"COMING TO KNOW": WEAVING ABORIGINAL AND WESTERN SCIENCE KNOWLEDGE, LANGUAGE, AND LITERACY INTO THE SCIENCE CLASSROOM

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ABSTRACT. Following the work of contemporary thinkers, we propose that every culture has its own science and that both indigenous and western science knowledge systems are valuable and have been useful to the cultures developing them. Because a valid interpretation of scientific literacy must be consistent with a prevailing image of science and rapid changes taking place in society, we propose more inclusive definitions and metaphors of science literacy. Science literacy for Aboriginal people must reflect a broad cultural approach that recognizes the unique way Aboriginal people live and present their experience and knowledge. Literacy programs from an Aboriginal perspective must go beyond reading, writing, and numeracy to include oracy – stories, songs, dances, symbols, ceremonies. Science literacy from an Aboriginal perspective involves being knowledgeable about the extensive examples and applications of Aboriginal science knowledge, as well as western science knowledge, and science discourse about the nature of science. Literacy also includes the wisdom component of Aboriginal science, which brings the discussion of values and ethics to science and technology and requires sustaining both community and environment. Aboriginal languages serve as storehouses of experience and perspectives that help maintain cultural identity, resist assimilation, and interpret the relationship between society and environment.

KEYWORDS: Aboriginal, culture, language, science, traditional ecological knowledge

Dutch
Samenvatting [Translated by Tanja Janssen]
In navolging van het werk van hedendaagse denkers gaan wij ervan uit dat iedere cultuur zijn eigen wetenschap heeft en dat zowel inheemse als westerse wetenschappelijk kennissystemen waardevol zijn en nuttig zijn geweest voor de culturen waarbinnen ze zijn ontwikkeld. Omdat een valide interpretatie van wetenschappelijke geletterdheid consistent moet zijn met een algemeen beeld van wetenschap en met de snelle veranderingen in de samenleving, doen we een voorstel voor meer omvattende definities en metaforen voor wetenschappelijke geletterdheid. Wetenschappelijke geletterdheid voor aboriginals moet een brede culturele benadering weerspiegelen, met erkenning van de unieke manier waarop aboriginals leven en hun ervaringen en kennis presenteren. Geletterdheidsprogramma's vanuit een aboriginal perspectief moeten verdergaan dan lezen, schrijven en rekenen; ze moeten ook mondelinge overlevering, verhalen,

Snively, G.J., & Williams, L.B. (2008). "Coming To Know": Weaving Aboriginal and Western Science Knowledge, Language, and Literacy into the Science Classroom
L1 – Educational Studies in Language and Literature, 8*(1), p. 109-133*

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liederen, dansen, symbolen en ceremonieen omvatten. Wetenschappelijke geletterdheid vanuit een aboriginal perspectief betekent: kennis hebben zowel van de uitgebreide voorbeelden en toepassingen van aboriginal wetenschappelijke kennis, als van westerse kennis en de manier waarop over de aard van wetenschap wordt gesproken. Geletterdheid omvat ook de component van wijsheid van aboriginal wetenschap, waarmee het debat over normen en waarden binnen science en technologie wordt gebracht, en die vereist dat zowel de gemeenschap als het milieu worden beschermd. Aboriginal talen dienen als rijke bronnen van ervaring en perspectieven die helpen de culturele identiteit te behouden, assimilatie tegen te gaan en de relatie tussen samenleving en milieu te interpreteren.
Keywords: aboriginal, cultuur, taal, science, traditionele ecologische kennis

French

Résumé [Translated by Laurence Pasa]
A l'instar des penseurs contemporains, nous pensons que chaque culture a sa propre science et que les systèmes de connaissances scientifiques indigènes et occidentaux sont d'égale valeur et ont tout deux été utiles au développement des cultures. Dans la mesure où une interprétation valide de la littérature scientifique doit être en accord avec l'image dominante de la science et les rapides changements de la société, nous proposons des définitions et des métaphores de la littérature scientifique plus inclusives. L'enseignement-apprentissage des sciences pour les populations indigènes doit refléter une approche culturelle ouverte qui identifie les peuples indigènes de manière singulière et présente leurs expériences et leurs connaissances. Dans une perspective indigène, les programmes d'enseignement doivent dépasser la lecture, l'écriture, et le calcul pour inclure l'oralité - histoires, chansons, danses, symboles, cérémonies. Dans une perspective indigène, l'enseignement des sciences suppose de connaître de nombreux exemples et applications des connaissances scientifiques indigènes, aussi bien que les connaissances scientifiques occidentales et le discours épistémologique. L'enseignement-apprentissage inclut également la sagesse comme composante de la science indigène, celle-là même qui lie la science et la technologie à une réflexion sur les valeurs et l'éthique et implique le soutien de la communauté et de l'environnement. Les langues indigènes servent d'entrepôts d'expériences et de perspectives qui aident à maintenir l'identité culturelle, à résister à l'assimilation et à interpréter le rapport entre la société et l'environnement.
Mots-clés: Indigène, culture, langue, science, connaissance écologique traditionnelle

Italian

Abstract. [Translated by Manuela Delfino].
In accordo con le opere dei pensatori contemporanei, affermiamo che ogni cultura abbia la propria scienza e che i sistemi di conoscenza scientifica sia indigeni, sia occidentali abbiano entrambi valore e che sia stato utile per le culture svilupparli. Poiché una buona interpretazione dell'alfabetizzazione scientifica deve essere coerente con l'immagine prevalente della scienza e con i rapidi cambiamenti che avvengono nella società, dell'alfabetizzazione scientifica proponiamo definizioni e metafore con un maggior potere di inclusione. L'alfabetizzazione scientifica per gli aborigeni deve riflettere un ampio approccio culturale che riconosca l'unicità di vita degli aborigeni e presenti la loro esperienza e conoscenza. Il programma di alfabetizzazione da una prospettiva aborigena deve andare oltre la lettura, la scrittura e la capacità di calcolo per includere anche l'oralità – racconti, canzoni, danze, simboli, cerimonie. L'alfabetizzazione scientifica da una prospettiva aborigena coinvolge l'essere informati in modo esteso su esempi e applicazioni della conoscenza scientifica degli aborigeni, così come della scienza occidentale e del discorso scientifico sulla natura della scienza. L'alfabetizzazione include anche la componente di saggezza della scienza aborigena, che porta con sé la discussione sui valori e sull'etica della scienza e della tecnologia e richiede di sostenere sia la comunità che l'ambiente. Le lingue aborigene sono utili come deposito di esperienze e prospettive che aiutano a conservare l'identità culturale, a contrastare l'assimilazione, e a interpretare e relazioni tra la società e l'ambiente.
Parole chiave: aborigeni, cultura, lingua, scienze, conoscenza della tradizione ecologica

Polish

Streszczenie Translated by Elzbiéta Awramiuk]
Podążając za pracami współczesnych myślicieli, twierdzimy, że każda kultura ma swą własna naukę i że oba systemy wiedzy naukowej, lokalny i zachodni, są wartościowe i użyteczne dla kultur, które je wytwarzają.. Ponieważ właściwa interpretacja umiejętności naukowych musi być spójna z dominującym wyobrażeniem nauki oraz szybkimi zmianami zachodzącymi w społeczeństwie, proponujemy szersze definicje i bardziej różnorodną metaforykę do zastosowania w kształceniu w zakresie nauk ścisłych. Edukacja

Aborygenów w tej dziedzinie musi obejmować rozległe podejście kulturowe, które uwzględnia swoisty sposób, w jaki Aborygeni żyją i prezentują swe doświadczenia i wiedzę. Programy nauczania opracowane z perspektywy aborygeńskiej powinny wykraczać poza samo tylko czytanie, pisanie i liczenie i uwzględniać oralność – opowiadania, pieśni, symbolikę, a także tańce i obrzędy. Edukacja w zakresie nauk ścisłych oznacza w tym kontekście również zapoznanie się z rozległym zasobem wiedzy Aborygenów, wraz z jej zastosowaniami, a nie tylko z dokonaniami nauki zachodniej. Kształcenie powinno uwzględniać także mądrościowy komponent aborygeńskiej wiedzy o świecie, który do nauki i technologii wnosi dyskusję o wartościach i etyce oraz sprzyja podtrzymywaniu zarówno społeczeństwa, jak i środowiska. Języki aborygeńskie są rezerwuarem doświadczeń i perspektyw, które pomagają zachować tożsamość kulturową, stawić opór asymilacji i oraz właściwie interpretować relację między społeczeństwem a środowiskiem.
Słowa-klucze: Aborygeni, kultura, język, nauka, tradycyjna wiedza ekologiczna

Portuguese

Resumo [Translated by Paulo Feytor Pinto]
Na sequência do trabalho de pensadores contemporâneos, consideramos que cada cultura tem a sua própria ciência e que tanto os sistemas de conhecimento indígenas como a ciência ocidental são válidos e têm sido úteis para as culturas que os desenvolveram. Uma vez que uma interpretação válida da literacia científica deve ser compatível com uma imagem predominante da ciência e com as mudanças profundas que ocorrem na sociedade, propomos definições e metáforas da literacia científica mais inclusivas. Para os povos aborígenes canadianos, a literacia científica deve radicar numa abordagem cultural abrangente que reconheça o modo único como esses povos vivem e que reflicta a sua experiência e conhecimento. Numa perspectiva aborígene, os programas de literacia devem ir além da leitura, da escrita e da numeracia para também incluírem a oracia – estórias, canções, danças, símbolos, cerimónias. A literacia científica, nesta perspectiva, inclui o conhecimento exaustivo de exemplos e de aplicações do conhecimento científico aborígene, mas também o conhecimento científico ocidental e o discurso científico sobre a natureza da ciência. A literacia inclui ainda a sabedoria da ciência aborígene que levanta a questão dos valores e da ética da ciência e da tecnologia e que obriga à sustentabilidade da comunidade e do meio ambiente. As línguas aborígenes servem de armazéns de experiência e de perspectivas que contribuem para a manutenção da identidade cultural, para a resistência à assimilação e para a interpretação da relação entre sociedade e meio ambiente.
Palavras-chave: aborígene, cultura, língua, ciência, conhecimento ecológico tradicional

Spanish

Resumen. [Translated into Spanish by Alejandro Arrington from Benemérita Escuela Normal Veracruzana, Mexico]
“Aproximaciones al conocimiento”: articulando los saberes cientificos aborigenes y occidentales, el lenguaje y el acercamiento al estudio de las ciencias en el salon de ciencias.
Considerando las aportaciones de pensadores contemporáneos, proponemos que cada cultura tiene su propia ciencia y que tanto el sistema de conocimiento científico occidental como el indígena son valiosos y han sido útiles para las culturas que los han desarrollado. Dado que una interpretación válida del acercamiento al estudio de las ciencias debe ser coherente con una imagen prevaleciente de las Ciencias y los cambios vertiginosos que ocurren en la sociedad. Proponemos definiciones y metáforas más inclusivas del acercamiento a las Ciencias. El acercamiento al estudio de las ciencias para los pueblos aborígenes debe ser el reflejo de un enfoque cultural amplio que reconozca la manera única en que los pueblos aborígenes viven y presentan su experiencia y conocimiento. Los programas de acercamiento al conocimiento desde una perspectiva aborigen deben ir más allá de la lectura, escritura y el conocimiento de los números para incluir el conocimiento de las habilidades orales –historias, canciones, danzas, símbolos, y ceremonias. El acercamiento al estudio de las Ciencias desde una perspectiva aborigen requiere el dominio de numerosos ejemplos y aplicaciones de los saberes científicos aborígenes, así como el conocimiento de las ciencias occidentales, y el discurso científico sobre la naturaleza de las Ciencias. El acercamiento al estudio de las Ciencias también incluye la Sabiduría de las Ciencias aborígenes, el cual propone la discusión de la ética y los valores de las Ciencias y la tecnología; y requiere la promoción de un desarrollo sustentable de la comunidad y el medio ambiente. Las lenguas aborígenes sirven como semillero de las experiencias y perspectivas que ayudan a mantener la identidad cultural, a resistir la asimilación cultural, e interpretar la relación entre la sociedad y el medio ambiente.

Palabras clave: aborigen, cultura, lenguas, ciencia, conocimiento ecológico tradicional

1. INTRODUCTION

Evidence points to the fact that in British Columbia (BC) schools the majority of students of Aboriginal ancestry are underrepresented in science courses and underrepresented in the sciences (BC Ministry of Education, 2002). An examination of Aboriginal performance and participation patterns over a five-year period (1997–2002) indicates that 36 to 42% of Aboriginal students graduated from grade 12. Of the Aboriginal students who graduated, 8 to 14% took Biology 12; 5 to 8% took Chemistry 12; and 2% took Physics 12. It is important to acknowledge that their average test scores in these three courses ranged from 63 to 73% and in the BC marking system indicates a high level of achievement for those students who do participate (BC Ministry of Education performance data, as yet unpublished). Of all students enrolled in a grade 11 science course, 15.1% of Aboriginal students and 7% of non-Aboriginal students took Science and Technology 11. The remaining Aboriginal students took either Forestry 11 or Earth Science 11 (BC Ministry of Education, 2003).

> None of these courses fulfill the requirement to be admitted into a postsecondary institution. Additionally, in order for students to enter postsecondary or pursue science-based careers, this low participation rate in approved science courses for the majority of Aboriginal students creates barriers and limits their career opportunities where science and mathematics form a foundation. (Snively & Williams, 2006)

Despite increases in the past decade of Aboriginal students graduating from postsecondary education programs, the lowest participation rates for Aboriginal students occur in agriculture, biological sciences, mathematics, and the physical sciences (Simpson, 2002). This situation arises from a type of science education in which Aboriginal science knowledge is rarely acknowledged and Aboriginal content is considered a token addition or is seldom, if ever, legitimized. Unless science classrooms and teaching materials provide a meaningful context for Aboriginal students (as defined by their local communities) and unless Aboriginal knowledge coexists with western science in the science classroom, many Aboriginal students will continue to find the science curriculum inaccessible, meaningless, and irrelevant.

It is clear that there is a very real need for Aboriginal people to gain expertise in the sciences. Science education has been promoted by the Science Council of Canada (1991) as a critical aspect of every student's education. The need to become scientifically literate was echoed by Aboriginal science educator Madeline MacIvor (1995) who noted that land claims settlements result in increased Aboriginal control over the management, development, use, and conservation of lands and resources, which makes the need for teaching scientific and technical literacy among Aboriginal people a pressing issue.

2. LANGUAGE RETENTION AND CULTURAL SURVIVAL

Language is by far the most significant factor in the survival of indigenous knowledge (Antone, 2000, 2005; Battiste, 2002). Aboriginal languages are the basic re-

positories of Aboriginal worldviews and thus contain within their grammatical structures the values and teaching of the people that construct them (Armstrong, 1995; Little Bear, 1998). Oracy, the traditional form of communication for North American Aboriginal people, passes cultural life histories from one generation to the next through storytelling, ceremony, songs, and teaching, as well as ritual and sharing (Antone, 2000). Absolon and Willet (2004: 8) explained:

> Each nation retained, recorded and recounted its own cultural histories. These histories reflect in the names of places, people and elements of creation, a spirit that is alive in the land. The names are imbued with meaning, teachings and spirit. These histories were then relevant and meaningful to the lives, culture and survival of each Indigenous nation. They were then and remain today etched in the memories of their people and their land.

In Canada, Aboriginal languages have been so severely subjected to the oppressive and destructive effects of colonisation and the assimilative policies that only 3 of the 72 languages in existence are predicted to have a long-term future (Assembly of First Nations, 1990). Missionary branches of various churches teamed up with the government to create residential schools where Aboriginal children were taken, often hundreds of miles from the influence of their parents, extended families, land, culture, and communities. The children were required to speak and write English or French and received harsh punishment for speaking their own language (L1). For the most part, students were neither prepared to participate in the social, cultural, or economic life of their own communities nor to participate in the coloniser society (Antone, 2000, 2005).

Battiste (2002) posited that, because Aboriginal languages and their symbolic, verbal, and unconscious orders structure Aboriginal knowledge, educators cannot stand outside of Aboriginal language to understand Aboriginal knowledge. Simpson (2002) added that developing Aboriginal languages within indigenous science and environmental education programs is an essential skill for communication within Aboriginal communities and with elders. It reinforces understanding of Aboriginal knowledge and lays the foundation for sustaining culture, community, and environment.

2.1 Forms of Literacy and Literacy Practice

Literacy in schools is usually defined as reading, writing, viewing, speaking, and listening. From an Aboriginal perspective, literacy spans a lifetime and is more than traditional print-based language arts and numeracy for gaining access to employment (Antone, Gamlin, & Provost-Turchetti, 2003). Antone et al. (47) stated:

> Meaningful Aboriginal literacy will develop and find expression in everything that is done. Consequently, literacy-training programs must reflect a broad approach that recognizes the unique ways that Aboriginal people represent their experience and knowledge. Literacy programs must reflect a cultural perspective that allows Aboriginal people to develop their literacy skills broadly as in developing skills related to narrative skills, artistic skills, and to hold to traditional values as they go about doing these things.

In an Aboriginal community, literacy includes oral speaking, story telling, songs, dances, symbols, crests, paintings, the carving of totem poles and masks, and ceremonies. All knowledge was precisely passed to each succeeding generation and shared amongst the entire nation by these oral traditions. To deny the multiple forms of literacy and restrict it to a print-based form, that of reading and writing, is to deny the interacting sociocultural and linguistic dimensions of Aboriginal cultures. Without this acknowledgement, Aboriginal literacy is couched in stereotypical terms and models that do not have a clear understanding of Aboriginal approaches to and expressions of literacy. Thus, according to the Canadian Education Association (2004), low literacy levels in their languages increase the risk of social and economic exclusion, poverty, and poor health.

Forms of literacy influence speech and affect knowledge and knowledge seeking. In the western literate world, one reads and writes and that drives what is disseminated. In an Aboriginal community, knowledge is transmitted and recorded in a different way. For example, every spring some members of some Nisg̲a'a families walk their salmon streams to ensure that spawning channels are clear of debris and that salmon are not obstructed in their ascent to spawning beds. In the course of such inspection trips, Nisg̲a'a observers traditionally used all their senses to pay attention to important variables: what plants are in bloom, what birds are active, when specific animals migrate and where, and so forth (Corsiglia & Snively, 1997). In some communities, when a hunter or group of hunters return to the family and community, they tell stories about the changes in the land, animals, and plants since their last hunt, sharing their knowledge and experiences so that everyone develops an intimate and current knowledge of the land. In this way, traditional communities have a highly developed capacity for building up a collective database and updating traditional stories of the environment. Any deviations from past patterns are important and noted. This is their literacy. For ocean people, their literacy is how to read the ocean; for forest people, literacy means to read the forest.

Some Aboriginal languages employ uniquely efficient conceptual and communications tools. For example, linguists report that Pacific Coast Aboriginal groups commonly use 'evidential markers' to enable speakers to annotate the reliability of information. Typically, a simple, one-syllable suffix indicates the context and reliability of a statement. Linguist Marie Lucie Tarpent (personal communication, April 2006) explained how Nisg̲a'a and Tsimshan speakers use evidential markers, such as *Quat /qat/*, which indicates *It was told to me by someone, but I can't tell you if it's true.* The suffix *ma'a* translates as *Maybe it's true, perhaps, but I don't really know enough to say for sure.* Other markers translate as *Yes, it's true, I saw it myself.* or *It might be true. I don't know. Other people told me.* or *You can't believe it. Not really. You must be kidding.* It appears that such categories of observation and discursive annotations qualify the oral claims much like hedging does in print-based communications, thereby enabling speakers of such a language system certain advantages of clarity of thought and expression.

As with oral language, these forms of literacy describe, defend, and present ideas that allow the community to share information and understandings and reflect on their thoughts. They shape conceptualizations, make claims, solve problems, establish permanent records, and establish proprietorship of intellectual and cultural

property as well as renewable resources. Protocols are adhered to: how to tell stories, who can tell stories, the repetition of stories, and how to get it right. These protocols ensure validity of the context and relationships in future retellings.

"We can think of language as a way of coming to grips with the external world and developing a symbolism to represent it so that it can be talked about and thought about" (Nettle & Romaine, 2000: 69). Indigenous languages have their own schema and categorization systems that reflect what they value in their world; for example, indigenous taxonomies may use function, colour, significant feature (such as the nose of the fish, placement of fins); time of year a plant is picked; age or size when fish or plants are best for use. These taxonomies are constructed as a result of a deep, observant, and intimate relationship with the environment.

In classrooms, students who have different worldviews from standard science or who come from different language communities use their knowledge to make sense of what is being discussed and explored. Williams, one of the authors, recalled visiting a grade 4 class of First Nations students when she observed a situation that illuminates what happens when students' prior knowledge and experience is not taken into consideration:

> The students were working on a categorisation activity. While the students were doing their independent work, I was going from student to student along with the class teacher. I noticed an interesting pattern on their worksheets. The top of the page had pictures of items (flower, mushroom, bird, boy, butterfly, rock, faucet, bowl, fence, building, cat), and the task was to label each item before putting the items into a given category: animate, inanimate, or vegetation. There were just enough blanks under each heading to put the pictures above. I noticed that 'rock' was at the bottom line of the inanimate category for many of the students, and some students had erased something from the animate category. When the class teacher began the discussion of the page, I asked the students what was the level of difficulty of the page – easy, medium, or hard. They answered easy, and I asked what made it easy. They had several reasons. Then I asked was there any item they had difficulty categorizing. There was a long pause. Some responded no. I waited just a little longer. Finally a student answered that he had difficulty with rock because in his traditional indigenous teachings rock is animate. Once the student offered this view and the students saw that I was interested in his response, a rich dialogue followed on the differences in worldview we are confronted with in school. For this group of students, it may have been the first time that they could bring their cultural world into a classroom and to be accepted and understood.

The talk in science classrooms involves a specialized use of the English language; students are expected to individually construct their own understandings of the concepts and language (Jarrett, 1999). Scientific inquiry in classrooms also favours questioning, describing, explaining, hypothesizing, debating, clarifying, elaborating, verifying, and sharing results. For many indigenous peoples, many of these language conventions contravene their social rules of discourse.

Science literacy from the contemporary definition involves the traditional sense of being knowledgeable about science and the fundamental sense of being literate in the discourse of science (Norris & Phillips, 2003). Science literacy from an Aboriginal perspective involves being knowledgeable about extensive examples and applications of Aboriginal science knowledge, as well as western science knowledge, and science discourse about the nature of science. Literacy also includes the wisdom

component of Aboriginal science, which brings values and ethics of science and technology and requires sustaining both community and environment.

2.2 Differences in English and Aboriginal Languages

Conflicts often arise during translation from one language to another if the cultural subtext is not recognized and retained. Although we can use the dictionary to translate one form into another, 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 science, students are asked to rely on observations. The process 'to observe' in English is full of categories that form more specific ones (observing generalises to seeing, hearing, touching, tasting, smelling). In many Aboriginal stories, there is the unspoken assumption that we can see with the mind and that the person doing the observing and the thing being observed are related in some way. Therefore, strictly speaking, there is no accurate translation of 'to observe'.

An example of what gets lost in translation is illustrated when we identify a plant, such as the western red cedar, *Thuja plicata*. Western science categorizes plants and animals according to a Linnean worldview, that is, according to physical structures (bark, leaf, wood, fruit), genetics, and position on the evolutionary tree of life. This worldview is useless in the context of survival based on knowledge of the diverse use of cedar trees that is embedded in Aboriginal stories, legends, and prayers about cedar trees. In some Aboriginal cultures, the important question to ask is *Who is cedar tree?* or *Who is Grandmother or Grandfather cedar tree?* Western red cedar is called SimGan in the Nisga'a language and means 'royal tree' just as SimGigat means 'royal people'. Amongst indigenous people wherever the cedar tree grows, it is considered a gift from the creator because it provides so much to the well being of the people. For the Lil'wat people, the cedar tree is known as *tsatawaoz*; it provides homes in both winter and summer, cooking pots and implements, carrying and storage containers, canoes for travel, waterproof clothing, mats, bedding mattresses, ceremonial regalia, building stakes, medicine, spiritual practices, and infant cradles. Cedar trees are held in great respect and are considered to be people, except that they are much more generous. Many uses of the cedar tree did not require the tree to be destroyed: planks for houses could be removed without destroying the tree; roots were harvested, and everyone was aware of where the roots were gathered so that the trees had time to regenerate before anyone harvested more; and the same was true for the bark and branches. For Aboriginal students familiar with the myriad images and concepts associated with the cedar tree (as with salmon, wolf, raven, bear, killer whale, frog, butterfly, etc.), this feeling or state of balance is at the heart of Aboriginal science.

A Linnean system places plants and animals in a hierarchy with humans at the top as being the most evolved, complex, and intelligent (thus, most important) and organisms with the simplest body structures at the bottom. By sharp contrast, an Aboriginal system places plants, animals, and all of creation in balance. Humans are not the controllers of nature, but they coexist with nature and can even be of lesser importance. According to an Ojibway view of the world (Johnston, 1984: 21):

> Mother earth and her life blood the waters is in first place for without them there would be no plant, animal or human life. The plant world stands second, for without it there would be no animal or human life. The animal world is third. Last, and clearly least important within this unique hierarchy come humans. Nothing whatever depends on our survival.

In Aboriginal science, thousands of seemingly unrelated pieces of information are organized through complex webs and levels of metaphor that are utterly alien to western taxonomies.

3. NATURE AND PHILOSOPHY OF SCIENCE

There are numerous versions of what science is and what counts as being scientific (Yore, Hand, & Florence, 2004). Terms such as *modern science*, *standard science*, *conventional science*, *western science*, and *official science* have been in use only since the beginning of the twentieth century. Following accepted standard definitions, science educators have defined western science as "people's attempt to search out, describe, and explain in natural terms generalizable patterns of events in the world" (Good, Shymansky, & Yore, 1999: 102). The search is driven by inquiry, limited by human abilities and technology, and guided by hypotheses, observations, measurements, plausible reasoning, and accepted procedures that utilize controls (Yore, 2008). They separate science-as-inquiry from technology-as-design and assert that technology is not simply an applied science.

In contrast, Ogawa (1995: 588) pointed science educators toward a broadly inclusive conceptualization of what science is by defining science rather simply as

> a rational perceiving of reality [where] perceiving means both the action constructing reality and the construct of reality[; the use of the word] perceiving [gives science a] dynamic nature [and acknowledges] that science can experience a gradual change at any time.

He further proposed that every culture has its own science and referred to the science of a given culture as its indigenous science. He stressed that all science students must work through both individual and indigenous science understandings in the course of constructing their knowledge of western science.

Cajete (1999: 83) stated:

> Indigenous science is a broad category that includes everything from metaphysics to philosophy to various practical technologies practiced by Indigenous peoples past and present … [and, like western science,] has models which are highly contextual to tribal experience, representational and focused on higher order thinking and understanding.

He argued that Aboriginal science includes exploration of basic questions, such as the nature of language, thought and perception, the nature of time, human feelings, human knowing, proper relationships to the cosmos, and a host of other questions about the natural world. It is a map of reality that gave rise to a diversity of technologies for hunting, fishing, gathering, making art, building, communicating, healing, and being. He stated (81-82):

> Whether there exists an Indigenous science in western terms is largely an incestuous argument of semantic definition. Using western orientations to measure the credence of non-western ways of knowing and being in the world has been applied historically to

> deny the reality of Indigenous people. The fact is that Indigenous people are; they exist and do not need an external measure to validate their existence in the world. Attempts to define Indigenous science, which is by its nature alive, dynamic, and ever changing through generations, fall short, as this science is a high-context inclusive system of knowledge.

Whether technology is an applied form of science has been debated amongst philosophers of science education. Kawagley (1998: 136) stated:

> Much of Yupiaq scientific knowledge is manifested most clearly in their technology. One may argue that technology is not science. However, technology does not spring from a void. To invent technological devices, scientific observations and experimentation must be conducted. Yupiaq inventions, which include the kayak, river fish traps, and a wide range of hunting and fishing gear, represent technology that could not have been developed without extensive scientific study of the flow of currents in rivers, the ebb and flow of tides in bays, and the feeding, resting, and migratory habits of fish, mammals and birds.

Similarly, the Wsanc people designed reef nets to fish for salmon in the bays and inlets of the Juan de Fuca Straits. Their design is based on their deep knowledge and respect for the salmon and their knowledge of the habitats, life cycles, and needs of the salmon (Claxton & Elliott, 1999). They know how to read the tides and wind patterns. They know in the years when there is an increased number of wasps that certain species of salmon will be abundant. They design an escape route for the salmon in their nets because they know that enough salmon in each run must live to continue the life cycle.

Our position is that the development of simultaneous exploration and comparison of Aboriginal science and western science can provide the foundation for the flexibility and creative orientations to thinking and application in science that is essential if we are to develop a truly cultural approach to science education programs. Traditional Aboriginal science interprets how the world works from particular, long-resident, cultural perspectives. Academics and western scientists generally view traditional science as a body of knowledge, with a strong bias toward labelling it as a product or commodity (Berkes, 1993). For example, Hardesty (1977: 291) described traditional science as "the study of systems of knowledge developed by a given culture to classify objects, activities, and events in its universe." By contrast, McGregor (2002: 2) suggested that traditional science is conceptualized as different from western definitions:

> Aboriginal understandings of TEK [and IK] tend to focus on relationships between knowledge, people, and all of creation (the natural world as well as the spiritual). … Aboriginal science is viewed as a 'process' (a verb) of participating fully and responsibly in such relationships, rather than specifically on the knowledge gained from such experiences.

Many scholars avoid using the term *Traditional Ecological Knowledge* (TEK) as it suggests a body of old data that has been handed down from generation to generation essentially unchanged (Riddington, 1990) and instead use the term *Indigenous Knowledge* (IK), which puts the emphasis on indigenous people (Berkes). According to McGregor (2002: 2), whether one calls it Aboriginal science, traditional ecological knowledge, or indigenous knowledge, "it is something one does." Equally fundamental from an Aboriginal perspective is that TEK is holistic and inseparable

from the people who hold it. It cannot be compartmentalized like western scientific knowledge (Roberts, 1996).

Examples of TEK and IK science may be accessed through living elders and various specialists or found in the burgeoning literature of TEK anthropology, ethnology, ecology, biology, botany, ethnobiology, medicine, horticulture, agriculture, astronomy, geology, climatology, architecture, navigation, nautical science, engineering, and mathematics. Numerous traditional people's science and technology achievements have been incorporated into modern applied science, such as medicine, engineering, wildlife management, nautical design, pharmacology, plant breeding, animal husbandry, and military and political science (Weatherford, 1988, 1991).

Traditional knowledge has much in common with western science, which is not surprising since both traditions derive from the same source: systematic observation of nature (Snively & Corsiglia, 2001). Both knowledge systems yield detailed empirical information of natural phenomena and relationships among ecosystem components. Both TEK and western science have predictive power; however, in both intellectual traditions, observations are interpreted within a particular cultural context. The collections of Berkes (1999), Ford and Martinez (2000), and Inglis (1993) provide excellent descriptive examples and cases.

TEK is increasingly being sought by academics, scientists, and policymakers as a source of knowledge and ideas for emerging models of ecosystem management, conservation biology, and ecological restoration. The United Nations Environment Program's Convention on Biodiversity (1992) and the World Conservation Union ("Tradition, conservation and development", 1986) called for recognition, protection, and utilization of TEK and IK. The document *Science for the Twenty-first Century: A New Commitment* (United Nations Educational, Scientific and Cultural Organization, 2000) set new standards for respecting Aboriginal knowledge. Aboriginal science is being recognized as having equal status with scientific knowledge and has been described as the intellectual twin to science (Deloria, 1995). Worldwide, working scientists associated with over 35 research institutes are collaborating with elders to collect and describe examples of Aboriginal science knowledge. All of these institutions and documents are central to helping formulate Canada's agenda for Aboriginal science education.

3.1 Recognizing the Wisdom Dimension

Traditional Ecological Knowledge and Wisdom (TEKW) brings the concept of wisdom to our discussion of science and technology and requires sustaining both community and environment (Berkes, 1993). Traditional wisdom may be thought of as that aspect of TEK that focuses on balancing human needs with environmental requirements (Bowers, 1995). All life forms must be respected as conscious, intrinsically invaluable, and interdependent (Brody, 1981). Corsiglia and Snively (1997: 23) noted:

> In practical terms, traditional wisdom extends the caring relationships associated with family life to communities and even to the environment. We are all relations, it is wrong to exploit other life forms or take more than one's share. … All creatures can be our

> teachers and while humans may readily affect other life forms, we need not see ourselves as superior.

The proper forms of human conduct are set forth in an elaborate code of rules; and deference is shown for everything in the environment, partly through gestures of etiquette and partly through avoiding waste or excessive use. TEKW can be thought of as the joining of detailed traditional knowledge with the values and ethics of traditional wisdom. Prayers were said to the spirit of the great cedar tree before felling it, that it might fall in the right direction and that its spirit would not be offended. The fisherman used many different prayers and songs to communicate with the spirit of the fish to achieve success in fishing (Emmons, 1991; Nelson, 1983; Stewart, 1977).

3.2 Recognizing Spiritualism

Although the unique features of TEKW and IK described above suggest its potential to complement and enrich western science, the differences between Aboriginal and western science may sometimes be taken as evidence that Aboriginal science cannot be classified as 'real science'. Critics often dismiss TEKW and IK as science because of its origins in oral cultures and because of its spiritual traditions, which they may see as superstitious and fallacious. Very often, when Aboriginal people describe the mechanics of reality, the essential point is that all aspects of creation are infused with consciousness and, therefore, deserve respect. This underlying reality may be discussed in many ways and can be readily described in spiritual stories where it is accessed through metaphor (Snively & Corsiglia, 2001). Oral information systems have been associated with the organization and management of countless, small, and stable home communities. Cruikshank (1981: 86) wrote:

> Oral tradition does not provide us with a series of data which stand by themselves. It is more like a prism which becomes richer as our ability to view it from a variety of angles improves. The question is not whether a particular tradition reflects the ways a particular individual views the world, but whether it broadens the worldview of the listener.

Johnson (1992) asserted that critiques often fail to recognize that spiritual explanations frequently contain important ecological, conservation, and sustainable development strategies. Johnson and Ruttan (cited in Johnson: 13) pointed out:

> Spiritual explanations [in TEK] often conceal functional and ecological conservation strategies. Further, the spiritual aspect does not necessarily detract from the Aboriginal harvester's ability to make appropriate decisions about the wise use of resources. It merely indicates that the system exists within an entirely different cultural experience and set of values, one that paints no more or no less valid a picture of reality than the one that provides its own (western) frame of reference.

Johnson further asserted that the spiritual acquisition and explanation of TEK is a fundamental component and must be promoted if the knowledge system is to survive. Knowing in the indigenous world has an integrated spirit, emotional, cognitive, and physical dimension.

Acknowledging TEKW and IK does not mean opening the doors to all and sundry. Snively and Corsiglia (2001: 24) argued that:

> TEK [and IK] is valuable precisely because it is refined over time with careful observation; it cannot arise spontaneously in modern imagination. Thus, no itinerant creationist or messianic breatharian may arrive in a new neighborhood and spontaneously generate authentic local TEK.

TEK grows out of respectful relating to the land and life forms and, unlike expansionist and generally authoritarian religions, places highest regard on all life forms rather than granting humans control and domination over the planet.

4. THE NATURE OF SCIENCE: TRANSFORMATIONS IN EPISTEMOLOGY AND ONTOLOGY

Epistemological and ontological questions concern a person's worldview and how she/he comes to interpret and create meaning in order to make choices and reach goals (Flint, 2003). Thus, epistemological and ontological positions have substantial implications for curriculum, instruction, societies, and cultures. Science educators need to understand deeply the consequences that the philosophical views of knowledge prevalent in curriculum and pedagogy have on the relevance of their teaching for their students and for society. Educators have a responsibility to empower students with the intellectual resources necessary to make reasoned judgment about what to believe or do, the decisions they make, and the potential they have to contribute to future generations, and to worldwide sustainable communities and environments.

Epistemology is a branch of philosophy that deals with the nature, source, and ways of knowing science (Beeth & Kwak, 2001). Guba and Lincoln (1994: 108) categorized alternative paradigms according to the epistemological question: "What is the nature of the relationship between the knower or would-be knower and what can be known?" Coffrey (1917) proposed that epistemology involved the philosophical investigation of human knowledge itself, from the standpoint of the truth-value of this knowledge.

Recognition of the fallibility of human inquiry corresponds with epistemological perspectives that are moving away from notions of one-to-one correspondence between reality and objective representation toward acceptance of the fallibility of claims of knowledge (Rescher, 1980). In other words, judgments currently sustained by evidence remain open to new evidence that could show the belief to be unwarranted (Ford, 1998). This does not rule out the potential for true belief; rather, it recognizes that we might never know how near we are to the truth (Hamm, 1989).

However, given the broad character of epistemology, the nature and attainment of knowledge can mean different things to different people, depending on what knowledge is valued (Hanohano, 1999). Stiffarm asserted (cited in Batiste, 2002: 18):

> The Aboriginal people of Canada have their own epistemology and pedagogy. Aboriginal epistemology is found in theories, philosophies, histories, ceremonies, and stories as ways of knowing. Aboriginal pedagogy is found in talking or sharing circles and dialogues, participant observation, experiential learning, modeling, meditation, prayer, ceremonies, or story telling as ways of knowing and learning.

Ontology deals with a specific conception of the elements and the ties between these elements, the structure of knowledge, and the underlying assumptions of a discipline (Yore et al., 2004). Ontology regards how the philosophy defines the nature and form of reality and, therefore, what is there that can be known about it (Guba & Lincoln, 1994). Ontology sometimes also meant a set of terms and their associated definitions intended to describe the world in question (Uschold, 1996). Each worldview and philosophical approach defines reality differently. Thus, ontologies can be grouped along a continuum from realism to idealism. From a realist perspective, "there is an existing material world apart from, and independent of, human experiences and human mental activity" (Beeth & Kwak, 2001: 3). Reality can be discovered and accurately described and will correspond with material objects and the real world; at the other end of the ontological spectrum is the idealist perspective in which "nothing exists beyond one's own mind" (Staver, 1998: 506). A somewhat middle-of-the-road ontology, naïve realism, described by Ryan and Aikenhead (1992: 561), posits "scientific knowledge is the reflection of things as they actually are". There is a real world beyond perception – although it may be difficult or even impossible to disentangle the descriptions of reality from human perceptions and misperceptions – but science is progressing toward a more accurate description of the real world. Our position on the ontology of science is loosely aligned with that of the naïve realist in that we believe there is a real world beyond sensory perception, we are born into it, and we are progressing toward a greater understanding of reality.

The difference between western and Aboriginal thought lies in several major distinctions regarding TEK and western science. One distinction is about man's place in nature: is he separate from nature or is he part of it? Trosper stated (2006: 3):

> On one level, acceptance of evolutionary theory would seem to say that science has answered the question: man is an animal and his powers, including language and thought, have emerged from a natural process. Yet the idea of 'pristine' ecosystems remains important, suggesting that some believe man and nature can be separated. The indigenous peoples of British Columbia, in participating or refusing to participate in public processes of land use planning, feel obliged to state clearly in their land planning documents that they see themselves connected to and part of the landscape. They state this because the dominant group's land plans seem to place man apart from nature, and seem to rely on science to assist in maintenance of this separation.

He suggested Latour proposed radically to restructure ontological concepts in which indigenous people are "not in harmony with nature because they had no nature. The distinction between 'society' and 'nature' did not exist" (Trosper: 3). Latour's rejection of a society/nature division "provides a useful language for discussing attempts to 'bridge' traditional knowledge and [western] science" (Trosper: 3).

From an Aboriginal perspective, the pursuit or gathering of knowledge differs tremendously in western and Aboriginal science perspectives (Hanohano, 1999). Western science appears to be aggressive and analytical and is generally guided by the proposition that the physical universe is knowable through rational, empirical thought. The methods of western science regularly seek to understand the organisms and entities of nature by studying the smallest or simplest manageable parts or subsystem in essential isolation. Thus, in attempting to view the world objectively,

western science has often fragmented and measured the external space in an attempt to understand it in all its complexity (Battiste & Barman, 1995).

As important as these differences may be, Freeman (1992) postulated that the principle difference has more to do with notions of physical causality where the scientist is concerned with understanding an essentially linear process of cause and effect. If causes of observed effects can be measured and understood, then predictive statements about future outcomes can be made and the natural world can be managed.

> [But] the non-western forager lives in a world not of linear causal events but of constantly reforming multi-dimensional interacting cycles where nothing is simply a cause or an effect, but all factors are influenced, impacting other elements of the system as a whole. … Linear approaches to analysis cannot be applied to cyclical systems, and, as everyone now realizes, ecosystems are in fact complex cycles of re-circulating energy, matter, and relationships. Nowhere does the Cartesian model of modern science fail so completely and utterly as in trying to explain the workings of natural ecosystems. (Freeman: 4)

Ross (1996: 63) summarized:

> I do not suggest for a moment that western and Aboriginal science took mutually exclusive directions, for that is clearly not the case. Aboriginal people indeed studied the characteristics of individual things: over 70% of all western drugs, for instance, have come from isolating the active ingredients in plants and animals that the world's indigenous peoples had already been using for medicinal purposes for centuries. And on the other side of the coin, western scientists have indeed paid attention to the workings of 'things put together' – whether in agriculture, chemistry, meteorology, geology, or physics.
>
> It does seem, however, that there has been a difference in emphasis between the two groups. The result appears to be that western science has achieved special excellence in its understandings of things and their properties, while Aboriginal science has achieved a special excellence, only now being recognized, in how things work together within systems as a whole.

This determination to place the primary emphasis on studying the relationships between things – and to try to accommodate those relationships instead of manipulating the things within them – seems to lie at the heart of a great many Aboriginal approaches to life.

Aboriginal science as an intellectual partner to western science offers a model for integration. In Aboriginal epistemology, a thing is understood only when it is understood with all aspects of human experience, that is, mind, body, emotion, and spirit (Cajete, 1994). Aboriginal science "recognizes the different strengths of multiple understandings and explicitly incorporates the cultural experience of the observer into interpretation of the natural world. It is highly rational, empirical, and pragmatic, while simultaneously integrating cultural values and moral perspectives" (Kimmerer, 2002: 437). With its worldview of respect, responsibility, and reciprocity with nature, Aboriginal science does not compete with western science or detract from its power but rather extends the scope of science into human interactions and relationships with the natural world.

Western science is often conducted in an academic culture in which the researcher attempts to view nature in an objective manner. In this aspect, TEK di-

verges significantly from western science (Pierotti & Wildcat, 2000). While the scientific community prides itself on data that are value free, TEK is laden with associated values and extends itself on data where science does not go (Kimmerer, 2002). TEK includes an ethic of reciprocal respect and obligations between humans and the non-human world. Such holistic ways of understanding the environment offer alternatives to the dominant consumptive values of western societies. Thus, each value system tends to orient its students differently toward nature (Ermine, 1995; McKinley, 1996; Snively & Corsiglia, 2001). For Aboriginal people, teaching is about learning to live in a respectful, harmonious, and relational way, preparing to assume the responsibility of caring for Mother Earth – everything, plants, animals, people, all entities of creation.

Bridging the two knowledge areas involves dealing with connections between ideas about ecological systems and the interdependence of humans and nature. Western science and TEK have been bridged often, as evidenced by the number of close relationships between western scientists and traditional practitioners (Anderson, 2005; Berkes, 1993, 1999; Nabhan, 1997; Turner, 2005). Trosper (2006: 1) stated: "These partnerships have generated significant synergies benefiting all participants."

Commoner (1972: 33) stated the first law of ecology: "Everything is connected to everything else." Additionally, Callicott (1982: 41) stated:

> The basic concept of ecology is that the myriad nonhuman natural beings – soil and water, plants and animals – are functioning members of a single natural community to which we also belong and upon which we utterly depend for the means to life.

The view that the world is a functioning system (common in contemporary biological sciences) not composed of discrete entities (common in traditional physical sciences) is not new in western culture, even though many scientific facts that support it have come to light recently. It is natural that biologists, ecologists, environmentalists, and other scientists associated with system theory research were more sensitive to and concerned with relations and connections in general, and thus among the first western scientists to form bridges between TEK and western science.

To summarize, outlined below are four principles that we believe characterize the cultural forms of Aboriginal discourse and, thus, represent the nature of epistemology and ontology from an Aboriginal perspective. We believe that these principles would be applicable in any Aboriginal science program or curriculum.

4.1 Context of Scientific Study – Place-based Knowledge

According to Christie (1991: 29), "the most fundamental principles taught by Aboriginal elders is that our subject matter is to be examined and interpreted only as it is found embedded within its context. This is in marked contrast with western science where environmental influences are considered confounding, and scientists do their work most often in the laboratory." Cajete (1999: 47) proposed that "Native science evolved in relationship to places and is therefore instilled with a sense of place. … [Therefore,] the first frame of reference for a Native science curriculum is reflective of their place." Everything is connected in a web of relationships. Nothing exists in

isolation. Indigenous people over millennia have lived in harmony with all living things in their environments. They learned the rhythms of each being in their ecosystems and how each life form, including their own, depends on each other.

4.2 Multiple Perspectives

A second principle the elders teach is that we are not so much meant to discover the one true picture of reality, but rather we are meant to construct the fullest and clearest picture of the situation we can by integrating our best collective knowledge. The more viewpoints and ideas included, the more complete and meaningful the picture will be. Knowledge embedded in context and interpreted from a network of perspectives has the opportunity to be rich in metaphors. It is not only the perspective of the people engaged in the dialogue whose views must be taken into consideration, but ideas are always examined against views of the ancestors embedded in people's memory and in the stories, songs, and dances. Equally, the viewpoints include future generations and how current decisions will affect them and their world.

4.3 Everything in the Universe Lives

In the Aboriginal world, everything of Mother Earth possesses a spirit. This spirit is conscious and has awareness – the wind, water, stars, frogs, rocks, smoke, people, cedar trees, salmon, and killer whales possess a spirit. Everything in the universe lives and has its own place. The universe is alive (Cajete, 1999, 2000; Deloria, 1995; Kawagley, 1999). If you are going to gain knowledge over something, you have to look after it; to make yourself ready to have that knowledge, you must form a respectful and positive relationship with self and everything around you.

4.4 Focus on Balance

The elders teach that plants, animals, and the elements are embraced by Aboriginals as kin and are given an active role in the production of knowledge. Seagulls teach the fisherman how to find their way home. If you observe the Bear Teacher in the woods, you will know what you can eat and what you cannot eat. Taking more than you need upsets the balance of nature. It not only upsets conservation, it imbalances one's sense of self-importance in the web of life. Aboriginal people give thanks for all life, to the sun, water, wind, earth, animals, plants, fish, and minerals. This simple practice helps humans live in harmony and balance.

5. TAKING A CROSS-CULTURAL PERSPECTIVE TO SCIENCE EDUCATION

In contemplating the implications of cross-cultural education, science educators have begun to consider what it means to prepare students in a culturally diverse world. Should we develop a teaching approach that merely develops an appreciation for Aboriginal science and TEK? Or, should we go further into the implications of

racism, history, and definitions and attempt to deconstruct old prejudices? This section attempts to consider the multidimensional cultural world of the learner by calling for a kind of parallel relationship between western and Aboriginal science in the science classroom. We encourage the reader to consider connections between the *Two-Row Wampum* model of relationships between parallel sciences (McGregor, 2002) and a border-crossing model of science education (Aikenhead, 1996, 2000). We conclude by making specific recommendations for helping students move back and forth between their cultural science and western science in the classroom.

5.1 Two-Row Wampum or Two-Way Knowing

According to leading Aboriginal science scholars, the model for science education is that western science and Aboriginal science should co-exist and replace current efforts to incorporate or integrate Aboriginal knowledge into non-Aboriginal science programs (Cajete, 1999; Kawagley, 1995, 1999). McGregor (2002) postulated that co-existence is a concept that has its roots in the way that numerous First Nations had originally hoped to work with the Europeans when they arrived on the North American continent. The concept suggests a parallel model of complementary co-existence, which enables different worldviews to exist separately yet side by side:

> Depicted in the Two-Row Wampum belts of the Haudenosaunee, the concept permits each side to retain its integrity through undertaking its own process according to its own worldview. This is a long-term mutually beneficial relationship, where each side respects the other's worldview and their right to live accordingly. The contrasting perspectives that the other brings to any discussion enrich each side. (McGregor: 3)

McGregor asserted that Aboriginal peoples are calling for this kind of relationship in a variety of settings (e.g., treaties, self-governance, and education). A later belt, the Friendship Treaty Belt, goes together with the Two-Row Wampum belt:

> The Friendship Treaty Belt depicting two figures holding hands supplements the Two-Row Wampum belt. The two belts go together, depicting different aspects of a relationship. The Aboriginal and non-Aboriginal peoples are linked together, and it is their responsibility to each other to never let go of each other, to always assist one another as they travel through life together. Each has a responsibility to its identity while being strengthened through the support of the other. (McGregor: 3)

A similar belt shows a zigzag line connecting two canoes and, by inviting the two sides to travel back and forth, illustrates that the two ways of knowing are complementary. By extension, the Two-Row Wampum model offers a realistic pedagogical approach for linking western science and Aboriginal science in the science classroom. It is the responsibility of science educators to always respect and recognize the validity of Aboriginal science knowledge and the rights and obligations of Aboriginal children to their cultural identify. The teacher's responsibility is to assist – as opposed to assimilate – Aboriginal students to navigate a hazardous path between the everyday world of the home culture and the world of school science.

5.2 Cross-Cultural Science Education as Border Crossing

Aikenhead (2001: 339) listed nine assumptions that define a cultural perspective on science education, six of which are included here:

> (1) Western science is a cultural entity itself, one of many subcultures, (2) people live and co-exist in several subcultures identified by language, ethnicity, social class, religion, geographic location, etc., (3) people move from one sub-culture to another, a process called 'border crossing', (4) people's core cultural values may be at odds with the culture of Western science to varying degrees, (5) learning science is a cross-cultural event for these students, and (6) students are more successful if they receive help negotiating their cultural border crossings.

Border crossing entails teaching traditional indigenous knowledge in parallel with western science. This approach to teaching and learning engages students in cultural negotiations where learning is experienced as coming to knowing (Ermine, 1998; Peat, 1994), two-way learning (Fleer, 1997), or both ways education (McTaggert, 1991). Coming to knowing is reflected in participatory learning activities that engage all students in exploring several sciences found within their school system.

Aboriginal science education uses a variety of language activities (talking, reading, writing, story telling, singing, dancing, carving) as a fundamental part of doing science. For example, having established that every culture has its own science, an array of alternative taxonomic systems is presented for analysis by the class. Local Aboriginal elders are invited into the class to talk about the cedar tree, demonstrate uses of the cedar tree, connect students to the local culture, and convey the value of the community's knowledge and wisdom. Indigenous plant names are often descriptive of ecological interactions, medicinal use, and habitat characteristics, and offer valid alternative ways of categorizing biodiversity. Next, the class studies local stories, prayers, and dances that advise how one should harvest cedar trees. A personal connection to Grandfather Cedar Tree and Mother Earth is achieved. The teacher follows this up with a systematic overview of the Linnean system of classification and concepts related to the grade level (e.g., organism, life cycle, habitat, photosynthesis, limiting factors, forest management, and conservation). The scientific values underlying these lessons are, for example, a naming system that is universal, mathematics to make observations more precise, and the underlying values of ecology that stress the interconnections of natural ecosystems. The border-crossing teacher invites students to compare the origins and utility of the Linnean system with Aboriginal classification schemes. The differing underlying values of the two knowledge systems suggest to students different assumptions about nature. Through cross-cultural comparisons, students come to understand that all classification systems are influenced by the observations available and respond to particular cultural needs. Exploring multiple interpretations requires students to think critically rather than passively accept a familiar paradigm.

Aikenhead (2001: 347) stated, "students should be able to state which culture they are speaking in, western science or Aboriginal or local common sense." The discourse embraced by students engaged in Aboriginal knowledge is very different from the discourse of western science. "As students bring their community's Aboriginal knowledge and values into the classroom, new power relationships replace

the conventional coloniser-colonised hierarchy" (Aikenhead: 347). Battiste (2000: 11) stated, "focusing on similarities between the two systems of knowledge rather than on differences may be a more useful place to start when considering how best to introduce education reform."

Since prior knowledge exists as a consequence of culture, it should be part of science teaching that all students be given the opportunity to reinterpret new information in light of their own orientation or worldview. Snively (1990, 1995: 63) found that it is possible to increase a student's knowledge of marine science concepts without altering the student's preferred spiritual orientation to the seashore:

> This is important. Educators need to know that it is possible to teach scientific concepts to Native students who hold a traditional spiritual view of the world without changing – in the sense of replacing – the students' preferred orientation. We can increase a student's [western] scientific knowledge so that it can be utilized in appropriate situations. It makes sense to talk about increasing Native students' knowledge about science concepts so that they can be successful in school, but we need to be careful about changing students' culturally grounded beliefs and values. What are the ethics involved?

It is imperative when developing cross-cultural curricula in an Aboriginal context to not distort local knowledge to make it conform to western science. Disrespect can occur if the teacher ignores the unifying spirituality that pervades Aboriginal science (Ermine, 1995). As well, inadvertent and even purposeful assimilation will take place in a science classroom if the local knowledge is taken out of its cultural context (Aikenhead, 2001; Snively, 1995). It should be possible to acknowledge the community's spirituality by simply identifying the spirituality in Aboriginal knowledge and then identifying its absence in western science.

From the authors' perspective, if it is serious bridge building and border crossing, then it is a two-way bridge. Both Aboriginal and non-Aboriginal students must be willing and open to exploring their own assumptions; there is a reciprocal relationship and a search for meaning on both sides. What are the benefits of acknowledging Aboriginal science? What are the possibilities for combining the two perspectives? Western science does not replace Aboriginal science; it enriches small components of it and vice versa.

In the past, reading, writing, and mathematics in science education centered on decoding, spelling, grammar, and literal expression. This approach to language outside of inquiry made direct experience irrelevant and suspended creative thought. A border-crossing or Two-Row Wampum approach to science encourages students to construct meaning from the text or in writing by integrating their prior knowledge and experiences with current experience in their sociocultural context. This approach is consistent with a constructivist model and calls attention to the importance of life experiences and cultural schemata in the process of making meaning.

By acknowledging western science's role in the colonisation of Aboriginals, a teacher can address Aboriginal students' conflicting feelings toward the culture of western science, thus making students feel at ease with learning and with appropriating that subculture's content without accepting its values and ideologies. The teacher identifies the coloniser and the colonised and teaches the science of each culture (Aikenhead, 2001; Snively & Corsiglia, 2001).

The Two-Row Wampum model acknowledges local cultures, which are in danger of erosion and loss of integrity, while at the same time acknowledging western science. Science units should be introduced by recognizing a community's Aboriginal science knowledge or worldview in a way that creates a need for western science, while simultaneously creating a need for non-Aboriginal students to know Aboriginal science. The aims are to empower students to feel at ease in each culture, to engage their prior experience and knowledge, to understand both Aboriginal and western science concepts, to be successful in school science, and to not lose their cultural identity.

6. FUTURE CONSIDERATIONS

Preparation for teaching Aboriginal science, language, and literacies is a pressing issue for teachers. Almost all teachers have been educated in Eurocentric systems that have dismissed Aboriginal knowledge as science, and they have taught a silent curriculum that attempts to assimilate Aboriginal students into mainstream thinking. To their credit, Eurocentric scholars are now struggling to respect Aboriginal science knowledge in the classroom.

In Canada, several jurisdictions have begun to move toward a new orientation and concept of science education. In 2005, for example, the BC Ministry of Education mandated the integration of authentic Aboriginal content into the kindergarten–grade 7 science curriculum with the support of Aboriginal people. All schools are expected to teach prescribed learning outcomes that incorporate examples of Aboriginal knowledge and wisdom. New textbooks and teaching resources purchased with Ministry funds must promote the understanding of BC's Aboriginal peoples among all students (BC Ministry of Education, 2005).

Despite such initiatives, few Canadian universities have made Aboriginal education, and specifically Aboriginal science education, a mission or a priority. Consequently, when teachers encounter differences in science knowledge or cross-cultural teaching and learning situations, they have very little, if any, knowledge, theory, research, or tested classroom applications to draw upon in order to teach in a way that is culturally sensitive, respectful, and responsible. What is needed is a national policy of science education that affirms Aboriginal science knowledge, establishes and supports centers of excellence in cross-cultural science teaching, promotes locally developed, culturally sensitive curriculum programs and materials, and honours and rewards elders as keepers of Aboriginal knowledge, values, and languages.

If we are going to survive, we will need to develop an economy and a lifestyle that is sustainable. It will not be supported by a constant and unchanging view of the world but by a mode of thinking that is sensitive to human needs, emotions, and values. In the controversy over the philosophy of science, it becomes important to recognize the magnitude of problems caused by an incomplete appreciation of the complexity and scope of Aboriginal knowledge and wisdom. The genius of Aboriginal science is its respect for nature and all living creatures. Through a cross-cultural approach to education, science education facilitates the enculturation of Aboriginal students into their own culture.

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