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Reconsidering Approaches to Aboriginal Science and Mathematics Education

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In Canada, Aboriginal postsecondary enrollment and completion rates are significantly lower than those of non-Aboriginal students. This is most evident in studies involving science and mathematics. The investigation of this issue was informed by focus group discussions with eight participants representing a Blackfoot community. Themes emerging in the data emphasize educational approaches of assimilation, segregation, and mutual dialogue. Intertwining Aboriginal and Western knowledge systems holds generative possibilities for science and mathematics education. Understanding the perspectives of Aboriginal educators in the context of science and mathematics education is a necessary beginning place for future investigations into improving postsecondary completion rates by Aboriginal students.

Au Canada, les taux d'inscription et de réussite aux études postsecondaires sont plus faibles, et de façon appréciable, chez les Autochtones que chez les non Autochtones. Cet écart est le plus évident dans les programmes d'études impliquant les sciences et les mathématiques. Notre recherche repose sur des discussions avec des groupes de consultation formés de huit membres qui représentaient une communauté Pieds-Noirs. Les thèmes qui ont découlé des données soulignent les approches pédagogiques touchant l'assimilation, la ségrégation et le dialogue mutuel. L'entrelacement du système de connaissances autochtone et du système de connaissances occidentales offre des possibilités génératives pour l'enseignement des sciences et des mathématiques. À l'avenir, les études portant sur l'amélioration des taux de réussite chez les étudiants autochtones doivent s'appuyer sur une connaissance de la perspective des enseignants autochtones dans le contexte de l'enseignement des sciences et des mathématiques.

In Canada, Aboriginal postsecondary enrollment and completion rates are significantly lower than those of non-Aboriginal students. This is most evident in studies involving science and mathematics. As researchers and educators, we wondered what Aboriginal educators might have to say about science and mathematics education. We invited eight participants representing a Blackfoot community to investigate the research question: How can Aboriginal and university communities co-construct educational opportunities for Aboriginal students in elementary, secondary, and postsecondary science and mathematics settings? In this article, we draw on the stories told by our participants to investigate three approaches to Aboriginal education that emerged in our conversations: assimilation, self-segregation, and dialogical interaction.

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Theoretical Framework

Indigenous[1] Science

Science and mathematics can be defined and understood in many ways. Science as defined by Little Bear (2000) is dependent on the definer as viewed specifically from his or her culture, world view, or paradigm. Ogawa (1995) also recognizes a relativistic perspective of science and defines it as "a rational perceiving of reality where perceiving means both the action constructing reality and the construct of reality" (p. 588). He believes that all cultures have empirically based rational descriptions and explanations of the physical world. Ogawa proposes that there are three types of sciences of interest to educators: Indigenous science, personal science, and Western modern science. Indigenous science refers to the science in a particular culture that reflects a collective world view. Examples of Indigenous science could include Chinese science, Japanese science, or Aboriginal science. Personal science is unique to each person and involves personal observations or explanations of the world. Ogawa describes Western modern science as "a collective rational perceiving of reality, which is shared and authorized by the scientific community" (p. 589). Rather than focusing on natural phenomena, "Western modem science pertains to a Cartesian materialistic world in which humans are seen in reductionistic and mechanistic terms" (p. 589). He claims that there is a vast gap between Western modern science and Indigenous science.

Cajete (2000) suggests that Native science is "the collective heritage of human experience with the natural world; in its most essential form, it is a map of natural reality drawn from the experience of thousands of human generations" (p. 3). He describes a broad perspective of Native science that includes metaphysics, philosophy, art, architecture, agriculture, and ritual and ceremony practices by Indigenous peoples. This view of science involves studies related to the earth and extends to include "spirituality, community, creativity, and technologies that sustain environments and support essential aspects of human life" (p. 2). Cajete writes, "*As we experience the world, so we are also experienced by the world.* Maintaining relationships through continual participation with the natural creative process of nature is the hallmark of Native science" (p. 20, italics in original).

The Western view of science using the Western paradigm of mathematical measurements may not coincide with how nature is experienced by the Aboriginal peoples. Nature cannot be superimposed by Western mathematics and examined from a mathematical grid. Little Bear (2000) suggests that Aboriginal science is a pursuit for knowledge and is not based on measurement because Native Americans never claim regularities as laws or finalities: the only constant is change. This can be related through the tradition of Native American storytelling because it is not the actual words but the lived experience that gives a holistic treatment of "livingness" and "spirit" (p. xii). This is the fundamental gap in the mathematics of Western science. Western science, according to Hayward (1997), leaves out the sacredness, the livingness, and the soul of the world. This lack of relevance emphasizes the difficulty with the Aboriginal experience of science and mathematics as taught from the Western perspective.

In much of the education literature, the term *science* is taken to mean *Western science*. However, science can be described in many ways. Throughout this article, we use Ogawa's (1995) distinctions to clarify the type of science we are describing. The term *science* is used to refer to the encompassing notion of science as a rational perceiving of reality. In this particular context, we use the term *Indigenous science and mathematics* to describe the science and

mathematics of Aboriginal peoples and use the term *Western science and mathematics* to refer to their respective Western modern disciplines. We believe that Ogawa's types of science help us to understand the perspectives of Aboriginal educators in the context of science and mathematics education.

Aboriginal Approaches to Indigenous Science and Mathematics Education

Battiste (2002) writes about the uniqueness of Aboriginal education. She identifies three main approaches to Indigenous education taken by non-Aboriginal educational institutions: reducing Aboriginal knowledge to static taxonomic categories (categorizing knowledge, practices, and techniques used by Indigenous peoples and assuming that these are immutable); reducing it to its observable empirical elements (assuming that Indigenous peoples' local knowledge of a particular geographical area can be elicited by scientists); and assuming that it has no validity in educational realms (treating Indigenous knowledges as normative or spiritual). These approaches, she suggests, ignore the holistic nature of Aboriginal knowledge and its fundamental importance to Aboriginal peoples.

In order to consider educational approaches in Aboriginal contexts, it is important to understand what Indigenous knowledges are. Battiste (2002) suggests, "Indigenous knowledge comprises the complex set of technologies developed and sustained by Indigenous civilizations" (p. 2). In her view, Indigenous knowledge is "an adaptable, dynamic system based on skills, abilities, and problem-solving techniques that change over time depending on environmental conditions" (p. 11). She states that Indigenous peoples have a complete knowledge system different from a Eurocentric system and that this knowledge is holistic and fundamentally important to Indigenous peoples. For Indigenous peoples, knowledge is a process, not a commodity. Customs for acquiring and sharing knowledge exist, thus emphasizing the responsibility and importance of knowledge-keepers.

In the Blackfoot context, balance and harmony with the environment are recognized as part of the knowledge system. Bastien (2004) writes, "Ontological responsibilities of *Siksikaitsitapi* are the beginning of affirming and reconstructing ways of knowing. These fundamental responsibilities must be renewed by coming to know the natural alliances" (p. 4). She suggests that Indigenous knowledge is linked to intricate interrelationships in nature. The environment is understood as "the source from which all life originates and from which all knowledge is born" (p. 39). Writing about Blackfoot physics, Peat (2002) emphasizes the importance of the web of interrelationships in nature and suggests that Indigenous knowledge comes through

> direct experience of songs and ceremonies, through the activities of hunting and daily life, from trees and animals, and in dreams and visions. Coming-to-knowing means entering into relationship with the spirits of knowledge, with plants and animals, with beings that animate dreams and visions, and with the spirit of the people. (p. 65)

Peat describes relational knowledge in Aboriginal contexts:

> Traditional knowledge comes about through watching and listening, not in the passive way that schools demand, but through direct experience of songs and ceremonies, through the activities of hunting and daily life, from trees and animals, and in dreams and visions. Coming-to-knowing means entering into relationship with the spirits of knowledge, with plants and animals, with beings that animate dreams and visions, and with the spirit of the people. (p. 65)

Indeed, Aboriginal approaches to Indigenous science and mathematics education emphasize relationships. Peat highlights the interconnectivity between Indigenous science and mathematics. He describes Indigenous mathematics as sacred and suggests that Indigenous mathematics should not be taught separately from other subjects and disciplines. Mathematics is relational: "The whole notion of relationship is central in Indigenous science. While we in the West place emphasis upon objects and categories, the Native mind deals with process and relations of relationship" (p. 162).

Educational approaches to Indigenous science and mathematics education involve an understanding of Indigenous knowledges. However, these approaches are not always viewed as successful. McMurchy-Pilkington (2008) investigates how Mäori, the Indigenous people of New Zealand, have developed the Pängarau, the first national mathematics curriculum document in the Mäori language. Ten Mäori teachers were contracted to write the document under the guidance of a Mäori project manager. This group was overseen by two advisory groups. Tribal input was invited to ensure that the mathematics vocabulary was inclusive of all tribes. However, the curriculum did not reflect Mäori knowledge and world views as the advisory groups insisted that this be a parallel document to the English-medium curriculum. Once the document had been submitted, the advisory groups sent it to the Mäori Language Commission to have it rewritten. In a report reviewing this curriculum process, recommendations included having Indigenous knowledges inform the curriculum in a more "comprehensive, inclusive, holistic, integrative curriculum framework that reflects Maori status as *tangata whenua* (Indigenous people of the land)" (p. 633). Although the intent of creating a Mäori mathematics curriculum seemed to offer an opportunity to integrate Indigenous knowledges and Western mathematics, the focus on the Mäori language became a token gesture of translation. In this case, creating a Mäori curriculum that conformed to the English-medium mathematics curriculum in both structure and outcomes seemed ineffective.

In North America, researchers have considered various Aboriginal approaches to Indigenous science and mathematics education from culturally responsive perspectives (Sterenberg et al., 2010). One such example is Math in a Cultural Context (MCC), a culturally based mathematics program for Yup'ik students in Alaska (Lipka, 1994). This educational approach is informed by Western and Indigenous knowledges and includes mathematics content knowledge, pedagogical knowledge, and contextual knowledge (Lipka et al., 2005). It was developed in collaboration with Yup'ik elders, teachers, schools, and communities. Modules in the mathematics curriculum for elementary students include Yup'ik knowledge about star navigation, kayak construction and use, and parka patterns. This educational approach is unique is its emphasis on starting from the elders' knowledge.

Investigating Blackfoot educators' perspectives of Indigenous science and mathematics education offers an opportunity to engage in dialogues that can contribute significantly to our understanding of how postsecondary completion rates by Aboriginal students can be improved.

An Aboriginal Research Methodology

This study falls within an Indigenous paradigm of social science research. Wilson (2007) uses the term *Indigenist* to identify a research paradigm related to Indigenous perspectives. He chooses to use this term because he believes "that an Indigenist paradigm can be used by anyone who chooses to follow its tenets" (p. 193). Wilson also suggests that in order to describe and use

an Indigenist research paradigm, "researchers and authors need to place themselves and their work firmly in a relational context" (p. 194).

As researchers, we have placed ourselves in such a context and have followed its tenets. Our work adheres to Wilson's (2007) guiding principles of Indigenist research. Specifically, it is conducted in a spirit of kindness, honesty, and compassion, and it attempts to respect the related and interconnectedness of all forms of life. The research is grounded in the reality of the Aboriginal experience and naturally harmonizes with an Aboriginal research paradigm. Our findings are supported by our participants who are living out an Aboriginal epistemology. Indeed, our research methods are process-oriented as we interact as co-participants in the project.

Research Study

A Blackfoot community in southern Alberta was the context of the study as it was the predominant Aboriginal culture of the area surrounding Lethbridge University. This community is part of the Niitsítapi (Blackfoot Confederacy) made up of four tribes: the Siksika (Blackfoot), the Kainai (Blood), the Piikani (Peigan), and the Blackfeet (South Peigan). Historically, the territory of the Piikani, Kainai, and Siksika bands was bordered by the North Saskatchewan River, the Yellowstone River, the Rocky Mountains, and the present Alberta-Saskatchewan boundary (McMillan & Yellowhorn, 2004). The population of the Blackfoot tribe in this study's context is over 10,000, and the community occupies one of the largest reserves in Canada.

Blackfoot knowledge systems involve the cyclical and interrelatedness of the Blackfoot values of integrity, responsibility, balance, relationship, respect, sharing, and kindness (Bastien, 2004). We entered into this study with a deep respect for Blackfoot knowledge systems. In the study we explored teaching and learning approaches that would benefit Aboriginal students by promoting Aboriginal knowledge systems and that would encourage interest, participation, continued enrollment, and retention in the sciences and mathematics.

The study emerged from informal conversations with members of the Blackfoot community and thus was responsive to questions identified by members of the Aboriginal community (Weber-Pillwax, 2004). Drawing on personal and professional relationships, we asked two community leaders, James, a University professor, and Walter, a former director of an Aboriginal college, to initiate the process of connection between us and Band Council members and the elders. They willingly did this. We knew Patrick, an Aboriginal student from the community, and invited him to work as our research assistant to aid in the connections with the Blackfoot community, to provide the necessary information and contacts in terms of protocol and Blackfoot knowledge systems, and to participate as a member of the focus group (all names are pseudonyms).

Using a snowball sample and input from our community leaders and research assistant, we invited an additional five members of the Blackfoot community to be part of the focus group. Through these preexisting relationships, we acknowledged the "relational quality of Indigenous research" (Wilson, 2008, p. 81). Participants included ourselves as well as Marie, an Elder; Sara, a university professor; Georgina, a teacher; Neal, a director of a First Nations, Métis, and Inuit (FNMI) program in a school setting; and Emma, a university student. All participants were chosen because they had a vested interest in the study as current or future educational leaders. The investigation of the research question was guided by a focus group made up of eight community members.

We met six times throughout one year to establish the initial goals of the project, to determine possible needs, and to explore potential approaches and protocols consistent with an Aboriginal research methodology. Although we did not use a formal talking circle, we sat around a circular table to encourage respectful and equal opportunities for participants to speak (Wilson, 2008). Marie began each meeting by leading us in prayer and by telling stories about her educational experiences. Often these were offered in the Blackfoot language. As researchers, we did not control the agenda, nor did we prepare interview questions: our role was to listen with respect in order to encourage ethical relationships.

The conversations and stories of the focus group were recorded, and Patrick was involved in collecting and analyzing the data. In analyzing the data, we wrote summaries of the conversations and chose stories from the transcripts that exemplified what we were learning in response to the research question. The transcripts and summaries were brought back to the focus group for review, feedback, clarification, and suggestions. Together, participants formed recommendations for teaching and learning approaches for Aboriginal students, at both school and postsecondary levels. These recommendations were connected to the educational experiences of our participants and were informed by stories of their experiences of various educational approaches. Their experiences of Western teaching and learning approaches became common and recurring themes throughout our conversations and were identified, organized, and named by our participants. It is these Western approaches to teaching Aboriginal students that we explicate in this article.

The Dominant Western Approach: Assimilation

Relationships between Aboriginal and Western communities have a legacy of disconnection (Council of Ministers of Education, Canada, 2002). Historically, non-Aboriginal communities have emphasized an approach to Aboriginal education based on assimilation. This has led to widespread distrust in the Aboriginal community of the educational system. Stories of several of our participants echo experiences of forced assimilation through residential schools.

Learning White Ways

Marie described her family's experiences of residential school. Her father attended one of the first schools in southern Alberta because his parents believed that it would benefit him. She described her grandfather as saying, "Take my kids, take my children … I want them to learn the White ways. I want them to be able to talk to the White people and understand the White people's ways." According to Marie, her father had positive experiences of schooling. He was a teenager when he began school away from the reserve, and because of intermittent contact with his parents when they traveled once a year to Edmonton to sell their hides and furs, he retained his understanding of his Blackfoot heritage. Yet he learned how to speak English and how to farm: "Some of [the students] were taken out to milk cows or into the garden and after about three years my dad was taught how to farm and he had cattle so he learned how to take care of the stock and to milk cows … My father said they really enjoyed it."

James attended a residential school as a boy. He had another perspective of the value of learning about agricultural practices. He described residential schools as the first attempts on the part of the government to educate Aboriginal peoples. The schools were "partly academic but partly working out in a farm actually, because each school actually had to subsist on its own.

They actually had their own farms … and the students were used for free labor." James' understanding of the nature of his schooling was as exploitive.

As newcomers, White people attempted to dominate the landscape. However, according to James, some Aboriginal people did not understand the notion of having their land taken away. Dempsey (1995) writes that the Blackfoot people did not believe they owned the land, but rather that the land belonged to the sun god. The treaty "was simply a promise that in exchange for letting the Whites come in, the Queen would 'furnish them plenty of food and clothing'" (p. 113) and, therefore, the Blackfoot people did not expect the White people to possess it. To Aboriginal peoples, the treaties meant that they were willing to live in harmony, coexisting with their new neighbors in the land. The White people's domination of the land spread to control of the people through education.

Marie shared her own experiences of residential school. Although her father could speak English, he did not use it at home, and she struggled because she could not communicate with her teacher in English. Although she had good ideas, she could not speak in English and would go to her desk and cry. So strong was her experience of frustration that she decided, "In the future, if I ever have children, they're going to speak English." Her own mother spoke Blackfoot, but she viewed this as detrimental because her mother "couldn't say what she wanted to say" to the White people. She believed that her children would "get ahead in the English way, the White way if I teach them right from the start to learn English." This experience has resulted in a current generation of largely non-Blackfoot-speakers.

The damaging effects of residential schools on Aboriginal culture and language are now widely recognized. To learn White people's ways was initially viewed as necessary for harmonious living. To learn agricultural practices in residential schools seemed to offer a way of blending Aboriginal knowledge with Western techniques. However, past experiences of schooling have resulted in a "deep mistrust among some Aboriginal people of mainstream educational institutions. The importance of obtaining a good education becomes secondary to what may be perceived as a further assimilative assault on Aboriginal culture, language and traditions" (Richards, 2006, p. 77). The government's agenda to assimilate Aboriginal peoples through schooling contributed greatly to a disconnection between Aboriginal and Western knowledge systems, especially evident in science and mathematics.

Learning New Languages

Many changes occurred for Aboriginal children when they attended residential schools. English was the dominant language, and identity was fragmented as new names were assigned to the children. According to James, the supervisors did not know the children's Aboriginal names, so new names were assigned: "We'll just call him McDonald because one of the people from Ottawa came and his name was McDonald, so he gave a name to that little boy." Even the commonly known tribe name *Bloods* was an English label.

The difficulty of learning Western science and mathematics in English can contribute to a lack of ease in these disciplines. Pewewardy (2001) suggests that the natural languages of Indigenous peoples reflect how their minds work. When subjects are taught in English, the content is made to fit the form of English. He describes English as a sequential language that does not reflect the more holistic knowledge systems. He writes, "We are also taught by mainstream institutions and influences to think in terms of blocks and boxes of time (linear thinking), which does not fit our natural way of thinking" (p. 20). Linking cultural extinction to

the rejection of Indigenous knowledge and Aboriginal participation in Western science, he writes,

> The language of mainstream society and science predisposes us to attempt to understand ourselves and our world by superimposing dialects, dichotomies, or dualistic grids upon experiences that they may not fit. We need to reverse the colonization of our minds so that we can think holistically again. We need to rediscover and recreate our own fundamental myths that will integrate the paradoxes of our experiences and our natures. Only then will we be able to link who we are with what science has to offer. (p. 21)

Similarly, Barton (2008) claims:

> A proper understanding of the link between language and mathematics may be the key to finally throwing off the shadow of imperialism and colonialisation that continues to haunt education for indigenous groups in a modern world of international languages and global curricula. (p. 9)

Although learning English enforces a particular way of thinking, learning Western science and mathematics also becomes problematic because of the specialized languages embedded in these disciplines. Aboriginal knowledge systems of science and mathematics are lost in the Western symbols, as suggested by James:

> Mathematics has become the language for scientists. And the scientists … speak this strange language called mathematics and it's a number, it's a whole bunch of hieroglyphics that nobody else can understand. But really, when you get past that and speak in common, everyday language, the ideas and concepts that they're talking about are not that hard to understand.

Learning Science and Mathematics

In addition to the challenging experiences of learning Western science and mathematics in foreign languages, there exists a perception that Aboriginal peoples are innately unable to learn Western science and mathematics. Walter suggested that anthropologists believe that "Native people are not going to do well in subjects like math, because we don't have the ability or capability to think in abstract thoughts." According to him, the struggle to learn Western science and mathematics becomes "a self-fulfilling prophecy." Moreover, there exists a generational gap, as parents who attended residential schools cannot help their children learn something that they themselves do not understand or have not adequately learned. These challenges indicate that the attempt to assimilate Aboriginal peoples has not been successful.

The dominant Western approach has not resulted in experiences of connection; disconnections between Aboriginal and Western communities are still prevalent. The Aboriginal population is the fastest growing population group in Canada (Mendelson, 2006; Statistics Canada, 2003), yet it has the lowest postsecondary education enrollment and successful completion rates. Recent improvements in Aboriginal rates of enrollment and completion have not kept pace with population growth, and the gap between enrollment and completion of postsecondary education has narrowed only slightly. Moreover, the gap between Aboriginal and non-Aboriginal participation in mathematics and the sciences is increasing (Indian and Northern Affairs Canada, 2005).

These statistics demonstrate educational disparities between Aboriginal and university communities. Researchers (Bourke, Burden, & Moore, 1996) suggest that in addition to a lack of academic preparation, the greatest obstacles to postsecondary participation are institutional insensitivity to Aboriginal cultures and forced assimilation by educational institutions. In other words, Aboriginal students' success is related to culture. One key route to improving enrollment and retention rates is to strengthen and control Aboriginal content in educational curricula. This is imperative in addressing issues of academic preparation and cultural differences faced by Aboriginal students in educational institutions (Canada Millennium Scholarship Foundation, 2004; Council of Ministers of Education, Canada, 2002). Many Aboriginal peoples advocate self-segregation as a means for reclaiming Aboriginal education and providing equality of education in science and mathematics. They believe that two separate parallel approaches are possible.

Parallel Approaches: Self-Segregation

Neal felt strongly that Aboriginal students needed to see themselves in the lessons. Working in a predominantly White educational context, he questioned the validity of his work:

> It's more of a challenge for me because I am a very, very, very, very, very visible minority in my system. I'm one Aboriginal person, you know, where our population is not even one percent of the employees. So … I don't have a lot of people standing behind me or working with me or brainstorming with me or developing programs with me–it's just me and my team, people who work under me. But if I were to be on a reserve setting then I think that there would be a lot more creativity in that way. Maybe that's one of the downfalls of where I work.

He suggested that ideally, there should be "First Nations teachers, First Nations principals, First Nations counselors, janitorial staff, maintenance people, everybody." He believed that it was important to provide an Aboriginal liaison service in the schools "so that in my mind when a teacher's teaching a concept about Native people they don't get it wrong." In describing the Aboriginal graduation ceremonies, he justified self-segregation in this context because it allowed students to celebrate their values and ceremonial protocols: "Protocol and understanding the process is very important and we take so much away from that experience. And to teach that to students who've overcome 12 years of school is very important." Implied in his words might be the notion that these students deserved special recognition for success in Western schooling.

Although he believed that self-segregation was desirable, he recognized that non-Aboriginal leaders might not support what could be perceived as special treatment. Possibilities for integrating Aboriginal tokens such as giving out eagle feathers into the regular ceremony were offered by some of the other group members, but he felt that this did not have the same meaning. He questioned how an Aboriginal person could teach the meanings quickly and have a non-Aboriginal person value this process in a short time.

Finding a Cornfield

Georgina spoke of the isolation that she experienced when leaving the reserve for school. Because of her experiences, she is committed to working in an Aboriginal context on the reserve:

> Growing up with the two different worlds, it was difficult because I went to [an off-reserve school]. And then coming home to this, it collided that I had to really find where my place was, and I think that's why I'm on the reserve right now working with the kids … I went to a non-Native school and going through it I had a power struggle of dealing with the outside as well as being raised with my grandmother … Now I see the importance of putting back that knowledge into our students, I see it as being so important. And working on the reserve I'm able to do that, to work with my own kind and just to be able to put some of this back. It means a lot to me and I'm sure it means a lot to them.

Learning in a segregated environment might offer experiences of relevance as Aboriginal knowledge systems are embraced and understood. Patrick offered the metaphor of *learning is a cornfield* as a way of demonstrating the importance of Indigenous knowledges. Referring to a presentation by Greg Cajete, he explained that children were compared to corn, and "Every child is a kernel on the cob, but everyone's unique." The incorporation of the corn metaphor based on Indigenous holistic values resonated with him because of his Aboriginal background. He suggested that this helped him understand Cajete's ideas of sustainable communities.

Indeed, Mt. Pleasant (2001) writes that this metaphor helped her to bridge her experiences with Western science:

> The cornfield as a place where science and Native culture meet is a metaphor for my life as I struggle to find my place and manage the tension between Western science and my Indian roots. I love working with corn, and as an agronomist I am in awe of its productivity. But I also know that it represents much more than a prolific agricultural crop. It is an enormous gift to human beings and speaks of life and connection to the earth in ways that are profoundly simple and complex at the same time. (p. 126)

This metaphor is markedly different from the Western understanding of agriculture. Richards (2006) writes:

> Since successful agriculture requires long periods of time over which to evaluate the effort expended, an efficient culture should reward those who display due diligence. A regime of communal property rights does not do that. Instead, agricultural societies require norms and institutions that enable farmers to capture the rewards of their effort. The institution of private property is just, argued the liberal philosopher John Locke, because God intended man to own the fruits of his labour. (p. 10)

The struggle to find one's place as an Aboriginal person who integrates Indigenous and Western mathematical and scientific knowledges emphasizes cultural differences that might only be addressed by self-segregation. Integrating Western science and mathematics to serve the needs of Aboriginal communities is problematic when Aboriginal learners are asked to participate in the dominant Western approach. Offering a separate yet parallel approach might offer improved learning possibilities for Aboriginal students.

However, lacking in a segregated approach is a consideration of how the strengths of Aboriginal knowledges of science and mathematics can contribute to the understanding of all students. Neal explained, "It's important to enrich our curriculum appropriately with our knowledge so that people everywhere, not just our students but everyone, see that. So that our students, our Native students, can feel pride that these concepts are not foreign." Parallel approaches offer experiences of separateness: intertwined approaches offer experiences of connection. Intertwined approaches embrace the strengths of each knowledge system.

Intertwined Approaches: Dialogical Interaction

Dialogical interactions seek to bridge educational experiences of disconnection and separation. The term *cultural infusion* has been used to describe the process of integrating Aboriginal and Western knowledges. Indeed, this term surfaced in some of the focus group conversations. To us, however, the metaphor of infusion suggests a pouring of liquid into a vessel, and in the context of education, this may infer an addition of content to the existing body of knowledge. We offer the intertwined approach of dialogical interaction where each knowledge system encircles the other as they embrace, twist, or wrap each other. This implies that each knowledge system is preserved, and the twisting together adds tensile strength to the learning.

Battiste (2002) writes, "To affect reform, educators need to make a conscious decision to nurture Indigenous knowledge, dignity, identity, and integrity by making a direct change in school philosophy, pedagogy, and practice" (p. 30). Similarly, the Minister's National Working Group on Education (2002) states, "We believe that strong cultural identity and equally strong individual academic performance will create First Nations citizens who walk with ease and confidence in two worlds" (p. 1). Battiste challenges postsecondary educators to blend Aboriginal and non-Aboriginal knowledge systems by underscoring "the importance of bringing [Aboriginal knowledge] into the mainstream to establish a body of knowledge that can be drawn on for the common good" (p. 6). However, blending might result in a dilution of Aboriginal knowledge systems; intertwining these knowledge systems draws on the strengths of both.

One place where these two knowledge systems might intertwine is in the understanding of the interconnectedness of the world and the Aboriginal experiences of the animate.

Making the Inanimate Animate: An Example of Intertwining

James offered the idea that all things are animate as a way of explaining the importance of experiential learning, an important dimension of Indigenous knowledges. According to him, "I'm experiencing this with my relatives, whether these relatives are humans, whether they are these other animals, but they're all my relatives. And so it's almost like I'm having an experience with my relatives and so everything is experiential. Everything, the approach is very much experiential."

Sara echoed the importance of animate relationships by paraphrasing her favorite scientist Albert Einstein. Viewing mathematics as inanimate, she suggested that Einstein questioned how something so inanimate could be used to try to describe what is occurring in life. She further explained, "In the Native world, everything is considered animate. And so if it is, if everything is considered animate, then … I relate to everything as being animate, being a person, being a spirit and so on. I relate to it as such."

James provided an example of how things can be viewed as animate. He recounted his experience of hearing an archeologist describe tipi rings. This particular archeologist said that he would "go in there and look at the rocks. They were just rocks." An Aboriginal scientist was with him and did not look at them as rocks. The first thing he looked for was the door. This experience of looking for the door so impressed the archeologist that he began to develop a deep respect for Aboriginal knowledge systems. He was later given a Blackfoot name in honor of the respectful manner in which he undertook his archeological excavations.

Walter offered another example of the importance of viewing objects as animate. Describing a class visit to an Aboriginal sacred site, he said that the students looked at the rocks and

remembered that "a great, great, great grandmother must have put this offering here for me that wasn't born yet. So here we are today, what are we doing for those that are not born yet?" The sense of history and responsibility was communicated through the animate rocks.

Making the inanimate animate seeks to recognize and respond to the interconnectivity of the world. A consideration of how Western science and mathematics could be more responsive to world and community needs was a theme throughout our focus group conversations. Viewing Western science and mathematics as linear trajectories void of social implications was seen as unfruitful. Aboriginal knowledges offer unique opportunities for responding to issues of survival in contemporary settings. Moreover, learning about Indigenous science and mathematics may provide powerful incentives to Aboriginal and non-Aboriginal students. When asked what might be crucial in attracting students to these studies, Emma said that after secondary school, she "had no interest in pursuing math and science ever again. I thought I was done with it." However, she became interested because she grew to understand how it really affected her and the world. She wanted to make a difference in issues such as global warming, recycling, and saving our planet.

Davis and Hersh (1981) describe a variety of mathematical experiences and conclude that the meaning of mathematics

> is to be found in the shared understanding of human beings, not in an external nonhuman reality. In this respect, mathematics is similar to an ideology, a religion, or an art form; it deals with human meanings, and is intelligible only within the context of culture. In other words, mathematics is a humanistic study. It is one of the humanities. (p. 410)

This perspective differs greatly from Western views that inform much of our approach to science and mathematics education. A reorientation of our thinking about these disciplines requires a shift in our understanding of the human role in their development. For many people, Western science and mathematics are understood as a set of infallible rules devoid of context. Observations of the world and our experiences in it are ignored. Intertwining Aboriginal and Western knowledges of science and mathematics provides a way of humanizing these Western disciplines.

Intertwining Through Mutual Dialogue

> What always comes out when we talk about these things is fear of saying things because there's always this underlying threat of violence. You get in line, you know, power is violence … I don't mean to sound cynical but we need to have a dialogue, a very honest, open dialogue both ways. We need to face up to some things that are not very nice, but we also need to be able to do that. (Walter)

Intertwining approaches through dialogical interactions is not straightforward. Historical issues of mistrust and forced assimilation and contemporary approaches of self-segregation do not necessarily facilitate mutual dialogue. However, respectful conversations can bridge the approaches of dominance and separateness. Vickers (2007) proposes camping spots as a metaphor for such a dialogue. She believes that people in two camps can come together through conversation. As Walter suggested,

> If we understand our world view then if we're going to learn from the land then we got to let the rivers be rivers. We got to let the eagle be an eagle; we got to let this be what they were meant to be. And that

> line of thinking is–we never tried to make the Cree Blackfoot, or the Cree never tried to make us Cree. Ultimately it's about the respect.

Western and Indigenous science and mathematics should be viewed as having complementary strengths. Recognizing the strengths of each view will maximize scientific and mathematical learning. To date very little has been done to intertwine these knowledge systems, and the reciprocity of cultural strengths in Indigenous and Western science and mathematics is not fully understood. This article attempts to initiate and engage in this dialogue.

Conclusion

According to researchers, a cross-cultural approach to science and mathematics represents a much-needed paradigm shift (Aikenhead & Huntley, 1999; Antone, 2000; Corbiere, 2000; Corsiglia & Snively, 1995; Davidson, 2002; Ezeife, 2002; Lewis & Aikenhead, 2001). Intertwining Aboriginal and Western knowledge systems holds generative possibilities for science and mathematics education.

Optimism is evident in our participants' stories. We are continually learning how to engage in dialogues that intertwine Aboriginal and Western knowledges of science and mathematics. We believe that the voices of our participants are both necessary and significant in these conversations:

> We take baby steps. I think that our people, our students, and definitely our parents want us to get there right now. But we just have to keep going and taking these first steps and knowing that the result may not come for multiple years, to see the benefits of. But I think that's important they get started to do something. Is it this professor who *doesn't* understand or *won't* understand? Sure, the professor may not always be there, and maybe perhaps there will be somebody new. And these younger teachers are coming in and I've got some great old teachers that I love but they still come from that old thinking. And now here's some younger teachers who [say], "Teach me, I want to learn." And I see some new ones every September. They're saying, "Teach me. Tell me about these things." There are some of those that are coming, which is promising." (Neal)

Notes

[1] In Canada, the term *Aboriginal* is used to describe Indigenous peoples who are First Nations, Inuit, or Métis. The term *Indigenous* is also used to include people of Aboriginal descent who may not have official Aboriginal status in Canada and people of Indigenous descent in an international context. Throughout this article, we use these terms synonymously.

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