13 Ministries of Education vigilantly guard their authority over the curriculum and teachers.

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

character, just as Indigenous knowledge is anchored in local, placed-based Indigenous cultures. Saskatchewan's curriculum renewal occurred in consultation with several stakeholders, including: a committee of science educators from schools and universities, a committee of Elders representing the various nations of Indigenous peoples in Saskatchewan, and selected teachers who implemented pilot projects.

These changes first occurred in grades 6-9. Curriculum indicators and outcomes for Indigenous knowledge were formulated with the guidance of Indigenous scholars and Elders, academic literature, and place-based research findings (e.g., Michell, 2005; Michell et al., 2008); and then revised, according to the advice of Indigenous school educators. Indigenous knowledge content was introduced in ways that relate to a science topic. 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. Curriculum documents respect the integrity of Indigenous knowledge as being different from, and complementary to, Eurocentric sciences. 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.

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 explicitly. 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 collaborate with a Dëne Elder to determine what might replace 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 development will be shared in large measure by local Indigenous knowledge keepers.

Science textbooks have been written to support teachers' enactment of this cross-cultural curriculum. Elders were employed by the textbook publisher (Pearson Education Canada) to explain Indigenous knowledge to the teacher-authors before they began writing. Some Elders were later interviewed about topics associated with some of the content found in the textbook units. (Four Eurocentric science units comprise each grade level, and one Elder was interviewed for each unit.) The interviews were summarized, and each summary appears in a section entitled "Ask an Elder." An Elder's ideas were reinforced by integrating them with Eurocentric science topics where appropriate, always making clear that the Elders' ideas are complementary to the scientific ideas. For instance, 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 classroom environment.

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 Indigenous knowledge keepers, in a manner described above.

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, and the process avoided typical neo-colonial problems 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; in other words, 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 became available in schools by mid 2009, in time for the September implementation. Grades 8 and 9 are in development. Similar developments will occur for all other grades in the near future.

References

Aikenhead, G.S. (1996). Science education: Border crossing into the subculture of science. *Studies in Science Education*, *27*, 1-51.

Aikenhead, G.S. (1997). Toward a First Nations cross-cultural science and technology curriculum. *Science Education*, *81*, 217-238.

Aikenhead, G.S. (2000). *Rekindling Traditions: Cross-cultural science & technology units*. Retrieved October 5, 2009, from http://www.usask.ca/education/ccstu/.

Aikenhead, G.S. (2001). Integrating Western and Aboriginal sciences: Cross-cultural science teaching. *Research in Science Education*, *31*, 337-335.

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

Aikenhead, G.S. (2009a). De quem é o conhecimento cientifico? O colonizador e o colonizado. Em G.S. Aikenhead, *Educação científica: Para todos* (147-163). Ramada, Portugal: Edições Pedago, Lda.

Aikenhead, G.S. (2009b). Educação cientifica: O cruzamento de fronteiras rumo à subcultura da ciência. Em G.S. Aikenhead, *Educação científica: Para todos* (85-146). Ramada, Portugal: Edições Pedago, Lda.

Aikenhead, G.S. (2009c). Os aspectos humanísticos e culturais do ensino da ciênci & tecnologia. Em G.S. Aikenhead, *Educação científica: Para todos* (49-83). Ramada, Portugal: Edições Pedago, Lda.

Aikenhead, G.S., & Michell H. (2010, in press). *Building cultural bridges: Indigenous and scientific ways of knowing nature*. Don Mills, Ontario, Canada: Pearson Education Canada.

Barnhardt, R. (2006). *Teaching/learning across cultures: Strategies for success*. Retrieved October 8, 2009, from http://ankn.uaf.edu/curriculum/Articles/RayBarnhardt/TLAC.html.

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.

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.

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.

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.

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.

Hammond, L., & Brandt, C. (2004). Science and cultural process: Defining an anthropological approach to science education. *Studies in Science Education*, *40*, 1-47.

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*(3), 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.

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

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.

MacLeod, R., & Collins P. (Eds.) (1981) *The parliament of science*. Northwood, Midx., UK: Science Reviews.

McKinley, E. (2005). Locating the global: Culture, language and science education for indigenous students. *International Journal of Science Education*, *27*, 227-241.

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.

Mendelsohn, E., & Elkana, Y. (Eds.). (1981). *Sciences and cultures: Anthropological and historical studies of the sciences*. Sociology of the Sciences Yearbook, Vol. 5. Boston: Reidel.

Michell, H. (2005). Nēhîthâwâk of Reindeer Lake, Canada: Worldview, epistemology, and relationships with the natural world. *Australian Journal of Indigenous Education*, *43*, 33-43.

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 July 31, 2009, from http://www.ccl-cca.ca/pdfs/FundedResearch/Michell-FinalReport-14Nov2008-AbL2006.pdf

Ninnes, P. (2000). Representations of indigenous knowledges in secondary school science textbooks in Australia and Canada. *International Journal of Science Education*, *22*, 603-617.

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.

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.

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.

Semali, L.M., & Kincheloe, J.L. (1999). *What is indigenous knowledge? Voices from the academy*. New York: Falmer Press.

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.

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.

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. (Contact: d.sutherland@uwinnipeg.ca)

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