Integrating Western and Aboriginal Sciences: Cross-Cultural Science Teaching

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Abstract

The article addresses issues of social power and privilege experienced by Aboriginal students in science classrooms. First, I present a rationale for a cross-cultural science education dedicated to all

students making personal meaning out of their science classrooms. Then I describe a practical R&D project, "Rekindling Traditions: Cross-Cultural Science & Technology Units," that modestly illustrates cross-cultural science teaching for grades 6-11, in which Western and Aboriginal sciences are integrated. This integration is discussed in terms of the "Rekindling Traditions" units, including the assessment of students.

Towards a Cross-Cultural Science Education

In 1975, Smolizc and Nunan called for "the demythologizing of school science" in response to school science conveying an ideology that exalted Western science over all other ways of knowing. This ideology assumed that science was purely objective, solely empirical, immaculately rational, and thus, singularly truth confirming. Since 1975, other scholars have delineated myths associated with the validity and authority of Western science, myths that comprise an ideology now called "scientism" (Nadeau and Désautels, 1984; Ogawa, 1998; Ziman, 1984). Scientism is scientific fundamentalism (science is the only valid way of knowing).

Of particular interest to science educators is the finding that science teachers tend to harbour a strong allegiance to values associated with scientism, for instance, science is: non-humanistic, objective, purely rational and empirical, universal, impersonal, socially sterile, and unencumbered by the vulgarity of human bias, dogma, judgments, or cultural values (Aikenhead, 1985; Brickhouse, 1990; Gallagher, 1991; Gaskell, 1992). Scientism seems to penetrate students' minds, like a hidden curriculum, when students learn to "think like a scientist" and take on other "habits of the mind;" goals emphasized in recent reform documents (AAAS, 1989; Millar and Osborne, 1998; NRC, 1996). These science curricula attempt to enculturate all students into the value system of Western science.

Enculturation is not a problem for a small minority of students whose worldviews resonate with the scientific worldview conveyed most frequently in school science (Cobern & Aikenhead, 1998). These "Potential Scientists" *want to* think like scientists (Costa, 1995). They embrace enculturation into Western science (Aikenhead, 1996; Hawkins & Pea, 1987). Enculturation is not a problem for Potential Scientists.

For the vast majority of students, however, enculturation into Western science is experienced as an attempt at assimilation into a foreign culture. Because students generally reject assimilation into the culture of Western science (Aikenhead, 1996), they tend to become alienated from Western science in spite of it being a major global influence on their lives. Alienation reduces their effectiveness at

"legitimate peripheral participation" in community matters related to science and technology (Roth & McGinn, 1997). As adults, alienated students will not possess the cultural capital to participate effectively in Western society.

The problem of alienation is more acute for Aboriginal students whose worldviews, identities, and mother tongues create an even wider cultural gap between themselves and school science (Cajete, 1986, 1999; Christie, 1991; Fleer, 1997; Harris, 1978; Linkson, 1998; McKinley et al., 1992; Snively, 1990; Sutherland, 1998). For centuries, attempts to assimilate Aboriginal peoples into Western societies (i.e. colonization) have had disastrous consequences (Battiste, 2000; Churchill, 1999; Hodson, 1998; MacIvor, 1995; McTaggert, 1991; Roberts & Wills, 1998). Any further attempt to assimilate Aboriginal students into Western science continues this colonization and raises issues of social power and privilege in the science classroom.

A socio-cognitive model of teaching and learning was proposed by O'Loughlin (1992) to clarify social power and privilege in science classrooms. Based on the social cognitive work of Delpit (1988), Lave (1988), and Wertsch (1991), O'Loughlin persuasively claimed:

> To the extent that schooling negates the subjective, socioculturally constituted voices that students develop from their lived experience... and to the extent that teachers insist that dialogue can only occur on their terms, schooling becomes an instrument of power that serves to perpetuate the social class and racial inequities that are already inherent in society. (p. 816)

O'Loughlin's model for equity science education is an alternative to the conventional, assimilative, authoritative discourse that transmits scientific knowledge and values to students. O'Loughlin focused on "dialogical meaning making" in the context of social power, thereby sharing the transformative goals of critical pedagogy (Freire, 1970):

> Dialogical meaning making occurs when the learner is influenced by the text, but is also allowed the space to play an active role in developing a personally constructed understanding of the author's or teacher's message through a process of dialogic interchange. (O'Loughlin, 1992; p. 813)

The discourse of instruction O'Loughlin proposed involves more than the conventional literacy for comprehension (reading the lines in science textbooks to infer comprehension, usually to pass exams and acquire credentials). His discourse of instruction is more than literacy for critical thinking (reading between the lines to infer hidden assumptions, alternatives, and changes of meaning). For O'Loughlin one learns "to *participate* in the culture of power, while simultaneously learning how to

reflect critically on the power relations of which they are a part" (p. 807, italics in the original). His discourse of instruction is more like van der Plaat's (1995) reading between the lines of privileged discourse to infer what ontology has been culturally constructed by that discourse and to understand that ontology in terms of its relationship to one's own culturally determined ontology. This type of literacy is very much needed by many Aboriginal students (Cajete, 1999; MacIvor, 1995; McKinley, 1996).

Although O'Loughlin's (1992) socio-cognitive model of meaning making addresses social power and privilege in the classroom, it does not explicitly treat meaning making from a *cultural* perspective. This, I argue, is a severe limitation of the model.

A cultural perspective on science education is founded on several assumptions listed but not fleshed out here: (1) Western science is a cultural entity itself, one of many subcultures of Euro-American society; (2) people live and coexist within many subcultures identified by, for example, language, ethnicity, gender, social class, occupation, religion and geographic location; (3) people move from one subculture to another, a process called "cultural border crossing;" (4) people's core cultural identities may be at odds with the culture of Western science to varying degrees; (5) science classrooms are subcultures of the school culture; (6) most students experience a change in culture when moving from their life-worlds into the world of school science; therefore, (7) learning science is a cross-cultural event for these students; (8) students are more successful if they receive help negotiating their cultural border crossings; and (9) this help can come from a teacher (a culture broker) who identifies the cultural borders to be crossed, who guides students back and forth across those borders, who gets students to make sense out of cultural conflicts that might arise, and who motivates students by drawing upon the impact Western science and technology have on the students' life-worlds. The assumptions posited here are described in detail in Aikenhead (1996, 1997, 1998), Aikenhead and Jegede (1999), and Jegede and Aikenhead (1999). These assumptions underlie a cross-cultural approach to science teaching; "two-way learning" (Fleer, 1997) or "both-ways education" (McTaggert, 1991).

A cultural approach to teaching and learning engages students in cultural negotiations (Christie, 1991, 1997; Stairs, 1993/94). Negotiation occurs in a context where learning science is experienced as "coming to knowing," a phrase borrowed from Aboriginal educators (Ermine, 1998; Peat 1994). Coming to knowing is reflected in participatory learning: "If the living, experiencing being is an intimate participant in the activities of the world to which it belongs, then knowledge is a mode of

participation" (Dewey, 1916, p. 393). The world in which most Aboriginal students participate is not a world of Western science, but another world increasingly influenced by Western science and technology.

Coming to knowing engages Aboriginal students in their own cultural negotiations among several sciences found within their school science. Four such sciences were identified by Ogawa (1995). First, students reflect on their own understanding of the physical and biological world. Second, students come to know the Aboriginal commonsense understanding held by their community. Third, students may encounter ways of knowing of another culture, including other Aboriginal peoples. Fourth, students are introduced to the norms, beliefs, values and conventions of Western science — the culture of Western science. Negotiating among these four sciences in school science is known as "multi-science education" (Ogawa, 1995). Cross-cultural science teaching facilitates these negotiations. Coming to knowing is about developing cultural identity and self-esteem (Cajete, 1999; McKinley, 1998; McKinley et al., 1992; Richie & Butler, 1990).

As mentioned above, a cultural approach to science education recognizes that learning Western science for most Aboriginal students is a cross-cultural event. Students move from their everyday cultures associated with home to the culture of Western science (Aikenhead, 1996, 1997, 1998; Phelan et al., 1991). These transitions, or border crossings (to use Giroux's [1992] metaphor), are smooth for "Potential Scientists," are manageable for "Other Smart Kids," but are most often hazardous or impossible for everyone else (Costa, 1995). Success at learning the knowledge of nature of another culture depends, in part, on how smoothly one crosses cultural borders. Too often students (Aboriginal and non-Aboriginal alike) are left to manage border crossings on their own (Phelan et al., 1991). Most students require assistance from a teacher, similar to a tourist in a foreign land requiring the help of a tour guide. In short, a science teacher needs to play the role of a tour-guide culture broker (Aikenhead, 1997).

Such a culture broker understands that Western science has its own culture because scientists generally work within an identifiable set of cultural attributes: "an ordered system of meanings and symbols, in terms of which social interaction takes place" (a definition by cultural anthropologist Geertz, 1973, p. 5). More specifically, the scientific community generally has its own language, beliefs, values, conventions, expectations, and technology. These attributes define a culture (Aikenhead, 1996). For Western science, these attributes are identified as "Western" because of the fact that the culture of Western science evolved within Euro-American cultural settings (Pickering,

1992; Rashed, 1997; Roberts, 1998). The culture of Western science today exists within many nations, wherever Western science takes place.

A culture-brokering science teacher makes border crossings explicit for Aboriginal students by acknowledging students' personal preconceptions and Aboriginal worldviews that have a purpose in, or connection to, students' everyday culture. A culture broker identifies the culture in which students' personal ideas are contextualized, and then introduces another cultural point of view, that is, the culture of Western science, *in the context of* Aboriginal knowledge. At the same time, a culture broker must let students know what culture he/she is talking in at any given moment (e.g. Aboriginal science or Western science), because as teachers talk they can unconsciously switch between cultures, much to the confusion of many students. (Aikenhead, 1997, 2000b; Linkson, 1998).

To facilitate students' border crossings, teachers and students both need to be flexible and playful, and to feel at ease in the less familiar culture (Lugones, 1987). This will be accomplished differently in different classrooms. As O'Loughlin (1992) argued, it has a lot to do with the social environment of the science classroom, the social interactions between a teacher and students, and the social interactions among students themselves. Thus, a teacher who engages in culture brokering should promote discourse (Cobern & Aikenhead, 1998; Driver et al., 1994) so students are provided with opportunities to engage in the following three types of activity: (1) students should have opportunities for talking within their own life-world cultural framework without sanctions for being "unscientific;" (2) students should have opportunities for being immersed in either their everyday Aboriginal culture or the culture of Western science as students engage in some activity (e.g. problem solving or decision making in an authentic or simulated event); and (3) students should be consciously aware of which culture they are participating in at any given moment.

Effective culture brokers substantiate and build on the validity of students' personally and culturally constructed ways of knowing (Michie et al., 1998; Pomeroy, 1994). Sometimes bridges can be built in various ways between cultures (Cajete, 1999; McKinley, 1998), other times ideas from one culture can be seen as fitting within the ideas from another culture. Whenever apparent conflict between cultures arises, it is dealt with openly and with respect.

For Aboriginal students especially, it would be helpful if a culture broker were to address Western science's social, political, military, colonial, and economic roles in history (Hodson, 1998; Linkson, 1998; McKinley et al., 1992). Smooth border crossings cannot occur if a student feels that he or she is associating with "the enemy" (Cobern, 1996). By acknowledging Western science's historical

roles in the colonization of Aboriginals, a teacher can address Aboriginal students' conflicting feelings toward the culture of Western science, thus making a student feel more at ease with learning and with appropriating that subculture's content without accepting its values and ideologies. In short, a culture-brokering science teacher identifies the colonizer and the colonized, and teaches the science of each culture (Aikenhead, 1997; Snively & Corsiglia, 2001). This key aspect of cross-cultural science education acknowledges the issues of social power and privilege in the science classroom.

Cross-Cultural Science Education as Praxis: "Rekindling Traditions"

What does cross-cultural science teaching for Aboriginal students look like in a classroom? We were not sure ourselves, so we initiated an R&D project, "Rekindling Traditions," to explore this new territory. A collaborative team of six science teachers from across northern Saskatchewan, Canada, and myself as facilitator (plus technical personnel, Elders, and other people in the teacher's local community) developed instructional strategies and units of study to support teachers wishing to become culture brokers in grades 6-11 science classrooms (Aikenhead, 2000a). Two of the teachers were Aboriginal. All teachers had a personal interest in developing their cross-cultural teaching skills further.

Our work was initially based on recommendations found in the literature for teaching school science to Aboriginal students (Allen & Crawley, 1998; Baker, 1996; Cajete, 1986; Ganambarr, 1982; Harris, 1978; Kawagley, 1995; Linkson, 1998; MacIvor, 1995; McKinley at al., 1992; Michie et al., 1998; Ritchie & Kane, 1990; Snively, 1995). For example, we consistently sought the wisdom of one Elder, although different Elders have helped the team at different times. One product of our R&D project was six cross-cultural science and technology units (described below). We also produced a "Teacher Guide" plus a document that describes our interactions with the community, "Stories from the Field." Funding came from a variety of sources and was sufficient to support the project for two calendar years (1999-2000). Teachers received a modicum of release time for research and writing in their community (nine days) and for attending six, two-day, work meetings. As the project evolved, the focus of each meeting changed from identifying themes to editing units to planning in-service workshops. Interestingly, progress was achieved only when the teachers interacted face to face, or when I interacted with them personally in their communities.

An important feature of our Rekindling Traditions project was the community's involvement in helping decide what is worth learning in school science. An Aboriginal way of knowing, defined by

the community itself, formed the foundation for each unit. Elders and other knowledgeable people in the community taught local content to students and their teacher, who in turn recorded this knowledge appropriately. The process taught students the proper protocol for gaining access to their community's knowledge and wisdom, and it taught them to value and respect their Aboriginal heritage. The process also meant that teachers learned Aboriginal knowledge, thereby modelling for their students life-long learning.

It is anticipated that other teachers will print out a Rekindling Traditions unit from our CD or web site (Aikenhead, 2000a) and take it to some people in their community who know the topic well. The teacher will then ask, "How could *we* modify this unit so it fits our community?" These local advisory people become a major resource for modifying the unit (or developing a new one) to make it suit the unique culture of the community. These local advisory people will also interact with students in the school or on a field trip.

A community's Aboriginal knowledge has a respected place in our Rekindling Traditions units. Some students discovered that they already possessed some of this Aboriginal knowledge because it had been taught at home, but it was not highly valued as legitimate knowledge for school. On the other hand, other students learned this Aboriginal knowledge for the first time in their science course. Aboriginal knowledge was given voice in the classroom in the dialogic sense of voice described by O'Loughlin (1992) as involving both the speaker and the listener in mutual respect. Each of our units validated "the ways of knowing students bring to school by grounding the curriculum in their voices and lives" (p. 814). A dialogic voice means that a teacher learns from students and from people in the community. Teachers modelled for their students successful border crossing between their own life-world and the culture of the community. In this context, students' Aboriginal identity had a legitimate place in classroom instruction. Cultural negotiation could occur. Coming to knowing had a legitimate place. The discourse of power no longer resided with the teacher. Power was more evenly shared.

Integration of Western and Aboriginal Sciences

A Rekindling Traditions unit brings Western science into the student's worldview rather than insisting that students construct a worldview of a Western scientist. In other words, we try to avoid teaching science in an assimilative way. All the same, students are expected to see the world through the eyes of a Western scientist just as we would expect students to understand another person's point of view, similar to an anthropologist learning about a foreign culture (Aikenhead, 1997).

Although each unit integrates Western and Aboriginal sciences differently, the units share common patterns of integration. For instance, each unit deals with a theme significant to the community. These themes are suggested by the units' titles:

1. *Snowshoes* (in Michif or Cree — Y dialect: *Asâmak*)
2. *Nature's Hidden Gifts* (Cree — Y dialect: *Iyiniw Maskikiy*)
3. *The Night Sky* (Dëne — S dialect: *Tth'ën*)
4. *Survival in Our Land (Cree* — Y dialect*: Kipimâcihowininaw ôta Kitaskînahk*)
5. *Wild Rice* (Algonquin or Cree — Y dialect: *Mânomin*)
6. *Trapping* (Dëne — S dialect: *Ɬts'usi Thëlai*)

The variety of local languages spoken across northern Saskatchewan reflects the diversity of Aboriginal cultures found in those communities. (Within each Aboriginal nation there are distinctive tribes, similar to the tribes — iwi — within the Māori nation.) Teachers have not been successful when they have tried to use materials developed in other Aboriginal communities, for example, materials published by Native Americans in the U.S. (Aikenhead & Huntley, 1999). To be successful, materials must speak to the unique culture of the individual community.

Another common pattern of integration is an Aboriginal framework established at the beginning of each unit. A framework reflects local knowledge. In a later lesson, Western science and technology from the Saskatchewan science curriculum will be introduced to students as useful knowledge from another culture. The introductory Aboriginal content takes the form of practical action relevant to a community, for example, going on a snowshoe hike, finding indigenous plants that heal, listening to an Elder, interviewing people in the community, or assisting in a local wild rice harvest. An introductory framework seems to be most successful when each student feels a direct connection to Mother Earth. A physical, emotional, mental, and spiritual connection helps ensure respect for the community's Aboriginal knowledge and begins to nurture students' coming to knowing.

It is challenging, yet crucial, not to distort local knowledge by making it conform to Western epistemology endemic to school culture. Inadvertent assimilation will take place in a science classroom if the local knowledge is taken out of its epistemic context. Disrespect can occur, for instance, if the teacher ignores the unifying spirituality that pervades Aboriginal epistemology (Ermine, 1995). Spirituality, whether pre-contact Traditional, Roman Catholic, Anglican, or Fundamentalist Christian, has epistemic force for most Aboriginal students even though it is purposefully absent from science classrooms where an adherence to a Cartesian duality is the cultural

convention. It is *not* the case that the community's spirituality is integrated into Western science in our units, but it is the case that the community's spirituality is given voice in the context of Aboriginal knowledge taught in our units. Although content from both cultures is studied for the purpose of understanding it, students are not expected to believe or to personally adopt that content. The culture-brokering teacher simply identifies spirituality in Aboriginal knowledge and identifies its absence in Western science.

Whenever possible, our units point out to students instances of Aboriginal science being distorted by a Western worldview. For example, the cyclic appearance of 13 full moons a year oriented Aboriginal peoples to key natural events of the year. There was no need to be more precise because within Aboriginal cultures, accurate observers of Mother Earth gave a tribe precise information on natural events. The 13 moons were only a secondary organization of yearly events. In the unit *The Night Sky*, we point out an instance of inadvertent assimilation when the topic "Aboriginal calendars" arises. English/Cree dictionaries, for instance, distort Aboriginal knowledge by forcing the 13 moons into 12 months. Very few documents provide the names of all 13 moons. (Appendix A of *The Night Sky* does.) Instead, only 12 moons are mentioned, paired with the 12 months of Western cultures. In short, an Aboriginal worldview is forced to conform to a Euro-Canadian point of view. Aboriginal and Western knowledge is bridged (integrated) in *The Night Sky* by using this example of local knowledge being distorted to fit a Western point of view. Students produce a 13-moon calendar for the year they are presently in (it changes from year to year). They can see with their own eyes how the two different systems (13 moons versus 12 months) co-exist side by side but cannot easily be translated from one to the other, as dictionaries and other documents pretend to do. This exercise sensitizes students to the problem of taking information from one knowledge system and placing it into another knowledge system, out of context.

Another source of conflict arises during the integration of Western and Aboriginal sciences when we translate from one language to another. With the aid of a dictionary or knowledgeable friend, we can translate an English word into, for instance, a Cree word. But we must be mindful that the thing we are actually referring to can change dramatically from one context to the next. For example, in both Western and Aboriginal sciences, people rely on observations. The process "to observe" in English might be translated into "wapahtam" in Cree (Y dialect). But wapahtam signifies two things not conveyed by the English verb "to observe." First, wapahtam suggests only one of five senses (sight) is being used. English is full of words (super-ordinates such as "to observe") that abstract general

categories from more specific ones (observing generalizes seeing, smelling, hearing, tasting, and feeling). The Cree language abstracts ideas quite differently, often through the use of complex verb forms. Secondly, there is an unstated assumption with wapahtam that the person doing the observing and the thing being observed are related in some way. There is no objective distancing in Aboriginal science's wapahtam as there is in the Western scientific "to observe." Therefore, a fundamental relationship changes between "to observe" and "wapahtam," a change not readily apparent on the surface. Each verb is embedded in cultural meanings that differ dramatically. Therefore, strictly speaking there is no accurate translation of "to observe."

Another example of what gets lost in translation is illustrated when we identity an animal as a "wolf." In the culture of Western science one asks, "*What* is a wolf?" — *Canis lupis*. The convention in the culture of Western science is to categorize animals according to a Linnean worldview. As our unit *Trapping* points out, this worldview is useless in the context of survival based on trapping. For trappers, the relevant knowledge is not Linnean classification, but instead, animal behaviour. (Animal behavior has no significance to a Linnean worldview.) Knowledge of a wolf's behavior is embedded in many stories and legends about mahihkan (wolf in Cree). In some Aboriginal cultures, the important question to ask is, "*Who* is mahihkan?" This is clearly a different question from the one posed by Western science (*How* is a wolf classified?). Only superficially does "*Canis lupis*" translate into "mahihkan." For an Aboriginal student familiar with mahihkan, the myriad of images and concepts associated with the word "mahihkan" is very different from the images and concepts science teachers want students to associate with "*Canis lupis.*" Crossing the culture border between Western science and Aboriginal science involves more than simple translation. A culture brokering teacher must be sensitive to the culturally embedded meanings of words in both cultures (e.g. *Canis lupis* and mahihkan).

The Aboriginal introduction to each Rekindling Traditions unit constitutes a framework for the whole unit. Throughout the unit, students will return to this familiar framework as needed. The actual time to establish an Aboriginal framework could be as short as 45 minutes or as long as several days.

Another aspect of integration common to all the units deals with values. Both scientific and Aboriginal values are made explicit in our units. Each lesson plan specifies either a scientific value (e.g. power and domination over nature) or an Aboriginal value (e.g. harmony with nature) to be conveyed by the lesson. In some cases where both cultures are compared within one lesson, both types of values are identified. Values are particularly salient in Aboriginal cultures (Cajete, 1999; Christie,

1991; Roberts & Wills, 1998). The introduction to a Rekindling Traditions unit clarifies key values that Elders expect students to learn. This practice is then extended to the clarification of values that underlie Western science when scientific content is studied later in the unit. Key scientific values become the topic of discussion where they can be critiqued. This tends to circumvent an indoctrination into Western values endemic to assimilative science teaching. Students can learn to identify vestiges of scientism in their textbooks (reading between the lines of privileged discourse; van der Plaat, 1995) and in the conversations of their everyday lives. As the ontology of the Western colonizer becomes more apparent (e.g. the mathematical idealization of the physical world), students are more free to appropriate Western knowledge and technique without embracing Western ways of valuing nature. (See Ogawa's [1996] four-eyed fish metaphor for a Japanese description of such appropriation, and Krugly-Smolska [1994] for other cultures.) This appropriation has been called "autonomous acculturation" (Aikenhead, 1997).

Each value system (Western scientific or Aboriginal) orients a student differently toward nature (Ermine, 1995; McKinley, 1996). The motivation for developing knowledge about nature is fundamentally different in the two cultures. While Western science values revealing nature's mysteries for the purpose of gaining knowledge for the sake of knowledge and material growth, Aboriginal science strives for living with nature's mysteries for the purpose of survival (Aikenhead, 1997; Bindon, 1988; Roberts et al., 1995; Simonelli, 1994; Snively & Corsiglia, 2001). Students' social power and privilege in the classroom increase when students sense a genuine respect for their Aboriginal values (Cajete, 1999).

Having established an Aboriginal framework and having identified key values as contexts for integration, the next mode of integration in a Rekindling Traditions unit is a border crossing event into Western science, *consciously* switching values, language conventions, conceptualizations, assumptions about nature, and ways of knowing. As a culture broker, the teacher clearly identifies the border to be crossed, guides students across that border, and helps students negotiate cultural conflicts that might arise (Aikenhead, 1997).

This border crossing event, and other attributes of a Rekindling Traditions unit (described above), can be illustrated by the unit *Wild Rice*. To begin the unit, local rice harvesters come into the class to talk about their work and to connect students with the local culture. The rice harvesters convey the value "the community's knowledge can be very useful and important." In the following lesson, the teacher follows this up with a systematic overview of the unit that reinforces ideas introduced by the

rice harvesters. Next the class studies the local stories that advise where one should plant wild rice. The class goes to a nearby potential site and plants some seeds. A personal connection to Mother Earth is achieved. The value conveyed here is "respect for traditional knowledge." Border crossing into Western science is initiated in a lesson that follows, called "The Habitat: Western Science Stories about *Zizania palustris*." Biology content is introduced in accordance with the curriculum expectations for the grade being taught. The scientific values underlying these lessons are, for example, "a naming system should be universal (it should work anywhere on the planet)," "math can make observing more precise," "more observations increase our confidence in a result," and "efficiency improves production." The Western science content (e.g. concepts of habitat, niche, competition, pH, electro negativity, percent germination) enhances and enriches the local knowledge by broadening students' perspectives, while at the same time, not requiring students to replace their community's knowledge with scientific knowledge. The differing underlying values of the two knowledge systems suggest to students different assumptions about nature. The unit *Wild Rice* continues with a field trip to a nearby wild rice stand, followed by water analysis studies and lessons on the science and technology of harvesting and of industrial processing. A personal or multimedia tour of a processing plant is included. The unit ends with a study of the nutritional value of foods in which students eat their investigations.

At any moment during any lesson within a Rekindling Traditions unit, students should be able to state which culture they are speaking in (Western science or Aboriginal or local common sense). For instance, students are expected to use the phrase "*Zizania palustris*" or "mânomin" or "wild rice," depending upon which one is appropriate to the context of a discussion. By convention, scientists say "*Zizania palustris*" when they speak Western science, and so should the students when they speak Western science. Cross-cultural teaching in a multi-science classroom makes this explicit. Some teachers use two different black boards — one for Aboriginal science, another for Western science. One board is used to record ideas expressed in the discourse of the community's Aboriginal knowledge, while the other board is used to express the culture of Western science. By switching from one board to the other (cultural border crossing), students consciously switch language conventions and conceptualizations. It is up to the teacher to assess the quality of students' learning associated with each board, but both have a place in the assessment (discussed below). This cross-cultural teaching helps students gain access to Western science without losing sight of their cultural identity.

Another feature of integrating Western and Aboriginal sciences often emerges when a teacher directly compares the two sciences. Sometimes Western science can powerfully clarify one small aspect of Aboriginal science. For instance in the *Snowshoes* and *Trapping* units, the technologies are originally studied from historical and cultural perspectives of the local community. Then the class takes a closer, in-depth, Western scientific look at the pressure exerted by snowshoes on snow and by traps on animals. By understanding the scientific stories about force, pressure, and energy, students learn to predict more accurately the effects of variations in the technology. While the Western science concepts do not improve students' know-how for snowshoeing or trapping, the concepts clarify one small aspect of the overall topic. Western science does not replace Aboriginal science, it enriches a small aspect of it.

As various topics in Western science are studied, additional, relevant, Aboriginal content is introduced. This is easy to do because the unit already has a framework for that content. The Aboriginal content is not just tacked on for the sake of creating interest. It frames the unit in a way that nurtures the enculturation of Aboriginal students into *their community's* culture (Casebolt, 1972; McKinley et al., 1992), not the enculturation into Western science (AAAS, 1989; Millar & Osborne, 1998; NRC, 1996).

The discourse embraced by people engaged in Aboriginal knowledge is very different from the discourse of Western scientists. Both discourses have a function in a Rekindling Traditions unit. As students bring their community's Aboriginal knowledge and values into the classroom, new power relationships replace the conventional colonizer-colonized hierarchy. Students are encouraged to share their coming to knowing with their teacher in a dialogic manner.

Assessment

Nelson-Barber and colleagues (1996) have mapped out the assessment of student achievement found in cross-cultural science teaching. They offer guidance and specific recommendations for developing a culturally responsive assessment system, beginning with the recommendation to treat linguistic and cultural diversity *as strengths*. Teachers in the Rekindling Traditions project found ways for students to express important skills and ideas they learned in their community. The teachers' assessment system rewarded students for doing so. Our units provided ample opportunity to learn community knowledge because the community's knowledge framed each unit. For instance, some students were given class credit for what they did with people in the community (e.g. living on a trap

line). Anecdotal notes were written by the people they worked with, indicating what the students had done. As well, extra credit was sometimes given to students if they wrote some of the classroom content in both English and Cree (or Michif or Dëne).

An example of student assessment from the Navajo (Diné) Nation demonstrated the fruitfulness of portfolio assessment (Nelson-Barber et al., 1996). Portfolios were shown to promote student autonomy and they reflected the cultural *context* of learning, not just the process and product of learning. Thus, coming to knowing is nurtured by portfolio assessment. Other kinds of culturally responsive assessment techniques can be designed rationally (Solano-Flores & Nelson-Barber, 1999; Solano-Flores et al., 1999).

The efficacy of student self-assessment (Black & Atkin, 1996) lends credence to negotiating with Aboriginal students on how school science will be assessed. Without such a negotiation, the balance of social power and privilege reverts back to the colonizer-colonized hierarchy.

Summary

The integration of Western and Aboriginal sciences within our Rekindling Traditions units does not follow any particular mode of integration described in the literature (Beane, 1997; Brownlie, 1991). At different times a unit will use multi-disciplinary, inter-disciplinary, and multicultural approaches to instruction.

In 1992, McKinley and her colleagues argued against a type of integration they called "bicultural science education," an approach supported by Ritchie and Butler (1990) and Ritchie and Kane (1990). Bicultural science teaching included Aboriginal examples and contexts to make Western science more relevant to Aboriginal students, but the approach apparently did not establish an Aboriginal framework for instruction. Instead, this bicultural approach maintained the science curriculum's Western framework as a basis for instruction, though it attempted to increase the self-esteem of Aboriginal students by placing value on their culture. As an alternative to bicultural science education, McKinley and her colleagues (1992) proposed a type of integration they called "bilingual education" where instruction was in Māori and the curriculum was entirely grounded within a framework of "Te Ao Māori," a Māori worldview (McKinley, 1996). McKinley (1996, pp.161-162) delineated various school structures that exist in Aotearoa-New Zealand for Māori education: "mainstream schools, bilingual units or schools, immersion units or schools, and kura kaupapa Māori

(Māori-based schools teaching through the medium of Māori).” Bilingual science education encourages kura kaupapa Māori as an alternative education system.

Our cross-cultural science and technology units lie somewhere between this “bicultural” and “bilingual” education. The units were developed in bilingual (English/Aboriginal) Saskatchewan government schools, not in schools run by Aboriginal governments located on reservations. We feel confident that the units addressed the needs of students because our units were developed in collaboration with key community people by teachers very familiar with the community. The bilingual approach to integration described by McKinley et al. (1992) and elaborated by McKinley (1996) represents the ideal case for Canadian Aboriginal science education, particularly for Aboriginal schools on reservations.

Culturally sensitive Rekindling Traditions units were designed to help Aboriginal students feel that their science courses were a natural part of their lives. Students participated in those units in ways that were culturally meaningful. The units gave students access to Western science and technology without requiring them to adopt the worldview endemic to Western science, and without requiring them to change their own cultural identity. However, for those students who have a natural gift or talent for Western science, a Rekindling Traditions unit lays the foundation and encouragement for further study in science and engineering. In the future, these graduates can play a critical role in strengthening the resource management, health care, and economic development of their Aboriginal community (MacIvor, 1995; McKinley et al., 1992).

For other students, the units identify two important cultures: the culture of their Aboriginal community, and the culture of Western science and technology. In the everyday world, both influence students’ personal cultural identities. The Rekindling Traditions units help students feel at ease in both cultures and help students move back and forth between the two cultures. Fleer (1997, p. 17) concluded, “Moving between world views creates high level thinkers.” Most students have a chance to master and critique aspects of Western science without losing something valuable from their own cultural way of knowing. By achieving smoother border crossings between those two cultures, students are expected to become better citizens in a society enriched by cultural differences. This is an essence of cross-cultural teaching.

Our cross-cultural science and technology units encourage a change in the power relationships between a teacher and his/her Aboriginal students in ways that promote mutual respect, coming to knowing, community involvement, life-long learning, and the ethic of harmony with Mother Earth.

In our cross-cultural approach, Aboriginal knowledge and languages are treated as an *asset* in the science classroom, rather than adopting a deficit model (i.e. an Aboriginal background puts a student at a disadvantage in school science). We recognize the advantages that accrue to Aboriginal students who can see the world from two different perspectives (Aboriginal and Western), and who can choose the one that better fulfills their goals at any given moment. The flexibility to move back and forth between cultures is a definite asset in society today. Some educators call this flexibility "empowerment," others call it walking on two different paths. It can occur when cross-cultural science instruction creates a change in the relationships of social power and privilege in the science classroom.

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References

AAAS. (1989). *Project 2061: Science for all Americans*. Washington, DC: American Association for the Advancement of Science.

Aikenhead, G.S. (1985). Collective decision making in the social context of science. *Science Education, 69*, 453-475.

Aikenhead, G.S. (1996). Science education: Border crossing into the subculture of science. *Studies in Science Education, 27*, 1-52.

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

Aikenhead, G.S. (1998). Many students cross cultural borders to learn science: Implications for teaching. *Australian Science Teachers' Journal*, *44*(4), 9-12.

Aikenhead, G.S. (2000a). "Rekindling traditions: Cross-cultural science & technology units" project. http://capes.usask.ca/ccstu.

Aikenhead, G.S. (2000b). Renegotiating the culture of school science. In R. Millar, J. Leach, & J. Osborne (Eds.), *Improving science education: The contribution of research*. Birmingham, UK: Open University Press.

Aikenhead, G.S., & Huntley, B. (1999). Teachers' views on Aboriginal students learning western and Aboriginal science. *Canadian Journal for Native Education*, *23*, 159-175.

Aikenhead, G.S., & Jegede, O.J. (1999). Cross-cultural science education: A cognitive explanation of a cultural phenomenon. *Journal of Research in Science Teaching, 36*, 269-287.

Allen, J.A., & Crawley, F.E. (1998). Voices from the bridge: Worldview conflicts of Kickapoo students of science. *Journal of Research in Science Teaching, 35*, 111-132.

Baker, D. (1996). Does 'indigenous science' really exist? *Australian Science Teachers' Journal*, *42*(1), 18-20.

Battiste, M. (Ed.) (2000). *Reclaiming Indigenous voice and vision*. Vancouver, BC: University of British Columbia Press.

Beane, J.S. (1997). *Curriculum integration: Designing the core of democratic education*. New York: Teachers College Press.

Bindon, P.R. (1988). Science in Aboriginal Australia. *The Australian Science Teachers' Journal*, *34*(2), 16-21.

Black, P., & Aiken, J.M. (1996). *Changing the subject: Innovations in science, mathematics and technology education*. London: Routledge for OECD.

Brickhouse, N.W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of Teacher Education, 41*(1), 52-62.

Brownlie, F. (1991). Curriculum integration: A challenge of the year 2000. *The Best of Teaching*, *2*(1), 18-21.

Cajete, G.A. (1986). *Science: A Native American perspective*. Unpublished doctoral dissertation, International College, Los Angeles.

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

Casebolt, R.L. (1972). *Learning and education at Zuni: A plan for developing culturally relevant education*. Unpublished doctoral dissertation, University of Northern Colorado, Bolder.

Christie, M.J. (1991). Aboriginal science for the ecologically sustainable future. *Australian Science Teachers Journal*, *37*(1), 26-31.

Christie, M.J. (1997). Notes on ethnoscience and knowledge production: Learning from Australian Indigenous scientists. *Science Teachers Association of the NT Journal*, *16*, 7-12.

Churchill, W. (1999). *Struggle for the land: A Native North American resistance to genocide, ecocide, and colonization*. Winnipeg, Canada: Arbeiter Ring Publishing.
Cobern, W.W. (1996). Worldview theory and conceptual change in science education. *Science Education, 80*, 579-610.
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 Publishers.
Costa, V.B. (1995). When science is "another world": Relationships between worlds of family, friends, school, and science. *Science Education, 79*, 313-333.
Delpit, L. (1988). The silenced dialogue: Power and pedagogy in educating other people's children. *Harvard Educational Review, 58*, 280-298.
Dewey, J. (1916). *Democracy and education: An introduction to the philosophy of education*. New York: Macmillan.
Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher, 23*(7), 5-12.
Ermine, W.J. (1995). Aboriginal epistemology. In M. Battiste & J. Barman (Eds.), *First Nations education in Canada: The circle unfolds* (pp. 101-112). Vancouver, Canada: University of British Columbia Press.
Ermine, W. (1998). Pedagogy from the ethos: An interview with Elder Ermine on language. In L.A. Stiffarm (Ed.), *As we see ... Aboriginal pedagogy* (pp. 9-28). Saskatoon, Canada: University of Saskatchewan Extension Press.
Fleer, M. (1997). Science, technology and culture: Supporting multiple world views in curriculum design. *Australian Science Teachers' Journal, 43*(3), 13-18.
Freire. P. (1970). *Pedagogy of the oppressed*. New York: Herder & Herder.
Gallagher, J.J. (1991). Prospective and practicing secondary school science teachers' knowledge and beliefs about the philosophy of science. *Science Education, 75*, 121-133.
Ganambarr, M. (1982). Thinking about writing an Aboriginal science curriculum. *Aboriginal Child at School*, *10*(5), 38-42.
Gaskell, P.J. (1992). Authentic science and school science. *International Journal of Science Education, 14*, 265-272.
Geertz, C. (1973). *The interpretation of culture*. New York: Basic Books.
Giroux, H. (1992). *Border crossings: Cultural workers and the politics of education*. New York: Routledge.
Harris, J.W. (1978). Aboriginal science, Western science and the problem of conceptual interference. *Australian Science Teachers' Journal*, *24*(3), 61-67.
Hawkins, J., & Pea, R.D. (1987). Tools for bridging the cultures of everyday and scientific thinking. *Journal of Research in Science Teaching, 24*, 291-307.
Hodson, D. (1998). Towards a curriculum framework for multicultural science and technology education. In D. Hodson (Ed.), *Science and technology education and ethnicity: An Aotearoa/New Zealand Perspective* (pp. 11-20). Wellington, New Zealand: The Royal Society of New Zealand.
Jegede, O. (1995). Collateral learning and the eco-cultural paradigm in science and mathematics education in Africa. *Studies in Science Education*, *25*, 97-137.
Jegede, O.J., & Aikenhead, G.S. (1999). Transcending cultural borders: Implications for science teaching. *Research in Science and Technology Education, 17*, 45-66.
Kawagley, O. (1995). *A Yupiaq worldview*. Prospect Heights, IL: Waveland Press.
Krugly-Smolska, E. (1994). An examination of some difficulties in integrating western science into societies with an indigenous scientific tradition. *Interchange, 25*, 325-334.

Lave, J. (1988). *Cognition in practice: Mind, mathematics and culture in everyday life*. Cambridge: Cambridge University Press.

Linkson, M. (1998). Cultural and political issues in writing a unit of western science appropriate for primary aged Indigenous students living in remote areas of the Northern Territory. *Science Teachers Association of the NT Journal*, *18* (Conference Proceedings of conasta 47), 90-100.

Lugones, M. (1987). Playfulness, "world"-travelling, and loving perception. *Hypatia, 2*(2), 3-19.

MacIvor, M. (1995). Redefining science education for Aboriginal students. In M. Battiste & J. Barman (Eds.), *First Nations education in Canada: The circle unfolds* (pp. 73-98). Vancouver, Canada: University of British Columbia Press.

McKinley, E. (1996). Towards an indigenous science curriculum. *Research in Science Education*, *26*, 155-167.

McKinley, E. (1998). Science curricula and cultural diversity: Are we doing enough for the aspirations of Maori? In D. Hodson (Ed.), *Science and technology education and ethnicity: An Aotearoa/New Zealand Perspective* (pp. 48-58). Wellington, New Zealand: The Royal Society of New Zealand.

McKinley, E., McPherson Waiti, P., & Bell, B. (1992). Language, culture and science education. *International Journal of Science Education*, *14*, 579-595.

McTaggert, R. (1991). Western institutional impediments to Australian Aboriginal education. *Journal of Curriculum Studies*, *23*, 297-325.

Michie, M., Anlezark, J., & Uibo, D. (1998). Beyond bush tucker: Implementing Indigenous perspectives through the science curriculum. *Science Teachers Association of the NT Journal*, *18* (Conference Proceedings of conasta 47), 101-110.

Millar, R. & Osborne, J. (Eds.) (1998). *Beyond 2000: Science education for the future*. London: King's College, School of Education.

Nadeau R., & Désautels, J. (1984). *Epistemology and the teaching of science*. Ottawa, Canada: Science Council of Canada.

Nelson-Barber, S., Trumbull, E. & Shaw, J.M. (1996, August). *Sociocultural competency in mathematics and science pedagogy: A focus on assessment*. A paper presented to the 8th Symposium of the International Organization for Science and Technology Education, Edmonton, Canada.

NRC (National Research Council). (1996). *National science education standards*. Washington, DC: National Academy Press.

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

Ogawa, M. (1996). Four-eyed fish: The ideal for non-western graduates of western science education graduate programs. *Science Education, 80*, 107-110.

Ogawa. M. (1998). Under the noble flag of 'developing scientific and technological literacy.' *Studies in Science Education*, *31*, 102-111.

O'Loughlin, M. (1992). Rethinking science education: Beyond Piagetian constructivism toward a sociocultural model of teaching and learning. *Journal of Research in Science Teaching, 29*, 791-820.

Peat, D. (1994). *Lighting the seventh fire*. New York: Carol Publishing Group.

Phelan, P., Davidson, A., & Cao, H. (1991). Students' multiple worlds: Negotiating the boundaries of family, peer, and school cultures. *Anthropology and Education Quarterly, 22*, 224-250.

Pickering, A. (Ed.) (1992). *Science as practice and culture*. Chicago: University of Chicago Press.

Pomeroy, D. (1994). Science education and cultural diversity: Mapping the field. *Studies in Science Education, 24*, 49-73.

Rashed, R. (1997). Science as a western phenomenon. In H. Selin (Ed.), *Encyclopaedia of the history of science, technology, and medicine in non-western cultures* (pp. 884-890). Boston: Kluwer Academic Publishers.

Ritchie, S., & Butler, J. (1990). Aboriginal studies and the science curriculum: Affective outcomes from a curriculum intervention. *Research in Science Education*, *20*, 249-354.

Ritchie, S., & Kane, J. (1990). Implementing Aboriginal content in the science program: A case study. *The Australian Science Teachers' Journal*, *36*(4), 88-91.

Roberts, M. (1998). Indigenous knowledge and Western science: Perspectives from the Pacific. In D. Hodson (Ed.), *Science and technology education and ethnicity: An Aotearoa/New Zealand Perspective* (pp. 59-75). Wellington, New Zealand: The Royal Society of New Zealand.

Roberts, M., Norman, W., Minhinnick, N., Wihongi, D., & Kirkwood, C. (1995). Kaitiakitanga: Maori perspective on conservation. *Pacific Conservation Biology, 2*, 7-20.

Roberts, M., & Wills, P.R. (1998). Understanding Maori epistemology: A scientific perspective. In H. Wautischer (Ed.), *Tribal epistemologies: Essay in the philosophy of anthropology*. Sydney: Ashgate.

Roth, W.-M., & McGinn, M. K. (1997). Deinstitutionalizing school science: Implications of a strong view of situated cognition. *Research in Science Education, 27,* 497-513.

Simonelli, R. (1994). Sustainable science: A look at science through historic eyes and through the eyes of indigenous peoples. *Bulletin of Science, Technology & Society, 14*, 1-12.

Smolicz, J.J., & Nunan, E.E. (1975). The philosophical and sociological foundations of science education: The demythologizing of school science. *Studies in Science Education*, *2*, 101-143.

Snively, G. (1990). Traditional Native Indian beliefs, cultural values, and science instruction. *Canadian Journal of Native Education, 17*, 44-59.

Snively, G. (1995). Bridging traditional science and western science in the multicultural classroom. In G. Snively & A. MacKinnon (Eds.), *Thinking globally about mathematics and science education* (pp. 1-24). Vancouver, Canada: Centre for the Study of Curriculum & Instruction, University of British Columbia.

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

Solano-Flores, G., Jovanovic, J., Shavelson, R.J., & Bachman, M. (1999). On the development and evaluation of a shell for generating science performance assessment. *International Journal of Science Education*, *21*, 293-315.

Solano-Flores, G., & Nelson-Barber, N. (1999, March). *Developing culturally responsive science assessment*. A workshop paper presented to the annual meeting of the National Association for Research in Science Teaching, Boston, MA.

Stairs, A. (1993/94) The cultural negotiation of Indigenous education: Between microethnography and model-building. *Peabody Journal of Education*, *69*: 154-171.

Sutherland, D.L. (1998). *Aboriginal students' perception of the nature of science: The influence of culture, language and gender*. Unpublished Ph.D. dissertation, University of Nottingham, Nottingham, UK.

van der Plaat, M. (1995). Beyond technique: Issues in evaluating for empowerment. *Evaluation*, *1*, 81-96.

Wertsch, J.V. (1991). *Voices of the mind: A sociocultural approach to mediated action*. Cambridge, MA: Harvard University Press.

Ziman, J. (1984). *An introduction to science studies: The philosophical and social aspects of science and technology*. Cambridge: Cambridge University Press.