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Toward a First Nations Cross-Cultural Science and Technology Curriculum

GLEN S. AIKENHEAD
Curriculum Studies, University of Saskatchewan, 28 Campus Drive, Saskatoon S7N 0X1 SK, Canada; e-mail: aikenhead@sask.usask.ca

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ABSTRACT: This article explores First Nations (Native American) science education from a cultural perspective. Science is recognized as a subculture of Western culture. Scientific and Aboriginal ideas about nature are contrasted. Learning science is viewed as culture acquisition that requires First Nations students to cross a cultural border from their everyday world into the subculture of science. The pathway toward the cross-cultural education explored in the article is: (1) founded on empirical studies in educational anthropology; (2) directed by the goals of First Nations people themselves; (3) illuminated by a reconceptualization of science teaching as cultural transmission; (4) guided by a cross-cultural STS science and technology curriculum; and (5) grounded in various types of content knowledge (common sense, technology, and science) for the purpose of practical action such as economic development, environmental responsibility, and cultural survival. Cross-cultural instruction requires teachers to identify cultural border crossings for students and to facilitate those border crossings by playing the role of tour guide, travel agent, or culture broker, while sustaining the validity of students' own culturally constructed ways of knowing. © 1997 John Wiley & Sons, Inc. *Sci Ed* **81:**217–238, 1997.

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Correspondence to: G. S. Aikenhead

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INTRODUCTION

As a Euro-Canadian, my non-Aboriginal background disqualifies me from formulating education policies for First Nations (Native American) students. Instead, I offer my support to First Nations educators such as Madeleine MacIvor (1995) who want students to learn Western science but, at the same time, not be assimilated into Western culture at the expense of their own Aboriginal culture and identity.

The purpose of this article is to strengthen First Nations science education aimed at treating Western science as “a repository to be raided for what it can contribute to the achievement of practical ends” (Layton, Jenkins, Macgill, & Davey, 1993, p. 135). “Practical ends” is broadly interpreted to mean: working at a job; preparing for a career (including a scientific or technological career); making a decision about a science-related societal or personal issue; or making sense of one’s community or nation increasingly influenced by Western science and technology. Three practical ends of significance to First Nations peoples are highlighted in this article: economic development; environmental responsibility; and cultural survival.

I shall adopt a recently developed cultural perspective on science education that treats Western science as a subculture of Euro-American culture (Aikenhead, 1996). Because the subculture of Western science can conflict with the cultures of First Nations students, learning Western science is recognized as culture acquisition that requires Aboriginal students to cross cultural borders from the everyday subcultures of their peers, family, and tribe, to the subcultures of school, school science, and science itself. My emphasis on border crossings implies a type of cross-cultural science curriculum for First Nations students, a curriculum designed for practical ends.

Accordingly, this article is organized into four main parts: (1) the nature of cultures and subcultures, focusing on Western science, First Nations knowledge of nature, and school science; (2) cultural border crossing; (3) a critical look at what type of knowledge leads to economic development, environmental responsibility, and cultural survival; and (4) an outline of a cross-cultural curriculum in science and technology education for Canadian First Nations students, a proposal which has direct implications for other non-Western or minority students in science classrooms.

For readers unfamiliar with First Nations education in the United States and Canada, a highly abbreviated description is presented here. History differs from tribe to tribe, but generally speaking, since early contact with the “white man,” First Nations peoples were forced onto reservations (usually inhospitable land) where starvation and foreign diseases such as tuberculosis decimated their population (Buckley, 1992). In the 19th and early 20th centuries, attempts (such as residential schools) at assimilating First Nations students into North American culture only succeeded in extinguishing the students’ own culture and failed to provide an alternative cultural support system (Barman, Hebert, & McCaskell, 1986). People who left the reservations fared no better. “Neither the proactive (policy) approach of the United States nor the passive (no policy) approach of the Canadian government has led to significant change” (Brady, 1995, p. 361). Consequently, First Nations peoples are the most disadvantaged minority in North American education and are the least represented in science and technology careers (Matthews & Smith, 1991; Nelson-Barber & Estrin, 1995). Apart from abject poverty, the main issue is *control* over education (Brady, 1995). During the past 30 years there have been concerted though isolated efforts to renew First Nations culture and to gain control and equity in educational opportunities (Battiste & Barman, 1995). This renaissance is occurring both on and off reservations.

CULTURES AND SUBCULTURES

A cultural perspective on science education views teaching as cultural transmission and views learning as culture acquisition (Contreras & Lee, 1990; Spindler, 1987; Wolcott, 1991), where culture means "an ordered system of meaning and symbols, in terms of which social interaction takes place" (Geertz, 1973, p. 5). We talk about, for example, a Western culture, and Aboriginals speak of their First Nations cultures, because members of each group share, in general, a system of meaning and symbols for the purpose of social interaction. Geertz's definition is given more specificity by anthropologists Phelan, Davidson, and Cao (1991) who conceptualize culture as the norms, values, beliefs, expectations, and conventional actions of a group.

Other categories describing culture have been used by First Nations educators; for instance: material, social, cognitive, and linguistic aspects of culture (Leavitt, 1995); and ecological, social, and cognitive aspects of culture (Stairs, 1995). These categories relate to other views on culture found in science education, views such as: Maddock's (1981, p. 20) "beliefs, attitudes, technologies, languages, leadership and authority structures;" Tharp's (1989) social organization, sociolinguistics, cognition, and motivation; or Ogawa's (1986) views of humans, views of nature, and ways of thinking. In different science education studies different aspects of culture have been used to highlight particular interests in cross-cultural or multicultural education (reviewed in Aikenhead, 1996; Cobern & Aikenhead, 1997). Phelan et al.'s (1991) definition of culture (above) is advantageous because it has relatively few categories and they can be interpreted broadly to encompass anthropological aspects of culture as well as the educational attributes often associated with science instruction: knowledge; skills; and values. Canonical scientific knowledge will be subsumed under "beliefs" in Phelan et al.'s definition.

Within First Nations cultures, subgroups exist that are commonly identified by nation, tribe, language, location, religion, gender, occupation, etc. Within Western cultures, subgroups are often defined by race, language, ethnicity, gender, social class, occupation, etc. A person can belong to several subgroups at the same time; for example, a female Cree middle-class research scientist or a Euro-Canadian male working-class technician. Large numbers and many combinations of subgroups exist due to the associations that naturally form among people in society. In the context of science education, Furnham (1992) identified several powerful subgroups that influence students' understanding about science: the family, peers, the school, and the mass media, as well as groups associated with various physical, social, and economic environments. Each identifiable subgroup is composed of people who generally embrace, or who in various different ways conform to, a defining set of norms, values, beliefs, expectations, and conventional actions. In short, each subgroup shares a culture, which I designate as "subculture" to convey an identity with a subgroup. Although a great deal of diversity exists within each subculture (due to a variety of factors), we can talk about, for example, the subculture of northern Saskatchewan Cree, the subculture of females, the subculture of our peers, the subculture of a particular science classroom, and the subculture of science.

The Subculture of Science

Science itself is a subculture of Western or Euro-American culture (Dart, 1972; Jegede, 1995; Maddock, 1981; Pickering, 1992; Ogawa, 1986; Pomeroy, 1994), and so "Western science" can also be called "*subculture science.*" Scientists share a well-defined system of norms, values, beliefs, expectations, and conventional actions—the culture of Western science or "*the subculture of science.*" These norms, values, etc., vary with individual scientists and situations (Aikenhead, 1985; Cobern, 1991, ch. 5; Kuhn, 1970; Gauld, 1982; Ziman, 1984) and have been investigated by scholars in a field called "social studies of science" (e.g., Fourez, 1988; Kelly, Carlsen, & Cunningham, 1993; Pickering, 1992; Rose, 1994; Snow, 1987; Stanley & Brickhouse, 1994). Their descriptions of the subculture of science often include the following attributes: mechanistic, materialistic, reductionist, empirical, rational, decontextualized, mathematically idealized, communal, ideological, masculine, elitist, competitive, exploitive, impersonal, and violent. This list does not define subculture science but identifies some of its aspects described by the social studies of science literature.

Because science tends to be a Western cultural icon of prestige, power, and progress, its subculture permeates the culture of those who engage it (Baker & Taylor, 1995; Dart, 1972; Hodson, 1993; Jegede & Okebukola, 1990, 1991; MacIvor, 1995; Ogawa, 1995; Pomeroy, 1994; Swift, 1992). This acculturation can threaten indigenous cultures, thereby causing Western science to be seen as a hegemonic icon of cultural imperialism (Battiste, 1986; Ermine, 1995; Maddock, 1981; Simonelli, 1994). In the case of First Nations peoples, the threat is real. To understand their position it is necessary to appreciate some cultural aspects to their view of nature, a topic to which we now turn.

First Nations Knowledge of Nature

Aboriginal knowledge about the natural world contrasts with Western scientific knowledge in a number of ways. Aboriginal and scientific knowledge differ in their social goals: survival of a people *versus* the luxury of gaining knowledge for the sake of knowledge and for power over nature and other people (Peat, 1994). They differ in intellectual goals: to coexist with mystery in nature by celebrating mystery *versus* to eradicate mystery by explaining it away (Ermine, 1995). They differ in their association with human action: intimately and subjectively interrelated *versus* formally and objectively decontextualized (Pomeroy, 1992). They differ in other ways as well: holistic First Nations perspectives with their gentle, accommodating, intuitive, and spiritual wisdom, *versus* reductionist Western science with its aggressive, manipulative, mechanistic, and analytical explanations (Allen, 1995; Ermine, 1995; Johnson, 1992; Knudtson & Suzuki, 1992; Peat, 1994; Pomeroy, 1992). "The Western world has capitulated to a dogmatic fixation on power and control at the expense of authentic insights into the nature and origin of knowledge as truth" (Ermine, 1995, p. 102). They even differ in their basic concepts of time: circular for Aboriginals, rectilinear for scientists.

Aboriginal and scientific knowledge differ in epistemology. Pomeroy (1992) summarizes the difference succinctly:

> Both seek knowledge, the Westerner as revealed by the power of reason applied to natural observations, the Native as revealed by the power of nature through observation of consistent and richly interweaving patterns and by attending to nature's voices. (p. 263)

Ermine (1995) contrasts the exploration of the inner world of all existence by his people with a scientist exploring only the outer world of physical existence. He concludes:

> Those who seek to understand the reality of existence and harmony with the environment by turning inward have a different, incorporeal knowledge paradigm that might be termed Aboriginal epistemology. (p. 103)

Battiste (1986) explicates an Aboriginal epistemology further by giving detail to what Pomeroy called "nature's voices":

> A fundamental element in tribal epistemology (lies) in two traditional knowledge sources:
>
> 1. from the immediate world of personal and tribal experiences, that is, one's perceptions, thoughts, and memories which include one's shared experiences with others; and
> 2. from the spiritual world evidenced through dreams, visions, and signs which (are) often interpreted with the aid of medicine men or elders. (p. 24)

On the one hand, subculture science is guided by the fact that the physical universe is knowable through rational empirical means, albeit Western rationality and culture-laden observations (Ogawa, 1995); while on the other hand, Aboriginal knowledge of nature celebrates the fact that the physical universe is mysterious but can be survived if one uses rational empirical means, albeit Aboriginal rationality and culture-laden observations (Pomeroy, 1992). For example, when encountering the spectacular northern lights, scientists would ask, "How do they work?" while the Waswanipi Cree ask, "Who did this?" and "Why?" (Knudtson and Suzuki, 1992, p. 57). Aboriginal knowledge is not static, but evolves dynamically with new observations, new insights, and new spiritual messages (Hampton, 1995; Kawagley, 1995; More, 1987).

The norms, values, beliefs, expectations, and conventional actions of First Nations peoples contrast dramatically with the subculture of science. In an earlier section, Western science was characterized as being essentially mechanistic, materialistic, etc. By comparison, Aboriginal knowledge of nature tends to be thematic, survival-oriented, holistic, empirical, rational, contextualized, specific, communal, ideological, spiritual, inclusive, cooperative, coexistent, personal, and peaceful. Based on these two lists, Western science and Aboriginal knowledge share some common features (empirical, rational, communal, and ideological). Consequently, it is not surprising that efforts are underway to combine the two knowledge systems into one field called "traditional ecological knowledge" (Corsiglia & Snively, 1995; Johnson, 1992). While a *romanticized* version of a First Nations peaceful coexistence with the environment should be avoided, Knudtson and Suzuki (1992) document the extent to which environmental responsibility *is* globally endemic to First Nations cultures, a quality that led Simonelli (1994) to define "sustainable Western science" in terms of First Nations cultures. Simonelli (1994) quoted a Lakota ceremonalist's view of science and technology: "This is not a scientific or technologic world. The world is first a world of spirituality. We must all come back to that spirituality. Then, after we have understood the role of spirituality in the world, maybe we can see what science and technology have to say" (p. 11). Deloria (1992b), also of the Lakota nation, challenged the objective validity claimed by Western science when he spoke about improving the subculture of science by getting science to adopt a First Nations sense of contextualized purpose.

> The next generation of American Indians could radically transform scientific knowledge by grounding themselves in traditional knowledge about the world and demonstrating how everything is connected to everything else. Advocacy of this idea would involve showing how personality and a sense of purpose must become part of the knowledge which science confronts and understands. The present posture of most Western scientists is to deny any sense of purpose and direction to the world around us, believing that to do so would be to introduce mysticism and superstition. Yet *what could be more superstitious* than to believe that the world in which we live and where we have our most intimate personal experiences is not really trustworthy and that another mathematical world exists that represents a true reality? (p. 40, italics added)

My brief characterization of Aboriginal knowledge of nature hints at the intellectual challenges faced by many First Nations students who attempt to cross the cultural borders between their everyday world and the world of science. These intellectual challenges are exacerbated by a critical dilemma posed by the subculture of school science.

The Subculture of School Science

Closely aligned with Western science is school science, whose main goal has been cultural transmission of both the subculture of science (Cobern, 1991, ch. 5; Layton et al., 1993; Maddock, 1981; Pomeroy, 1994) and the dominant culture of a country (Archibald, 1995; Krugly-Smolska, 1995; Stanley & Brickhouse, 1994). Thus, the subculture of school science is comprised by a dynamic integration of these two main cultural influences, plus many more influences from diverse stakeholders in science education (Apple, 1979; Fensham, 1992). In this article I shall focus on the influence of the cultural transmission of science, but it is important to keep in mind the many other crucial influences experienced by educators of First Nations students.

Transmitting a scientific subculture can either be supportive or disruptive to students. If the subculture of science generally harmonizes with a student's everyday culture, science instruction will tend to support the student's view of the world, and the result is *enculturation* (Contreras & Lee, 1990; Driver, Asoko, Leach, Mortimer, & Scott, 1994; Hawkins & Pea, 1987). But if the subculture of science is generally at odds with a student's everyday world, as it can be with First Nations students, then science instruction can disrupt the student's view of the world by forcing that student to abandon or marginalize his or her indigenous way of knowing and reconstruct in its place a new (scientific) way of knowing. The result is *assimilation* (Jegede, 1995; MacIvor, 1995) which in some circles has highly negative connotations as evidenced by such epitaphs as "cultural imperialism" (Battiste, 1986, p. 23), the "arrogance of ethnocentricity" (Maddock, 1981, p. 13), and "racist" (Hodson, 1993, p. 687). Assimilation has caused oppression throughout the world and has disempowered whole groups of people (Gallard, 1993; Hodson, 1993; Urevbu, 1987), including Canadian First Nations peoples (Barman et al., 1986; Ermine, 1995).

Although the cultural function of school science has traditionally been to enculturate or assimilate students into the subculture of science (a prime example is *Science for All Americans*, AAAS, 1989), many students persistently and ingeniously resist assimilation (Driver, 1989; Hills, 1989; West & Pines, 1985) by playing a type of school game that allows them to pass their science course without learning the content assumed by the teacher and community. The game can have explicit rules which Larson (1995) discovered as "Fatima's rules," named after an articulate student in a high school chemistry class. Latour (1987) anticipated the phenomenon when he noticed one of the cultural expectations of school science: "Most schooling is based on the ability to answer questions unrelated to any context outside of the school room" (p. 197). Fatima's rules tell us how to do just that without understanding the subject matter meaningfully. For instance, one rule advises us not to read the textbook but to memorize the bold faced words and phrases. The cultural perspective on the conventional school science curriculum described here is summarized in Figure 1.

Understandably most First Nations educators reject the conventional science curriculum (Archibald, 1995; MacIvor, 1995), but they face a dilemma: How does one nurture students' achievement toward formal educational credentials and economic and political independence, while at the same time develop the students' cultural identity as Aboriginals (Kawagley, 1995; Leavitt, 1995; Nelson-Barber & Estrin, 1995; Philips, 1972; Snively, 1995; Stairs, 1995)? In other words, to what extent, and how, can First Nations students learn non-Aboriginal school subjects such as science without being harmfully assimilated by science's dominant Western culture?

GOAL

Cultural transmission of canonical science content (the knowledge, values, and skills used by the scientific community).

PROCESSES

Enculturation: a student learns the canonical content of science, which is in harmony with her/his indigenous view of the world, by incorporating that content into a personal view of the world. Scientific thinking enhances a person's everyday thinking.

Assimilation: a student learns the canonical content of science, which is at odds with her/his indigenous views of the world, by replacing or marginalizing those indigenous views. Scientific thinking dominates a person's everyday thinking.

Fatima's rules: school "games" played by a student and teacher allow students to get passing or high grades without understanding the course content in a meaningful way, the way the community assumes students understand it. Scientific thinking does not exist for a student and hence it does not connect with a person's everyday thinking.

Figure 1. The conventional school science curriculum.

Responses to the dilemma range between two extremes, each representing a different amount of risk of assimilation. At the low-risk extreme, educators dedicate themselves to preserving the culturally distinctive modes of communication, thought, and life styles of the students' Aboriginal culture. For instance, "Inquisitiveness about mystery and continued exploration of the inner space is a legacy we must promote in our own lives" (Ermine, 1995, p. 105). At the high-risk extreme, educators push talented students into a science career "pipeline," hoping that their success as a future role model will outweigh any personal loss to their self-identity as an Aboriginal (Massey, 1992).

The middle ground between these two extremes has been charted by Stairs (1995) in terms of the *degrees* of incorporating Aboriginal culture into current school practice (a five-step hierarchical model beginning with instruction in students' indigenous language—a "limited cultural inclusion" first step), and by Pomeroy (1994) in terms of nine distinct *research agendas* she abstracted from the science education literature: (1) science and engineering career support projects; (2) an indigenous social issues context for science content; (3) culturally sensitive instructional strategies; (4) historical non-Western role models; (5) demystifying stereotype images of science; (6) science communication for language minorities; (7) indigenous content for science to explain; (8) compare and bridge students' worldviews and the worldview of science; and (9) explore the content and the epistemology of both Western and Aboriginal knowledge of the physical world. Pomeroy (1994) pointed out:

> The nine agendas . . . generally move from a more static multicultural view, which maintains the structure of the institutions of science and culture as they are, to a more dynamic inter, or cross-cultural view which requires deconstruction of the view of Western science as universal with a new construction of and, most important, access to alternative views and methods. (p. 68)

Agendas 1–7 lead to the assimilation of students into Western science, whereas agendas 8 and 9 challenge us to conceive of alternatives to assimilation (and to Fatima's rules). Pomeroy drew upon Giroux's (1992) *Border Crossings* to suggest that teachers and students should together become "cultural border crossers" (Pomeroy, 1994, p. 50), a theme I elaborate in a later section.

MacIvor's (1995) response to the dilemma faced by First Nations educators belongs to Pomeroy's ninth agenda because MacIvor proposes an integration of Aboriginal and science education for the survival and well being of First Nations peoples: "The need for the development of scientific and technical skills among our people is pressing. . . . [R]easserting authority in areas of economic development and health care requires community expertise in science and technology" (p. 74). This resolution to the dilemma holds promise.

To achieve MacIvor's goal, school science should encourage students to learn science in a way that empowers them to make everyday choices about participating in either a First Nations cultural setting or the dominant Canadian cultural setting. Students would be capable of engaging in modes of communication, life styles, thought processes, and occupations of either culture (Hodson, 1992; Philips, 1972). In other words, First Nations students should develop the facility to cross cultural borders from the everyday subcultures of their peers, family, and tribe, into the subcultures of school science, and science and technology. These border crossings are essential to the success of cross-cultural education for First Nations students.

BORDER CROSSINGS

Two scenarios illustrate some of the difficulties that First Nations students can encounter when they move between cultures or subcultures. In each scenario a misunderstanding arises because at least one of the players does not recognize that a cultural border has been crossed.

1. Two Aboriginal students in Susan Chandler's 10th grade science class again did not follow her lab instructions. When she reviewed her instructions for these lab partners, her frustration peaked as she demanded, "Look me in the eye when I'm speaking to you!" Susan had failed to realize the deep respect the two students thought they were showing her by not making eye contact when she explained what they had done wrong.
2. University science student Coddy Mercredi disobeyed his faculty advisor by avoiding geology courses throughout his university career. Coddy did not want to spoil his aesthetic understanding of nature's beauty by polluting his mind with mechanistic explanations of the earth's landscapes. He understood science all too well and chose not to cross one of its borders. His advisor thought he was lazy and not worthy of a science scholarship.

These scenarios alert us to the potential obstacles that students face when they travel from the culture of their everyday world to the subculture of a science classroom and to the subculture of science itself. Coddy Mercredi, for instance, feared he would be assimilated by geology and therefore border crossing for him was problematic. For some students, however, such border crossings seem easy to negotiate.

Research in developing countries has identified problems experienced by students who have an indigenous "traditional" background and attempt to learn a subject matter grounded in Western culture (Akatugba & Wallace, 1996; Baker & Taylor, 1995; Dart, 1972; George & Glasgow, 1988; Jegede, 1995; Jegede & Okebukola, 1990, 1991; Knamiller, 1984; Pomeroy, 1994; Swift, 1992). Similar research with minority students in Western countries has also documented obstacles for students (Allen, 1995; Atwater & Riley, 1993; Barba, 1993; Contreras

& Lee, 1990; Krugly-Smolska, 1995; Lee, Fradd, & Sutman, 1995; Rakow & Bermudez, 1993). Allen (1995), for instance, documented worldview differences between Kickapoo Native American children and their science instruction; differences that make cultural border crossings "perilous" for many students. (Interestingly, many Western students in Western science classes face similar problems; see Aikenhead [1996], Cobern & Aikenhead [1997], and Ogawa [1995].) Pomeroy's (1994) review of cross-cultural studies (summarized above) addresses both non-Western and minority domains of research, and also overlaps with reviews of First Nations research in science education (MacIvor, 1995; Nelson-Barber & Estrin, 1995). One ubiquitous research finding from all of these reviews was summarized by Hennessy (1993, p. 9) when she concluded, "Crossing over from one domain of meaning to another is exceedingly hard."

Border crossings need not always be problematic, however. In our everyday lives we exhibit changes in behavior as we move from one social setting to another; for instance, from our professional colleagues at work to our families at home. As we move from the one subculture to the other, we intuitively and subconsciously alter certain beliefs, expectations, and conventions; in other words, we effortlessly negotiate the cultural border between professional and family settings. Only a few researchers have studied individual differences in terms of moving in and out of Western science. Medvitz (1985) documented cases of African scientists who moved effortlessly between the subcultures of a scientific laboratory and their tribal village, even when they recognized the contradictions between the two. Similar results were found for some high school graduates in a rural Melanesian culture in the South Pacific (Waldrip & Taylor, 1994). One of Medvitz's (1985) participants reported:

> It (the ability to shift cognitive patterns) is very interesting to us and we talk about it among ourselves in the university. When we are in our offices and laboratories we behave very scientifically. When we go home we make sure that the water is boiled for our babies. But when we put on our robes and go home to the villages and visit our parents and elders, we think very differently. It's not that we are behaving in a way to please them. It's that we are *thinking* differently. (p. 14, emphasis in the original)

Vice versa, the experience of border crossing by a Western physicist into a First Nations worldview was also described in terms of *thinking differently:* "we should all learn to talk and listen together without prejudgment, learn to suspend our prejudices, and allow our consciousness to flow along new lines" (Peat, 1994, p. 42). The capacity and motivation to participate in diverse subcultures are well-known human phenomena.

However, such capacities and motivations are not shared equally among all humans, as anthropologists Phelan et al. (1991) discovered when they investigated students' movement between the worlds of their families, peer groups, schools, and classrooms:

> Many adolescents are left to navigate transitions without direct assistance from persons in any of their contexts, most notably the school. Further, young people's success in managing these transitions varies widely. (p. 224)

The significance of these results has direct implications for First Nations students:

> Yet students' competence in moving between settings has tremendous implications for the quality of their lives and their chances of using the education system as a stepping stone to further education, productive work experiences, and a meaningful adult life. (p. 224)

Phelan et al.'s data suggested that differences between students' worlds lead to four types of transitions: congruent worlds support *smooth* transitions; different worlds require transitions to be *managed;* diverse worlds lead to *hazardous* transitions; and highly discordant worlds cause students to resist transitions which therefore become virtually *impossible.*

Costa (1995) provides a link between Phelan et al.'s anthropological study of schools and the specific issues faced by science educators. Based on the words and actions of 43 high school science students enrolled in two Californian schools with diverse student population, Costa concluded:

> Although there was great variety in students' descriptions of their worlds and the world of science, there were also distinctive patterns among the relationships between students' worlds of family and friends and their success in school and in science classrooms. (p. 316)

These patterns in the ease with which students move into the subculture of science were described in terms of familiar student characteristics, and then clustered into five categories (summarized here in a context of cultural border crossing): (1) "Potential Scientists" cross borders into school science so *smoothly* and naturally that the borders appear invisible; (2) "Other Smart Kids" *manage* their border crossing so well that few express any sense of science being a foreign subculture; (3) "'I Don't Know' Students" confront *hazardous* border crossings but learn to cope and survive; (4) "Outsiders" tend to be alienated from school itself and so border crossing into school science is virtually *impossible;* and (5) "Inside Outsiders" find border crossing into the subculture of school to be almost *impossible* because of overt discrimination at the school level, even though the students possessed an intense curiosity about the natural world.

Costa's research provides a framework within which important issues in First Nations education can be identified and discussed. The ease with which Aboriginal students cross cultural borders into the subculture of science, for instance, can be described roughly by Costa's categories, and these categories have implications for curriculum development (Aikenhead, 1996), as will be evident later in this article. In addition, the ease of border crossing could likely determine a student's capability to raid Western science for practical ends and achieve goals defined by First Nations science education (Kawagley, 1990, 1995; MacIvor, 1995).

Before we address some of the implications for the science curriculum, we need to clarify what content in science education has significance for Aboriginal students.

APPROPRIATE KNOWLEDGE FOR FIRST NATIONS STUDENTS

What knowledge from science education will help achieve such practical ends as economic development, environmental responsibility, and cultural survival? Barriers to economic development have been *uncritically* attributed to a nation's lack of science education (Medvitz, 1985; Ziman, 1984). In spite of political rhetoric to the contrary, economic development in industrialized countries depends on factors other than a scientifically literate population; factors all beyond the influence of public science education; for example: emerging technologies, industrial restructuring, poor management decisions, and government policies that affect military development, monetary exchange rates, wages, licensing agreements, etc. (Bishop, 1995; Cuban, 1994; David, 1995; Rotberg, 1994). Nelson-Barber and Estrin (1995) argue persuasively that current economic problems in the United States have nothing to do with recent claims of inadequacies in the country's science education system because "there are at present too many college-educated workers for the available jobs requiring a college degree" (p. 2). A sound general education that nurtures flexibility, adaptability, and prepares students for future on-the-job retraining holds greatest promise for economic development (David, 1995; Keep & Mayhew, 1988; Waddington, 1987). Similarly, environmentally responsible action is almost uncorrelated with achievement in environmental education (Cross & Price, 1992; Johnson, 1992; Simonelli, 1994; Solomon, 1994). In other words, formal education normally found in school science does not usually translate into economic development or environmental responsibility. First Nations educators did well to reject our conventional science education curriculum.

In addition, science education does not normally enhance an adult's understanding of his/her everyday world, a world replete with science-related problems (personal or professional), social issues, or practical decisions (Furnham, 1992; Hennessy, 1993; Layton et al., 1993; Wynne, 1991). Engineers and lay persons *cannot simply apply* scientific knowledge to a particular problem because there are so many nonscientific factors at play that in many cases the most effective resolution is to ignore the science (e.g., the workers in a nuclear plant avoiding scientific evidence of possible harm, because there is nothing the workers could do about it, short of quitting their jobs). But even when the science is effectively applicable, the best that one can do is to deconstruct science from its mathematically ideal form and reconstruct it in the unique context of use (Layton, 1991). Based on case study research into adults' attempted applications of scientific knowledge, Jenkins (1992) commented that using science in the everyday world:

> is about creating new knowledge, or where possible, restructuring, reworking and transforming existing scientific knowledge into forms which serve the purpose in hand. Whatever that purpose (political, social, personal, etc), it is essentially concerned with action or capability, rather than with the acquisition of knowledge for its own sake. (p. 236)

One hazard, then, in negotiating the cultural borders between the everyday world and the subculture of science is the need to restructure or transform scientific knowledge. (One advantage of Aboriginal knowledge of nature is that it comes already contextualized, and hence there is no need to restructure it before putting it to use; Latour [1987, ch. 5].)

Sometimes science actually hinders, rather than facilitates, a practical solution, as Waldrip and Taylor (1994) observed in a rural community of a Third World country, or as Medvitz (1985) discovered in a case study of 19th century millwrights in the United States whose work with water mills dramatically outperformed French engineers. The self-taught Americans were unaware of the science of hydrodynamics. Their judgments about water mills were made on the effectiveness of the product rather than on the adherence to scientific principles. The French engineers, on the other hand, were obliged to warrant their designs on known hydrodynamic principles, thereby being held prisoner to the 19th century science of hydrodynamics, which did not include principles known today by fluid engineers.

The American Association for the Advancement of Science (AAAS, 1977) claimed that the prime obstacle to First Nations peoples' participation in science was science's lack of relevance to their everyday lives and to their cultural survival. Similarly, the knowledge, skills, and values found in the typical secondary science curriculum have been widely criticized throughout the world for being isolated and irrelevant to everyday events that affect economic development, environmental responsibility, and cultural survival (Knamiller, 1984; Layton et al., 1993; MacIvor, 1995; Simonelli, 1994; Swift, 1992). "Science learned in school is learned as science in school, not as science on the farm or in the health clinic or garage" (Medvitz, 1985, p. 15). Cobern (1994) similarly talks about students practicing "cognitive apartheid," referring to the isolation and segregation of school science content within the minds of students, which for some students may not necessarily be a negative way to cope (as discussed in the next section). Jegede (1995) has proposed a "collateral learning theory" to explain various degrees of cognitive apartheid. This foreign nature of science content has been the focus of research in the field of situated cognition (Furnham, 1992; Hennessy, 1993; Lave, 1988) which concludes that scientific content traditionally learned in science classrooms can seldom be applied to the everyday world. This finding seriously challenges the efficacy of the conventional science curriculum, not only for Aboriginal students, but for all students, except perhaps the small minority categorized as "Potential Scientists" by Costa (1995).

What knowledge, then, is related to the goals of economic development, environmental responsibility, and cultural survival? Layton (1991) and MacIvor (1995) argue in favor of practical instruction that integrates science, technology, and indigenous (commonsense) knowledge so that as adults, students will be able to construct "situation-specific knowledge which (is) often more functional in relation to their problem than that offered to them by 'scientific' sources" (Layton, 1991, p. 58). Knowledge for practical action is constructed eclectically from several knowledge systems relevant to a situation. It may be helpful for curriculum developers to recognize three types of knowledge systems useful to practical action: commonsense knowledge (Reif & Larkin, 1991; Ryle, 1954; Solomon, 1992, ch. 1); Western technological/engineering knowledge (Gardner, 1994; Layton, 1991; Schauble, Klopfer, & Raghaven, 1991; Snow, 1987); and Western scientific knowledge (Kuhn, 1970; Snow, 1987). Although the three systems share common facets (Brickhouse, Stanley, & Whitson, 1993), they have notable differences:

- *Commonsense knowledge*—socially situated, context dependent, human centered.
- *Technology knowledge*—problem situated, context dependent, efficiency centered.
- *Science knowledge*—puzzle situated, context independent, rationalistically centered.

If science education is going to contribute to First Nations economic development, environmental responsibility, and cultural survival, students will need to learn, and to eclectically use in practical everyday situations, many ways of knowing: Aboriginal common sense, Aboriginal and Western technology, and Aboriginal and Western knowledge of nature (Deloria, 1992a; Johnson, 1992; Hewson, 1988; Kawagley, 1990; MacIvor, 1995; Pomeroy, 1992, 1994; Simonelli, 1994; Yakubu, 1994). This recommendation is fleshed out in the next section.

CURRICULUM IMPLICATIONS FOR FIRST NATIONS STUDENTS

Because the subculture of science tends to permeate the culture of those who engage it, curriculum specialists and teachers need to develop a science curriculum that explicitly eschews assimilation and vigilantly circumvents unwanted acculturation. An ideal goal is to have First Nations students "master and critique scientific ways of knowing without, in the process, sacrificing their own personally and culturally constructed ways of knowing" (O'Loughlin, 1992, p. 791). The capacity and motivation to master and critique scientific ways of knowing seem to depend on the ease with which students cross cultural borders between their everyday worlds and the world of science. One curriculum implication, therefore, is to develop instructional materials that:

1. Make border crossings explicit for students.
2. Facilitate border crossings.
3. Substantiate the validity of students' personally and culturally constructed ways of knowing.

4. Teach the knowledge, skills, and values of Western science and technology *in the context of* societal roles (social, political, economic, etc.), including the role of a hegemonic icon of cultural imperialism.

This implication strengthens item nine in Pomeroy's (1994) review of cross-cultural agendas, and harmonizes with curriculum proposals for First Nations peoples (Kawagley, 1995; MacIvor, 1995; Nelson-Barber & Estrin, 1995; Snively, 1995) and for students in developing countries (Jegede, 1995; Medvitz, 1985; Yoong, 1986).

The dynamic nature of Aboriginal culture (Hampton, 1995; Kawagley, 1995; More, 1987) suggests that a certain degree of acculturation is warranted, although the power to decide what is warranted must reside completely with a First Nations community. Even so, acculturation models for First Nations education have been criticized. When these models are placed in a wider context of the dominant culture of Canadian society, with its shameful history (past and present) of promoting economic and social poverty for First Nations peoples (Barman et al., 1986; Buckley, 1992), the acculturation models for education are admonished for masking inevitable agendas of assimilation by Canadian society (Urion, 1993). This new dilemma might be resolved by emancipatory research and development intended to teach Aboriginal students to recreate "the terms in which they articulate their social histories and the terms of their empowerment" (Urion, 1993, p. 105). Omani (1992) describes how to initiate such research and development, which he calls "community-based participatory research."

Clearly, community-based participatory research is one way to develop an appropriate subculture for school science. However, no one has systematically explored the redefinition of science education proposed by MacIvor (1995); that is, "(to) transform the science curriculum from one which is essentially assimilationist to one which honours, respects, and nurtures our traditional beliefs and life-ways, and which presents science and technology in a more authentic way" (p. 90). Her approach integrates selected science and technology content into an Aboriginal worldview and requires a coordination "with economic, social, and resource developments to ensure that students can apply their new skills within their local communities" (p. 77). A science curriculum dedicated to raiding Western science and technology for practical action is a curriculum that appropriates science and technology to further the goals of First Nations peoples (Pomeroy's ninth agenda), not unlike a type of curriculum experienced in Japan as "Japanized science" (Kawasaki, 1996).

To achieve the curriculum implication described above, I suggest we consider, as a first step, a type of science curriculum already developed internationally. It is dedicated to a student-oriented, critical, and environmentally responsible approach to science, and it contextualizes Western science in the social and technological settings relevant to students—Aboriginal students in this case. This type of science curriculum is called science–technology–society (STS) and has a 25-year history of research and development (Bingle & Gaskell, 1994; Solomon & Aikenhead, 1994). A *cross-cultural* STS science curriculum would emphasize cultural border crossing for the purpose of enhancing students' capabilities and motivations to eclectically draw upon Aboriginal cultures and upon the subculture of science and technology, for the purpose of taking practical action toward economic development, environmental responsibility, and cultural survival.

Kawagley (1995, ch. 5) offers a real-life example—a fish camp as a science and technology "classroom." I provide details of a more conventional cross-cultural STS science and technology curriculum elsewhere (Aikenhead, 1996). These details are summarized here in the context of First Nations education.

Enculturation of First Nations students in a cross-cultural science course relates to the cultural transmission of Aboriginal content. Science content is not transmitted by enculturation

GOAL

Transmission of Aboriginal culture along with a cross-cultural transmission of science and technology.

PROCESSES

Enculturation: a student learns Aboriginal knowledge, values, and skills in harmony with his/her indigenous view of the world, by incorporating them into a personal view of the world. Aboriginal thinking enhances a person's everyday thinking.

Autonomous acculturation: a student borrows or adapts (incorporates) some content from Western science and technology because the content appears useful to him/her, thereby replacing some former indigenous views. Everyday thinking is an integrated combination of commonsense thinking and some science/technology thinking.

"Anthropological" instruction: a student learns the content of subculture science similar to an anthropologist learning the ways of a foreign culture. The subculture of science is a repository to be raided, but its thinking does not connect with a person's everyday thinking, yet a person can do either type of thinking, depending on the context.

Figure 2. A Cross-cultural perspective on the school science curriculum for First Nations students.

due to the enormous differences between Aboriginal and Western ways of knowing. What are the alternatives? Two are depicted in Figure 2, autonomous acculturation and "anthropological" instruction.

Autonomous acculturation is a process of intercultural borrowing or adaptation in which one borrows or adapts attractive content or aspects of another culture and incorporates (assimilates) it into one's indigenous culture. Autonomous acculturation represents one way of raiding Western science and technology for practical action of benefit to First Nations peoples. A clear example is documented in George's (1995) case study of a Trinidadian woman who combined aspects of Western medicine with her indigenous folk medicine. The phrase "autonomous acculturation" seeks to avoid negative connotations associated with acculturation (mentioned above). Autonomous acculturation meets Lijnse's (1995) stringent requirement that constructivist learning must allow students to "construct in freedom" (p. 192). When MacIvor (1995) asserts that "conventional science must be presented as a way, not *the* way, of contemplating the universe" (p. 88, italics in the original) in the context of First Nations control over the science content and its presentation in classrooms, she could be describing autonomous acculturation. Snively's (1990) case study of Luke, an Aboriginal boy in grade 6 studying the seashore, documents autonomous acculturation in action.

> Clearly, after instruction, Luke continued to have many ideas and beliefs about seashore relationships consistent with a spiritual (Aboriginal) view of the seashore and many ideas and beliefs consistent with an ecological view of the seashore (gained from science instruction). . . . It is possible to increase a student's knowledge of science concepts without altering substantially his or her preferred orientation. . . . It makes sense to talk about increasing a student's knowledge and changing certain alternate beliefs and science concepts. (pp. 53–54)

Snively observed that the teaching process effectively supported First Nations students who found border crossings hazardous—Costa's (1995) "I Don't Know" Students. Autonomous acculturation may also transform students who have been Outsiders in science classes (to continue Costa's terms) into "I Don't Know" Students or into Other Smart Kids.

But autonomous acculturation is not the only process that nurtures learning, because students do not need to modify features of their indigenous culture to understand the subculture of science (Solomon, 1984, 1987). In other words, the conceptual modification associated with autonomous acculturation is set aside in favor of conceptual proliferation dictated by specific social or practical contexts (Dart & Pradham, 1967; Driver et al., 1994; Furnham, 1992; Hennessy, 1993). By analogy, cultural anthropologists do not need to accept the cultural ways of their "subjects" to understand and engage in some of those ways (Medvitz, 1985). A different type of teaching, one I call "anthropological" instruction of science, puts students in a position not unlike an anthropologist. "Anthropological" instruction addresses the needs of students who find border crossings to be manageable or smooth—Costa's (1995) Other Smart Kids or her Potential Scientists—as Medvitz (1985) in Nigeria or Waldrip and Taylor (1994) in the South Pacific discovered, for example. The subculture of science can be treated as a professional intellectual game (for Potential Scientists) or as a repository to be raided pragmatically for the benefit of practical action (for Other Smart Kids). MacIvor's (1995) view of science education seems to be consistent with "anthropological" instruction. Jegede's (1995) collateral learning theory explains how students might benefit from "anthropological" instruction and it suggests that a learner be guided through a progression of types of collateral learning, a progression that appears to move from "anthropological" instruction to autonomous acculturation; that is, from learning science as cognitive apartheid (Cobern, 1994) to learning science integrated with one's other knowledge.

In this regard, the Ahkwesahsne Mohawk Board of Education (1994) are pioneers in curriculum development, producing a series of modules, *Circles & Lines,* for Mohawk students in grades 7 to 9. The autonomous acculturation and "anthropological" instruction endemic to their materials integrates several school subjects (science, math, social studies, and language arts) within an Aboriginal framework. Border crossing between Mohawk culture and the subculture of science is evident in modules called "Ways of Knowing," studied in grade 7 and again in grade 9. In other modules, science and technology are contextualized within historical, economic, and political events of importance to the Mohawk nation. There is a critical need for similar cross-cultural STS materials for all Aboriginal students. In addition, successful projects in non-Western countries might serve as guides or inspiration (e.g., Jegede, 1994; Pomeroy, 1994; Ogawa, 1995; Wilson, 1981; Yakubu, 1994). Individual teachers can effectively instruct First Nations students by planning cross-cultural STS science classes that explore and respect both Aboriginal and scientific beliefs about nature (Snively, 1990). Snively (1995) provides specific suggestions on how to proceed, including a table of topics for various grade levels and a five-step process for teachers to follow. She also considers implications for teacher education programs.

In cross-cultural STS science education, students and teachers become cultural border crossers between First Nations cultures and the subculture of science. The metaphor "teacher as culture broker" was used by Stairs (1995) to analyze the teacher's role in resolving cultural conflicts that arise in cross-cultural education. In the cross-cultural science education that I propose, students are "tourists" in a foreign culture and depend on teachers to be "tour guides" or "travel agents" who take (or send) students across cultural borders into Western science and direct the use of science and technology in the context of the students' everyday world (Aikenhead, 1996). Some students need more help (some more independence) than others when they cross into the subculture of science. Snively (1990) describes how a teacher became such a travel agent for both Aboriginal and non-Aboriginal students in her classroom. Similarly, Lijnse (1995) talks about guiding "students in the activity of 'scientificalizing' their world" (p. 192).

Border crossings within a cross-cultural STS science curriculum may be facilitated by studying the subcultures of students' everyday worlds (peers, family, tribe, nation), by contrasting those subcultures with a critical analysis of the subculture of science (its norms, values, beliefs, expectations, and conventional actions), and by *consciously* moving back and forth between the everyday world and the science world, switching language conventions explicitly, switching conceptualizations explicitly, switching values explicitly, switching epistemologies explicitly, but never requiring students to adopt a scientific way of knowing as their personal way (Aikenhead, 1996). This "no assimilation" rule, however, does not preclude teachers from capturing a student's interest and curiosity in science and then doing a good job at a rite of passage into the subculture of science.

CONCLUSION

Can we be optimistic about developing a First Nations cross-cultural science and technology curriculum for economic development, environmental responsibility, and cultural survival? Stairs (1995) finds optimism in the ongoing shift in First Nations education from the token inclusion of Aboriginal content to an Aboriginal perspective that serves as a base for the integration of non-Aboriginal content. She also finds optimism in educators developing roles that she describes as "culture brokers between Native and Euro-Canadian ways of knowing" (p. 150), of which the teacher in Snively's (1990) study is a prime example. I find optimism in successful curriculum development projects such as *Lines & Circles* (Ahkwesahsne Mohawk Board of Education, 1994). Research with First Nations students also suggests reasons for optimism (MacIvor, 1995; Snively, 1990, 1995), as does research in non-Western countries (Baker & Taylor, 1995; George, 1992; Jegede, 1995; Medvitz, 1985; Ogawa, 1995).

A horizon for educators to aim at has been painted by MacIvor's (1995) "Redefining Science Education for Aboriginal Students." The present article has attempted to clarify a pathway toward that horizon by conceptualizing science education as cross-cultural instruction in keeping with Pomeroy's (1994) ninth agenda (presenting and exploring both Aboriginal and Western ways of knowing about nature). The pathway I propose is illuminated by cultural border crossings which teachers facilitate in their role as tour guide, travel agent, or culture broker. Teachers will "help students feel that the school program is a natural part of their lives and help them move more smoothly back and forth between one culture and the other" (Leavitt, 1995, p. 134). Students' intelligence and ingenuity ensures their resilience during hazardous border crossings into the subculture of science, as long as students feel respected, and provided that the science and technology content enhances their knowledge for practical action to further the goals of First Nations peoples (Kawagley, 1995). Such knowledge eclectically draws upon indigenous common sense, Aboriginal and Western technology, and Aboriginal and Western knowledge of nature. Autonomous acculturation and "anthropological" instruction encourage students to learn Western science and technology without losing their Aboriginal culture and identity. The pathway I propose is partly mapped out by established STS curricula, examples of which are now emerging from First Nations education and from non-Western countries.

A cross-cultural perspective for the science curriculum suggests that learning results from the ever-changing interactions among: (1) the personal orientations of a student; (2) the subcultures of a student's family, tribe, peers, school, media, etc.; (3) the culture of his or her nation; and (4) the subcultures of science and school science. Much more research and development is needed to understand these interactions more clearly.

In addition to bringing appropriate science and technology to First Nations peoples, culture brokerage can work in the opposite direction. Non-Aboriginal students, as well as scientists and engineers, have much to learn from First Nations cultures (Peat, 1994), especially how to coexist with Mother Earth and be environmentally responsible (Johnson, 1992; Knudtson & Suzuki, 1992; Simonelli, 1994; Snively, 1995; Swift, 1992; Yakubu, 1994). This issue is reviewed by Corsiglia and Snively (1995) in their analysis of First Nations knowledge of nature (its characteristics, strengths, and limitations) and their analysis of the new field "traditional ecological knowledge." In addition, we can learn something about our own knowledge system by comparing it with alternative systems. Western students could develop insights into the nature of Western science by comparing and contrasting it with Aboriginal knowledge of nature. For example, Western students could benefit from learning why Deloria (1992b, quoted previously) thinks that some fundamental ideas in Western science are superstitions. Ogawa (1995) argues persuasively for this type of instruction which he calls a "multiscience" perspective on teaching science.

Simonelli (1994) relates a fascinating Aboriginal prophecy concerning the four peoples of the earth, each learning different bodies of knowledge: the red people will be keepers of the earth; the black people will know water wisdom; the yellow people will be keepers of air knowledge; and the white people will know the ways of fire. (The ways of fire are dramatically evident in industrial production, resource depletion, combustion engines, and nuclear weapons.) The prophecy states that on the initiative of the white people, the four peoples of the earth will one day combine their knowledge into an integrated whole. Before the white people can initiate a coming together, however, they need to recognize the border crossings of First Nations students and be open themselves to experience their own hazardous border crossings into a First Nations culture.

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