Interconnecting Aboriginal and Western Paradigms in Post-secondary Science Education: An Action Research Approach

MICHELLE MARIE HOGUE
University of Lethbridge

The University of Lethbridge resides within the heart of Blackfoot territory, surrounded by the largest reserve in Western Canada. Yet the Aboriginal[i] student presence on campus is very small relative to the non-Aboriginal student population, and Aboriginal students are virtually absent from the sciences. As someone of Métis heritage from a different province – an urban Aboriginal for the most part – Western-educated, and someone who has always been in the sciences academically and professionally, I am continually bothered by the lack of Aboriginal representation and success in post-secondary science education. It is critical in this time of both global and economic crisis that Aboriginal people be successful at post-secondary education, so that they are not sequestered to their same poor socio-economic conditions, but that they are able to work as Aboriginal professionals in their own communities and in Western society. It is of critical importance that they have an equitable voice and representation in all aspects of society.

Journal of the Canadian Association for Curriculum Studies
Volume 10 Number 1, 2012

As a post-secondary educator I have witnessed first-hand the struggle of Aboriginal students in the sciences. Those Aboriginal students who do attempt and do stay in post-secondary education most often choose non-science-related disciplines. If they are required to take a science course, they will generally take one that involves little mathematics – such as environmental science – as mathematics is also a challenge for them. Much of the literature indicates that the difficulty begins in the middle years and, by secondary school, most Aboriginal students avoid science and mathematics. This difficulty is further exacerbated by the challenges associated with the transition to university. Although there are many initiatives at university to ease the transition from secondary school to university, they have been only marginally successful, and the gap between Aboriginal and non-Aboriginal participation, particularly in the sciences, continues to grow (CMEC, 2002, 2006, 2010; CCL, 2006a, 2006b; Gregory, 2002; Helin & Snow, 2001, 2009; INAC, 2005). As Kirkness and Barnhardt (1991) suggest

> To the extent that students are willing and able to check their own cultural predispositions at the university's gate, these kinds of initiatives can and do assist them in making the transition to the culture of the institution, but such intensification efforts alone do not appear to produce the desired results of full and equal participation of First Nations people in higher education. (p. 3)

In other words, Aboriginal students must leave their culture at the door and adopt Western approaches to education and curriculum to succeed. Historically, the academic environment has not enabled Aboriginal academic success in any way other than from a Western perspective. Most research on Aboriginal academic success in the Western education

system has been as a result of studies or analysis performed on success in comparison to non-Aboriginal students, and they are studies largely done by Western non-Aboriginal institutional, governmental, and political evaluators (CMEC, 2003-2011) rather than by the Aboriginal people themselves (Burns, 2001; CCL, 2006a, 2006b, 2007a, 2007b; CMEC, 2002, 2006, 2009). As a result, the literature is largely quantitative, and, although such reports do have merit, they most often do not offer the voice of the Aboriginal people themselves. Aboriginal people do not get to say what they feel is needed to ensure success in post-secondary education, an important and critical piece missing in the literature.

As an educator, I wanted to understand the issues and challenges from the perspective of the Aboriginal people themselves in order to find ways of addressing those issues and to develop recommendations for implementation that can enable the post-secondary success of Aboriginal students, with a particular focus on succeeding in science. Such knowledge will help educators to develop different methodologies and practices appropriate for Aboriginal students. If we listen to the voice of the Aboriginal people themselves, we might better understand their difficulty with the Western education system. Academic success in science and mathematics is a critical first step in opening the doors to science and mathematics[ii]-related careers. This must be a continual and active process of implementing attentive practices, evaluation and change.

The purpose of this study was to initiate and develop collaborative relationships between the Blackfoot community and the university, given the institution's central location within this southern Alberta community. As an educator and researcher, I wanted to come to qualitatively understand – from the Aboriginal perspective – the educational experiences of the members of the Blackfoot community and begin the process of 'action research', that is, putting into action some of their recommendations to effect positive change and enable their success in

post-secondary education. This research focused on four primary questions: (1) *What do members of the Blackfoot community perceive as reasons for low post-secondary participation rates, particularly in science?* (2) *What do members of the Blackfoot community perceive is needed to increase for participation rates in science to increase?* (3) *How can holistic traditional Aboriginal teachings and concepts bridge the sciences and the contemporary university learning environment?* (4) *How can relationships between the Blackfoot and the University of Lethbridge communities be fostered?* The intent and goal of this research was to address issues of successful transition into and through post-secondary education, specifically focusing on the sciences, and provide recommendations that could be put into practice.

The Participants[iii]

Participants of the focus group were from the surrounding Blackfoot community and included elders, university professors and college instructors, teachers, directors of First Nations, Inuit and Métis (FNMI) programs, a university student, and a research assistant. Six focus group/dialogue[iv] meetings were held over the course of the study where, in a round-table format, we discussed each of the aforementioned questions. Recommendations were co-constructed by the Blackfoot participants to address the research questions and provide project and action outcomes. Many findings ensued from those focus group meetings, some of which have been previously presented (Hogue, 2011; H-duke & Sterenberg, 2009; H-duke & Sterenberg, 2008). For the purposes of this paper, further selected findings of those dialogues and recommendations for implementation and action at the institutional level are categorized, discussed and evaluated. An 'action research-medicine wheel' is used to enable an understanding of what the Blackfoot people themselves see as challenges to academic success in a Western academic system.

Action Research and the Medicine Wheel

Action research, known by names such as participatory action research (PAR), collaborative inquiry, and action learning, consists of a family of methodologies that pursue outcomes of both research (understanding) and action (change) (Carson & Sumara, 1997; O'Brien, 2001). The simple premise is "learning by doing" (Aikenhead, 2002a, 2011; Cajete, 1999, 2000; CCL, 2006a; McTaggart, 1991) which, not surprisingly, is the foundational premise of the Aboriginal paradigm (Aikenhead, 2011; Battiste, 2002; Cajete, 2000). PAR is driven by a need to know in order to bring about the desired change (Wadsworth, 1998) and, as its name suggests, it requires responsiveness, flexibility and action. The aim is to effect intervention, development and change within a community or group. The action research method is cyclical, moving through the stages of 1) planning, 2) taking action or putting into practice, 3) observing and evaluating the effects of that action, and 4) engaging in critical reflection prior to planning the next cycle (Carson & Sumara, 1991; McNiff, 2002; McTaggart, 1991; Reason & Bradbury, 2001).

In action research, a group of people – often those who are directly affected – identify a problem, evaluate it and develop plans of action to address the problem and do something about it. The action is evaluated and adjustments made according to the outcomes, be they positive or negative, to be incorporated into further cycles or processes. Action research not only addresses the issue at hand, but it has further, far-reaching goals to continually effect change (Dick, 2002; McNiff, 2002; Reason & Bradbury, 2001). It is a process of planning, action, implementation, and evaluation, with the intent to begin again with new and deeper understandings learned from the previous cycle of experience. Thus, depending on the context and situation, action research often spans a number of cycles.

The Aboriginal medicine wheel is used as the frame for this action research study. The Aboriginal paradigm is predicated on the concept of circles as well as the number four, both of which are at the core of,laws,

spirituality and many traditional beliefs (Aikenhead, 1996; Cajete, p.c. 2005-2009; Little Bear, p.c. 2005-2010; Ogawa, 1995; Plett, 1999; Thunderbird, 2009), a concept that is often expressed in the philosophy of the medicine wheel. In the Aboriginal paradigm, everything is related and inter-related. Unlike the linear philosophy of the Western paradigm, the Aboriginal paradigm operates in a circular and cyclical fashion, always beginning again in a renewed or different light. This is a concept I call "end-beginnings" (H-duke, 2004). The circular mandala of the medicine wheel, bisected vertically and horizontally, or sometimes diagonally, into four equal quadrants, represents this philosophy. Also known by other names such as The Circle of Life, The Wheel of Life, Sacred Hoops, or The Four Directions (Thunderbird, 2010), the medicine wheel embodies Mother Earth with each of the directions – East, South, West and North – representing the quadrants. In parallel, the quadrants represent birth, growth, harvest/death and rest/renewal. Every aspect of life can be represented by the concept of the medicine wheel, which, in the Aboriginal paradigm, is the metaphoric guide to living and being.

The philosophy of the Aboriginal medicine wheel can be superimposed upon the philosophy of action research. In fact, "action research" is akin to the foundational principles of the Aboriginal medicine wheel. The action research cycle begins with an idea or a plan, something new, a question about a problem or an issue. In the Aboriginal paradigm, new beginnings start in the East. It is a time of newness, when all things begin to grow and awaken. In action research, beginning anew is equivalent to spring in the Aboriginal medicine wheel: new seeding, new birth, and new ideas. One then translates the idea into action by doing or learning how to do, by growing cultivating, and putting the plan into practice. In the medicine wheel, this concept is represented by south, a time when we tend to our garden and nurture our new seedlings. Nurturing, accepting change, growing and coming to understand leads to maturation and growing into an adult. That learning

or implementation leads to an outcome, either positive or negative, equivalent to products of the garden or experiences of the summer. The west, or the fall, in the medicine wheel, represents the "harvest." This is akin to evaluation in action research, a time to determine both the yield and the quality of the yield. It is a time to tally the outcome, to see what has worked, what has not worked, to evaluate the results of controllable and uncontrollable efforts, implementations, circumstances, environmental effects et cetera. The reflection and re-evaluation of action research, of what to do the next time around, the next season, takes place in the down time of winter, or north in the medicine wheel, where energy is stored for the next cycle. This allows for resting and planning for the spring, evaluating what and how to put into the next practice, what to do the next "time around" or the next cycle. In action research, this is the planning stage for the next cycle. Like the medicine wheel, action research is a continual and cyclical process of learning and growth.

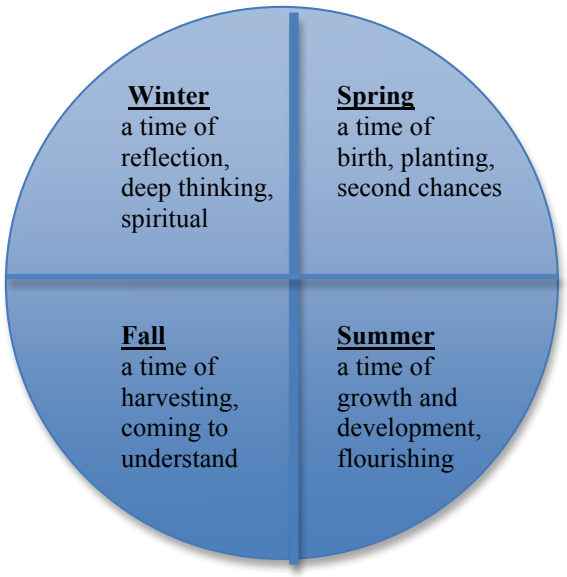

Figure 1: Action Research-Medicine Wheel.

Using this guide, the results of this focus group study are divided into four themes east (spring), south (summer), west (fall) and north (winter). The questions that framed this research have been correspondingly categorized for the purpose of this analysis.

Spring – East

Spring is a time of planting and new growth. It requires attention to preparation for planting, for what is needed to enable successful germination of seeds or rooting of seedlings. In answer to the question, *what do members of the Blackfoot community perceive as reasons for low post-secondary participation rates in science and mathematics* – in other words, *what nutrients are needed – ,* the Blackfoot members felt that both academic and social preparations prior to entering into post-secondary education were critical to success. Equally important, they felt, was that the environment into which the students were entering had to be prepared so that it was culturally inviting. This is analogous to preparing the soil in the spring for good germination of the seeds planted. When and if the environment is right, the seeds will germinate and the plants will grow. However if the environment is not right, the soil not well-prepared, if it is too acidic or basic, or toxic, and it does not have enough or has the wrong nutrients, or if there is not enough light, warmth or water, then the seeds planted will not germinate, or the seedlings will not grow well; they may be stunted,not have the strength to survive harsh conditions or not grow at all. While the seeds themselves do have some resident (stored) nourishment they bring with them in the spring, it is insufficient to sustain growth in the wrong environment. Therefore, we have to make sure the environment is optimum and healthy

This is analogous to Aboriginal students in the Western academic environment. Each member of the dialogue-focus group suggested that the post-secondary environment, particularly in the sciences and

mathematics, was not an inviting environment. Three talked specifically of residential school and how the classroom environment was often so bad that it served as a deterrent rather than an invitation to learning. In other words it was not healthy; it was not conducive to academic germination. Many felt that their academic preparation, particularly in the sciences and mathematics, was insufficient and, as a result, they did not have the background or "storage" nutrients to fuel their germination. Consequently they were unable to develop strong roots in the Western post-secondary academic environment. Many said the teachers who end up on the Reserve[v] are generally "white" and often "not the best teachers" and "have little to no cultural knowledge or understanding." "These teachers", they said, "are most often the ones who couldn't get a 'regular' teaching job" and were often there for only a very short time. This high turnover rate resulted in little or no continuity and, as a result, no consistency. Most knew nothing of the Blackfoot culture and their ways of learning and "coming to know." "They do not understand the culture and our ways" was the most common statement given by the focus group members. "They do not validate the knowledge we bring to the academic table and therefore they have no way of knowing how to enhance and build on that knowledge." Like a seed that begins germination using its own internal storages, Aboriginal people have their own internal storage of knowledge (resident nourishment), knowledge that is from a different (not lesser) perspective (a different paradigm) and is gained by a different way of coming to know. Each of the individuals in the focus group felt that their Aboriginal knowledge, particularly scientific and mathematical, is not respected in a Western academic environment. Collectively, they felt the Western approach to science excluded their own cultural ways of coming to know and had little relevance or applicability. The top-down and linear, lecture teaching methodology of the Western academy was "intimidating," "confusing," and "not connected" to their culture. This lack of relevance

and failure of Western science curricula to foster concept building from an Aboriginal perspective led to feelings of isolation in an unwelcoming academic environment. Each Blackfoot participant spoke of particular incidences when they had felt "isolated and alone" and had "no idea how to navigate the environment" they were in.

The focus group members talked of having to learn in the "white" way from textbooks and lectures. This is contrary to the traditional "hands-on" and practical way of "learning by doing" in the Aboriginal paradigm. Gregory Cajete (1994, 1999, 2000, 2006) intimates that Indigenous learning is traditionally practical, hands-on and *holistic*. It requires an attentiveness, presence of being and inter-related engagement that is not found in Western academic textbooks. Aboriginal learners often do well in science and mathematics in elementary school where learning is more hands-on, but the abrupt switch from the more holistic approach of early education to a very specific curriculum-focused, textbook-driven, approach at the higher levels makes it a difficult transition for students with alternative learning styles. As well there is an emphasis on grades rather than the achievement of understanding that characterizes the methodology and learning in the Aboriginal paradigm. The members of the group suggested this type of environment was not conducive to good beginnings for young learners, and in fact, served to contribute to the avoidance of science and mathematics in particular, as they moved out of this primary stage.

To augment this difficult beginning, many of the Blackfoot members suggested the linguistic differences are a challenge for Aboriginal people and, as a result, issues of interpretation and understanding arise. One of the elders in the group talked of her experience in residential school, of not knowing how to speak the language and being unable, as a result, to communicate with her teachers effectively for nearly three years. She would put her head down on her desk in frustration and cry. If one cannot speak or understand the language, whether it is the language of

communication or the language of an academic discipline, such as the language of chemistry, biology, physics, or mathematics, then learning in that "language" will be greatly impeded. In most, if not all Aboriginal languages, there are no words for the various Western educational terms, particularly those of science. So bridging is a challenge. In addition, many Aboriginal students do not categorize or construct abstract concepts in the same way as English-speaking students do because their parent language is not rooted in the same fashion as English (Frantz, 2006). It is verb-based rather than noun-based and therefore action-oriented. As Frantz (p. c. 2004-2010, 2006) indicates in his Blackfoot dictionary, one word in the Blackfoot language can have many different meanings simply because of intonation. The scientific vocabulary, for example, is not part of the Blackfoot language and often there are no comparative or bridging words. This creates barriers for students who must not only learn in a different, less holistic way, but also learn a different scientific language, which often cannot be translated into their own language or culture. The first time I taught in the First Nations Transition Program, I incorporated a hands-on component to the chemistry course. The first laboratory class was an orientation into the laboratory, safety rules and equipment locker check-in. I handed out a glassware check-in sheet that lists the glassware the students are required to identify and check off as being present in their kit. I stepped into the prep area for a few minutes and, when I came out, my students were looking very bothered. Some were picking up various pieces of glassware, others were whispering to each other and all looked nervous. In asking what the problem was, I learned that the Blackfoot students had never seen any of the glassware before. There were no science labs in their community school. As a result, they had no idea of the scientific terminology for the pieces or what they might even be used for. Having taught labs for years in the Western system, I took for granted that students who entered this course would have the knowledge and the

scientific language from their secondary schooling years according to the secondary curriculum, as all my non-Aboriginal first-year students had previously had. So I made a game of it and the students gave each piece of glassware a Blackfoot name of some sort. I do not know if the assigned names were correct or not. They could have jokingly been calling it something ridiculous and I would never have known; like them, how was I to know? In fact, upon reflection, and after getting to know my students and their fun and mischievous personalities, I am pretty sure that was the case. I learned my Blackfoot vocabulary list in conjunction with the students. It was a challenging education for me, as I too had to learn a new language. In taking the test, I failed miserably while my Blackfoot students passed. More importantly, I came to understand the challenges my students faced. Concepts are not readily translatable and learning the "science" language is significantly more difficult for Aboriginal students than non-Aboriginal students who do not have to make that cultural-linguistic bridge. There must therefore be a linguistic bridge built that will enable the language of science to germinate within our students so they are able to speak and understand the science language as they grow.

Tending to the environment and the conditions into which Aboriginal students are entering, like tending the soil and environment needed for successful germination of seeds in spring, is critical for ensuring success of the educational germination of our Aboriginal students when they enter post-secondary education. All members of the dialogue-focus group believed attention to the learning environment needs to happen right at the beginning of elementary school, and that germination of the educational seeds requires qualified, preferentially Aboriginal teachers with an understanding of Aboriginal ways of learning, to ensure an optimum learning environment.

The varied sets of unique cultural experiences each Aboriginal student brings to the learning table should be treated as a valued

resource, a stored nutrient, rather than a liability or contaminant as such experiences are often viewed. Many Aboriginal students have unique challenges, challenges not experienced by non-Aboriginal students, so we as educators need to ensure they have a good start in a nurturing, safe environment in order that they may germinate and establish their roots, grow and flourish in the next stage of the cycle. It is possible, as in a garden, to nurture even the most struggling. What it requires is *attention* and *time*. These two factors are often lost in the Western educational system where teachers must "cover the curriculum." But both are critical factors to the success of Aboriginal students in post-secondary classrooms, and both are foundational to the Aboriginal paradigm.

Summer - South

Summer is the growing season. It is a time of removing barriers, a time to nurture the environment so that each seedling has the opportunity to reach its maximum potential. It is a time of ensuring there is enough water, pulling weeds that might overtake and choke out the plants, adding more nutrients to the soils as they grow in order to ensure maximum growth, removing pests, and providing good space for the seedlings to grow to maturation. Watering quenches the thirst of the plants and keeps them from dehydrating and drying out. Like plants, each person is unique and may require individual attention at times. We cannot assume each individual is the same in the way Western education classifies students into grades. Nor can we assume that each student has the same needs. Rather, educators must pay attention to the needs of the individual such that he or she can also contribute to the whole. How do we as educators ensure that Aboriginal students have a culturally safe and nutritionally rich environment in which to grow and flourish? How can the impediments, the barriers, and the contaminants that hinder their

progress be removed? In answer to the question of *what is needed to ensure participation and success of Aboriginal students in post-secondary education* – in other words attend to their educational garden – members of the dialogue-focus group suggested the following *basics* were critical to nurturing the growth of Blackfoot students.

First, they felt it is critical to encourage Aboriginal cultural and academic sensitivity in instructors. Given the location of the university within the Blackfoot territory, they felt it is imperative that the academic community learn more about the Blackfoot culture. Not only should instructors be knowledgeable about different modes of learning but even more importantly, they should understand how learning takes place within an Aboriginal culture. The focus group members indicated that Aboriginal students need an applied, hands-on approach given their cultural "practical" or applied learning style. Many students need extended time to process and build their own connections or bridges, particularly when the ideas are very different or are in conflict with *Aboriginal [Blackfoot] Ways of Knowing* or understanding. As an example, in biological sciences we teach the scientific perspective of evolution of species from a lower to a higher species over time, a concept that does not include a creator of the spiritual sort. This concept conflicts greatly with the traditional creation stories of the Aboriginal peoples where "all things" animate and inanimate, are created equal by the Creator and have a spirit. Thus they are to be treated equally and with respect, regardless of whether that "thing" is a rock, an animal or another human being. In comparison, the Western perspective is hierarchical, with humans superior to all things, again contrary to many Aboriginal cultural beliefs. Finding a balance between both paradigms is a critical challenge.

Second, members of the dialogue-focus group felt that cultural relevance and applicability are critical to Aboriginal student engagement and learning. The current educational curriculum is designed for

"middle class *white* students" and has little applicability to the Aboriginal culture. The students in the group said the content of science was "not relevant" to anything in their life, which made it "boring and uninteresting." It was suggested that examples of practical experience and knowledge, and interweaving stories and culture that personify an intimate understanding of the natural phenomena of science and create a bridge to Western science, would make science for Aboriginal students more relevant and easier to learn. All felt that having instructors who, at the very least, had an understanding of the Aboriginal paradigm – even if they were not Aboriginal themselves – or who had a deep interest in learning the culture – which has historically been rare – would go a long way to enabling Aboriginal student success. This is particularly important in the most challenging subjects of science and mathematics where there is the greatest cultural disjoint. Ultimately, they suggested, there should be Aboriginal teachers teaching Aboriginal students whenever possible.

Third, effective communication is critical to Aboriginal learning. Aboriginal students are often intimidated by authority. The dialogue-focus group members explained that, culturally, Aboriginal people are taught not to express opinions, but rather to respect, and not question, those in authority. Those members of the group who had attended residential school talked of not being able to voice their opinions nor challenge or question those in authority. If they did, they were punished. For many Aboriginal people, Western education has been seen as an abusive, authoritative and assimilative system where the Aboriginal voice is not heard. This experience makes them sensitive to the questions and reactions of others. Asking questions and expecting immediate answers, as is often done in the classroom, puts Aboriginal students – who are taught to think before answering – on the spot and can be embarrassing for them. A professor member of the group told of a situation when he was in school in which a teacher picked on a student

in class, asking him a particular math question. When the student did not answer immediately, the teacher ridiculed him for "not knowing something so basic" and moved on to the next student, and the next and the next, all who refused to answer. "We all knew the answer," he said, "but we weren't going to tell him that. Not after he made a fool of our friend." They did not want their friend to feel bad or different so they simply made themselves the same as him in order to protect him. So often in Western education, a hesitation or slow-to-respond answer is judged in the negative, as not knowing, when, in fact, the student may simply be taking time to formulate an appropriate and respectful answer. Our members suggested a more informal and open approach should be taken to allow students to present their ideas and respond to questions appropriately, in order to nurture students along and provide a *safe* environment to learn these skills. Understanding cultural ways of communication and interaction is critical for enabling Aboriginal students' participation in the classroom.

Fourth, in the Blackfoot culture, all are considered to be equal. Cooperation and sharing are foundational, and competition and selfishness (gathering only for oneself) are seen to be disrespectful. Status is gained through generosity rather than competition, and helping and sharing are important, expected and respected cultural values. Being able to teach each other and work together is important because it is reflective of the cultural value of sharing what you know for the benefit of all. Therefore, group work and teamwork are more effective ways of learning for Aboriginal students. The members of the dialogue-focus group felt that the Western competitive, individualistic way of education was an impediment to learning for Aboriginal students. Instructors, they suggested, should emphasize cooperative learning and encourage an interpersonal, relational approach to learning rather than an impersonal goal-oriented one. The focus should be on improvement rather than competition for grades. Group work, teamwork, and diverse peer

tutoring boost student self-confidence and are more effective ways of teaching Aboriginal students.

Fifth, according to the group, is the importance of story. Storytelling, oratory, and experiential learning are a very large part of Aboriginal education and such modalities should be seriously considered when trying to enhance curriculum as well as teaching and learning strategies. Such cultural modalities provide context, connection and relevancy. Listening to story is a critical way of learning for Aboriginal people, and the stories of others, especially elders, are critical pieces of oral knowledge and literature. Not only is storytelling a form of teaching and holding the cultural text, but it is also an important means of mentoring. As an oral culture, textbooks are not a part of the Aboriginal way of recording information. Consequently, many Aboriginal students do not have the skills to find information in a textbook. They have always been taught to go the source of the information, which is most often the elders, or to be practical and learn through watching and then trial and error. Often, Aboriginal students need to be shown how to do something. One of our young students explained how she finally learned biology, chemistry and mathematics, "It was important for me to sit beside the instructor and just learn it, see how she was doing it." It seems this would be particularly important for Aboriginal students in the very challenging and foreign discipline of science. As an instructor I have found the practical "laboratory" hands-on approach and individual attention to have the greatest success with Aboriginal students. As suggested by the group, such attentive teaching methodologies take time and require instructors who have the time and desire to learn different teaching strategies. Neither is factored into Western education, often for such reasons as financial impracticality. This is particularly true at the post-secondary level where classes are large and individual one-on-one learning is rare (CMEC, 2006, 2009).

Metaphorically, summer is the period of time and attention. There needs to be sufficient time to grow, to tend, to nurture, and to allow for maturation. This is needed in education as well. We do need to attend to the individual as well as the whole. How in academia might we be able to arrive at such a way of attending to a different way of learning such that we can nurture our students to maturity so they are ready to move forward on their own? It requires truly listening, to understand what is needed and what works best. Many in the focus group felt this needs to happen in the early years and we need to keep tending to that so Aboriginal students are prepared to move into more advanced courses or educational institutions. Without that attention, like plants that are not tended to in a garden, they will not survive or mature sufficiently to harvest. We need to prevent them from withering and dying, or leaving.

Fall - West

In the medicine wheel, fall is the time of harvest, a time of change that brings with it a new awareness of the successes and failures of spring and summer. It is a time of coming to understand what was effective in the spring and summer, what was less effective, and what failed, and the impact these effects had on the overall maturation and yield. If the environment of growth has not been appropriately attended to in the earlier seasons, then we may get few who reach the maturation stage for harvest, resulting in a poor yield or sometimes even a failed harvest**.** This of course precludes any environmental effects that are out of our control such as hail or flooding rains. In part it requires the cumulative knowledge of not only our own experience but that of others, of what was successful in the preceding seasons to arrive at a place of a good harvest. West, in the medicine wheel, means we are responsible to all things and to each other. In parallel, if we as educators come to a better understanding of what works, we might be better able to cultivate the

academic garden for success or "harvest" for Aboriginal students in post-secondary education. In reflecting on how to bridge Aboriginal and Western paradigms for such success the question "how can holistic traditional Aboriginal teachings and concepts be bridged with the discipline of science and the contemporary university learning environment – *and* to further augment the question – such that we get the best harvest, with the highest yield?" was posed to the dialogue-focus group.

Accommodation and attention to student preparedness is imperative for Aboriginal students who, more than any group indigenous to their own area, have very different levels of preparedness and a different cultural understanding coming into post-secondary education. As a result, the initial learning curve and cultural bridging required for Aboriginal students differs from non-Aboriginal students. One important difference and consideration is how learning is approached. In the Aboriginal paradigm, learning is based on readiness, not on age grouping as it is in the Western educational paradigm. It is important that the instructional period be extended to allow the necessary time to attune to a different way of learning. Cultural bridging is not necessary for Western non-Aboriginal students who are most often the majority in the classroom, particularly at the post-secondary level; therefore, Aboriginal students, who need such a bridging, are at a disadvantage in the mainstream system. The consequence is that instructors teach to the majority and, often, the Aboriginal students – particularly when it comes to science (Aikenhead, 2002b; Battiste, 2005; CCL, 2006a, 2006b) – are left behind, as they struggle to make their own connections. Program and performance expectations should, as a result, be matched with each student's initial preparedness, such that they can be nurtured to reach maturity.

The dialogue-focus group members felt that an understanding of Aboriginal ways of knowing, and specifically in this area Blackfoot ways

of knowing (Bastien, 2004), were foundational and critical to bridging the Western and Aboriginal paradigms, a condition necessary to enabling student success. Aboriginal people, historically and currently, are expected to leave their culture at the door when they enter into the Western education system (Aikenhead, 1994; 2002b; Battiste, 2002). For many in the focus group this was challenging because, not only were they not allowed to bring their culture with them into the classroom, they were expected to have the knowledge and ability to function in the dominant Western culture. As a group, they felt that there was no room to be Aboriginal in the Western system, particularly in the sciences, and that, in order to succeed, their culture had to be suppressed. This can be a challenge for many, and members of the group suggested that the inability to do meet this challenge or to create the bridges, without help, were significant reasons for lack of success. Bridges between Aboriginal and Western paradigms would allow for connections and enable a bridging of understanding. Such bridge-building, however, requires that equal merit be given to *both* ways of knowing and, again, this has not historically been the situation in Western education. It is impossible to build bridges if both parties do not exert an equal effort to learn about the "Other" (Aikenhead, 2002a; Burns, 2001; Cajete, 1999; CCL, 2006b, 2007a).

Collectively, the members of this focus group felt that their ways of knowing "science" were not given the same merit as Western ways of doing science. An elder professor provided an example of the accuracy of Aboriginal science and mathematics. The Majorville medicine wheel north of Lethbridge has one of the spokes aligned nearly exactly with the solstice. Scientific measurements of that medicine wheel show it is within a .07-degree accuracy of the solstice, more accurate than many of the early measurements using Western scientific instruments have been. He poses the question of how that would be possible if "we (Aboriginals) didn't know science or Indian math" (as he calls it); "How then could

you do that?" Such measurements have taken Western scientists and their instruments decades to perform. "How could we share this knowledge with each other," he asked, "rather than having only one be the correct one?" Building bridges between the two such that connections are made, rather than setting up dichotomies, is critical to making those links. If the gap or distance between Aboriginal and Western views of science is connected by bridges, making it easier to see the relationships, then the connection for our students might be an easier. Metaphorically, it is significantly easier to journey across a bridge than to attempt to cross a chasm or gap without any supports in place to connect the two sides.

So much of Western science is curriculum-driven and textbook-taught, a way of teaching and learning so different from Aboriginal ways of coming to know. The Elders in this group talked of Indigenous science as being a creative exploration of natural phenomena in a way different from Western science. However, both Aboriginal and Western peoples share the same environment, so curriculum content can be comparatively derived from the immediate environment of the student. This would provide those much-needed connections for Aboriginal students.

The yield of fall is determined by the effectiveness of the spring and summer cycles. To increase the yield of Aboriginal success in post-secondary science, there has to be prior nurturing, during the academic growth years (or summer). Evaluating what was effective or not is critical not only for garnering energy in the winter but also for planning how to begin again in the spring.

Winter - North

North in the Aboriginal medicine wheel is represented by the season of winter, a time to rest and store energy. Winter is a time for seeds, soil and plants to rest and garner energy for the spring. The cumulative

effects of the previous cycles will become the foundation for how effectively germination will take place in the spring. Metaphorically it is a time to evaluate, to come to an understanding of the results of our interactions with the other "seasons" and to use that knowledge to move forward into the next cycle. As institutions and academics within those institutions, we have an obligation to evaluate what are effective teaching practices and what is inclusive curriculum, what isn't working and what has worked. It is our job to reflect upon this, to evaluate what works and what needs to change, and then implement any changes as a way of being both progressive and inclusive of different paradigms and different modalities and ways of learning and coming to know. This requires the input of all. With this in mind, the question "*How can relationships between the Aboriginal, specifically the Blackfoot, and University of Lethbridge communities be fostered to address these issues?"* was posed to the dialogue-focus group.

All members of the group have some level of experience in post-secondary education – either in completing a degree or degrees – or they were currently students in the Western academic system. Their experience is critical to understanding what worked, what enabled them to succeed, what did not work or was not in place for them, and what they see as being critical for the support of academic success for Aboriginal students such that we as teachers, curriculum and program developers within the Western academic system might begin to build on that experience in the next cycle. In action research, as in the next cycle of the medicine wheel, using the knowledge gained in the previous cycle is critical to moving forward in an informed way.

In order for change to occur, the participants felt strongly that the institution needed to provide leadership in implementing programs at a systemic level. Many native students do achieve relatively high scores on standardized tests in science from kindergarten to the fourth grade, but tend to fail out later grades (CCL, 2006a; 2006b). By middle school many

Aboriginal students avoid science and mathematics courses, and, as a result, many do not enter science-related courses in either high school or post-secondary. In addition, there is a tendency to stream Aboriginal students into lower, remedial levels of these courses or into disciplines such as Native American Studies, Fine Arts and the Humanities, disciplines requiring little or no science or mathematics. There is a bias, as one member of the group suggested, that "Indians can't do science" and "Indian science" is not real science. As a result many don't even try. This precludes them from entering into the sciences and related programs and, ultimately, into related professions. Members of the group felt that bridging programs to post-secondary are important for most Aboriginal students who are entering into an environment that is both culturally and socially different from the environment and paradigm from which they come. A few who had been through the First Nations Transition Program (FNTP) offered by the university felt this was effective in enabling their transition as well as providing community. Post-secondary education is daunting for even the academically accomplished Aboriginal student, so having a connection to an Aboriginal community on campus would enable a sense of belonging.

A welcome orientation is critical for Aboriginal students to provide direction on many topics and to ease a sense of alienation as well as to create a greater sense of belonging. Aboriginal students need to be mentored by other Aboriginal students on campus. Given the small number of Aboriginal students, and virtually none in science, Aboriginal mentoring of Aboriginal students is nearly nonexistent. However, matching and mentoring of Aboriginal students by other experienced non-Aboriginal students in the Aboriginal student's specific field or discipline of choice, is a good alternative.

An Aboriginal student resource center - a center for meeting and a location for Aboriginal resource materials - would provide students with

a place, home and location within a large institution. Such a place of community and support is necessary for Aboriginal students. Counselling and other support services, as well as places for studying and tutoring, could be housed within this center.

Tutoring in science and mathematics is critical for those students who struggle with the curriculum and the transition to the higher expectations of university. One-on-one tutoring rather than group tutoring is most effective for Aboriginal students. Within the classroom situation, peer tutoring or working in groups (collective learning) can aid in understanding.

As discussed, Aboriginal students rarely consider science and mathematics when entering post-secondary education, often because they are not prepared, but most often because somewhere along the way, as most in the group said, they were turned off by lack of support and lack of qualified teachers teaching Aboriginal students. Science and mathematics camps could be offered as a way of initiating middle-school connections and garnering early interest, turning on students to these disciplines at an engaging level. These camps could be offered on and off Reserve to make the bridge between the communities and post-secondary institutions less intimidating. Post-secondary institutions could extend invitations to Reserve schools for orientation visits. Early mentoring is a key factor in engaging students, particularly if mentors are Aboriginal. Mentoring programs should be established between the post-secondary institution and high schools in science. Many in the group spoke of a person they looked up to, someone who mentored them and enabled their success.

Culturally-infused programs are critical to engaging Aboriginal students and to their success. The Aboriginal paradigm and Aboriginal people have not been well represented in the Western curriculum, , and still are not, especially in science and mathematics. Until very recently, and still in most disciplines, the very best has been tokenism, a passing

mention. Tokenism is not inclusion and should not be seen as that. All those in the focus group felt that the curriculum is taught only from the Western perspective or point of view. Many felt that starting with a methodology or way of learning from an Aboriginal, rather than the traditional Western, perspective would enable Aboriginal students to see their contribution to such disciplines. Acknowledgement of traditional knowledge and Aboriginal ways of knowing as alternative and equally valid sources of information should be part of cultural inclusion in the curriculum. The weaving of the "Aboriginal ways of knowing' with the Western paradigm is important to finding bifurcation points for understanding not only for Aboriginal students, but also for non-Aboriginal students to understand an alternative to the Western perspective.

If Aboriginal students do not see themselves in the curriculum, or it is irrelevant to their own life, then it is not tangible for them. Using natural phenomena situates the student and the instructor in the center, which becomes a place of 'situated learning' (Brown, Collins & Duguid, 1989; McLellan, 1996). Including culturally relevant materials from the home, community, school, as well as incorporating stories and teachings were some suggestions by the group members to enable situated learning. Contemporary Aboriginal issues can be integrated (i.e. land rights, Reserve issues, Aboriginal "sacred" artefacts, resource management, relevant social issues such as diabetes and water quality issues) with Western issues. Art, music, and theatre can be used as vehicles for creatively teaching science and mathematics. Such non-traditional tools can be expanded to exemplify scientific concepts and allow for further expression of culturally related ideas. Elders can be asked to tell about the history of Aboriginal people as it is related to specific foci in the course curriculum. Students can build on the Aboriginal culture as a storied culture by writing about the scientific and culturally relevant issues of Aboriginal people today. Importantly, if we are *truly* building

bridges, then Western students can and should be taught in a similar fashion, so they learn to think in an interconnected and holistic fashion and learn a different perspective to the "culture of science." Such parallel connections can be used as a means of building bridges of communication between Aboriginal and Western paradigms and enabling learning from multiple approaches drawn from both.

Inquiry-based skills in creative problem-solving situations can be developed such that the knowledge learned is applied in a relevant and practical manner. Applicable or "hands-on" learning bridges theory to practice and is conducive to the Aboriginal learning style. David Kolb (1984) suggests experience is critical to learning and developing one's own ideas. Kolb's cyclical concept of experiential learning, influenced by the work of John Dewey and Kurt Levin, parallels the Aboriginal cyclical medicine wheel. Learning is cyclical according to Kolb, and like the medicine wheel, each time around brings the learner back to the beginning, but with a new and deeper knowledge and understanding as a result of one's experience. Kolb (1984) believes "learning is the process whereby knowledge is created through the transformation of experience" (p. 38); one pre-understands based on one's experience. How we distil that experience, come to understand it in a hermeneutic way, becomes a foundation or base from which we can come to understand further experiences. Experience is critical but it is also personal. It is important, as educators, to note that there are differences between different Aboriginal cultural groups and, unlike Western academia where education is "standardized," Aboriginal ways of knowing and coming to know are not "standardized" and do vary among different Aboriginal groups. Therefore, there has to be room for flexibility and understanding.

Experientially-based learning situations provide applicability, which in turn provides relevancy for Aboriginal learning and is critical to bridging theory and practice. Field trips to sacred sites, the study of

artefacts, visiting job sites, job shadowing, incorporating guest speakers, and bringing in Elders with a directed focus on the topic can build the science. Importantly, bridging courses at a more introductory level are required to provide the background or foundation that is lacking for incoming Aboriginal students. Such transition courses, also offered in parallel as part of the "mainstream" curriculum, should have different titles so they are not seen as "dumbed down" versions for Aboriginal students. These courses carry with them a stigma of "not quite good enough." Such names as *ethnoscience* and *ethnomathematics* could be used.

As well as having a sense of purpose, Aboriginal students need a sense of belonging to a community of "like." Building a visible Aboriginal community within the institution is critical to the sense of belonging. Aboriginal students often demonstrate a strong identification with the community they serve and a post-secondary institution that recognizes that would be welcoming rather than isolating to Aboriginal students. There should be a strong emphasis on creating a collaborative learning community because collaboration and working together as a community are a critical part of Aboriginal culture.

Most important is a sense of success. Native graduate students who have completed post-secondary studies should be profiled. All those in the dialogue-focus group spoke of friends or relatives who had completed post-secondary education and who were their sources of inspiration. However, if you are the first to attend post-secondary education, there may be very few if any role models from whom to draw upon or to seek advice. This is particularly true in science and mathematics. It is critical to profile success in order to counterbalance the myriad of negative statistics addressing the lack of Aboriginal success. It is critical that research to generate statistics is done by the appropriate Aboriginal groups rather than research being done "on" Aboriginal peoples. Having successful Aboriginal students give presentations about their journey, about their accomplishments as well as talking about their

struggles, would validate those who are currently on their academic journey and would positively promote success at post-secondary education. In essence, success enables success. Educators and institutions of higher learning need to change the image of Aboriginal education from a deficit description of "not" to one of potential and possibility, of "can."

End-beginnings - The Next Cycle

End-beginnings (H-duke, 2004), arriving at the end, bring us back to the beginning again, with different experiential knowledge that can inform the next cycle. This is again the principle of the medicine wheel and also of action research. McTaggart (1996) suggests that action research is not a research method or procedure but rather a series of commitments and principles to observe and problematize through practice and social enquiry. Implementation and evaluation of recommendations requires continual attention. Aboriginal success in science and mathematics is imperative, as the need for Aboriginal people in fields that require these foundational subjects is critical. The Aboriginal voice is currently missing from such fields. Perhaps even more importantly is the need for Aboriginal people with both paradigm knowledges to work with Aboriginal people to build bridges between cultures and to serve as mentors enabling the next seven generations.

The results of the research dialogue-focus group raised and addressed many of the issues from the voice of the surrounding Aboriginal community. The group has provided educators with a direction as to what is needed to facilitate Aboriginal student success not only at the academic level in terms of curriculum, teaching and development of courses, and programs but also at the social level of culture and community. This study was only the beginning step, and the

results presented in this paper are only a few of the many preliminary implementations based on the focus group recommendations.

As an instructor in a Western post-secondary system, I am continually changing my own teaching practice. For example, in teaching chemistry to FNTP students, I have experienced 100% attendance and engagement in the laboratory portion of the course, yet in the classroom lecture portion, attendance and engagement drop off. Most of the students were intimidated by chemistry, the concepts and the mathematics, yet in the laboratory it was a different situation. So I lobbied for more laboratory time and began providing a larger hands-on component to the course. I saw huge improvements. This cycle around, I am teaching the course entirely in the laboratory and beginning each concept with a hands-on practical experience followed by a conceptual explanation. Whenever possible, I use practical applications and Elder teachings first, and then I bridge to the Western model or concept.

The First Nations Transition Program is a program that enables Aboriginal students to bridge to mainstream post-secondary education from their own unique starting point. Many of the students enter this program with varied academic and cultural backgrounds and skill sets and, as such, their starting place and focus in this Eurocentric academic system is not the same as non-Aboriginal students. Yet they are expected to leave their culture at the door and behave and perform as if they are "white." If this is to be the expectation then, at the very least, there need to be bridges built that will enable their connection and support their transition from their starting point to post-secondary education. The students begin in this program with an orientation period and then proceed through the program as a cohort. They take six foundational courses: two required in mathematics, one required in each of library science, computer science and writing and one elective in either anthropology or indigenous studies. Those with a nursing goal take eight courses, adding biology and chemistry, and replacing

anthropology or indigenous studies with health sciences. The students are restricted to a maximum 80% course load per semester (to ensure balance and time) and a minimum 60% load (to ensure funding). With the exception of the first mathematics course, these courses are used for credit towards their first year of university but there is a built in buffer that allows them to choose a maximum of two for a credit/non credit designation. The instructors who teach these courses, with the exception of myself,unfortunately have no Aboriginal heritage, so having Aboriginal teachers teaching Aboriginal students has not been a possibility so far. However, the instructors who teach the courses are experienced and dedicated to teaching and working with an inclusive Aboriginal focus and are attentive to Aboriginal ways of learning. Additional supports are in place, including tutoring, mentoring, counselling, learning facilitation to name just a few, to ensure the students are able to grow into their academic journey successfully. As well, I coordinate and run a First Nations Speaker Series that profiles successful Aboriginal individuals from various professions. They share their own journey, where they are currently and lessons they have learned along the way. This has been valuable for the students, particularly because it not only validates their own journey and struggles, but also shows them where success at post-secondary education can take them.

When this program first began four years ago, the attrition rate was high and the success rate for continuation after the program low. In the third year of the program, when we began implementing particular changes, many as suggested by this research, we had a 60% success rate for completion and continuation into year two. In the past year, we had 80% completion and continuation – our most successful year.

Each year begins with a different profile of students and thus a different dynamic. This requires continual evaluation of the program: what has been successful and what has not, each year, and the

implementation of subsequent changes based on the results prior to beginning each new academic cycle. It requires continual attention and evaluation but this has led to successful results in terms of student retention. The greatest challenges are still in the sciences and mathematics. However, all who entered into this program with the goal of nursing this past year were successful in garnering positions within the nursing program, and one of our former students was accepted into medicine. While it may be slower than we would like, each cycle yields positive results.

Conclusion

For First Nations students, science and mathematics are difficult subjects as the concepts and traditional Western ways of teaching these subjects are far removed from the Aboriginal way of knowing and learning. The unfortunate result of this impediment of education is the critical under-representation of Aboriginal individuals in professions such as medicine, dentistry, nursing, optometry, nutrition, health care assistant positions of all sorts, pharmacy, physiotherapy, chiropractic, research science, computer science and engineering as well as education positions in science and mathematics at all levels (post-secondary professorial positions, secondary and elementary teaching positions) and many other science and mathematics related careers. The use of science and technology is pervasive in all sectors of the economy and, with the retirement of the Baby Boomer population already beginning, as a nation we will experience a severe shortage of individuals in these professions. The fact that the median age of the Aboriginal population – the only growing population in Canada – is 10-15 years less than the median age of the non-Aboriginal population, makes our resident population a *renewable* resource upon which to draw. In this time of globalization this is critical. However, it will require significant attention to Aboriginal

education at all levels, particularly in the successful transition to and completion of post-secondary education. Traditionally, universities have been the least successful in educating First Nations students, particularly in the sciences and mathematics. In order to open the doors of access to these science and mathematics related careers, the difficulties at the educational level must first be understood, addressed and continually attended to. The findings presented in this paper only begin to touch upon the suggestions of our dialogue-focus group, insights from the voice of the Aboriginal people themselves, to which we need to critically and continually attend.

Notes

[i] The research for this project was done in collaboration with members of the surrounding Blackfoot community, the Aboriginal community indigenous to southern Alberta. The words Aboriginal, Indigenous, Native will be used interchangeably within this paper and are meant to be inclusionary of Aboriginal peoples. Blackfoot specifically refers to members of the surrounding Aboriginal community involved in this project.

[ii] I include mathematics here because many science courses and related degrees require various levels of mathematics. For most Aboriginal students, mathematics is a struggle and in order to see success in the sciences, there needs to be success in mathematics courses.

[iii] Rather than include individual responses, I have used quotation marks to indicate the summarized comments of the participants in an inclusive manner, as many often said the same thing in the meetings.

[iv] A dialogue in the Aboriginal culture is akin to a focus group in the Western paradigm. Both are a group of people with a vested interest in the topic. They meet to share and exchange ideas pertaining to the topic

of concern or action. In this paper the terminology will be used interchangeably or hyphenated as dialogue-focus group.

[v] I capitalize Reserve with respect and to be inclusive of all Reserves. It is a place and as such a proper noun and in the English language, proper nouns are capitalized.

References

Aikenhead, G. S. (1994). The social contract of science: Implications for teaching science. In J. Solomon & G. Aikenhead (Ed.), *STS education: International perspectives on reform* (pp. 11-20). New York, NY: Teachers College Press.

Aikenhead, G. S. (1996a). *Rekindling traditions: Cross-cultural science & technology units*. Retrieved from http://www.usask.ca/education/people/aikenhead/cjsmte.htm

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

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

Aikenhead, G. S. (2001). Students' ease in crossing cultural borders into school science. *Science Education, 85*, 180-188.

Aikenhead, G. S. (2002a). *Integrating Western and Aboriginal sciences: Cross-cultural teaching*. Retrieved from http://www.usask.ca/education/people/aikenhead/CJSMTEedpol.htm

Aikenhead, G. S. (2002b). Cross-cultural science teaching: Rekindling traditions for Aboriginal students. *Canadian Journal of Science, Math and Technology Education*, *2*(3), pp. 287-304.

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

Aikenhead, G. S. (2011). Towards a cultural view on quality science teaching. In D. Corrigan, J. Dillon & R. Gunstone (Eds.), *The professional knowledge base of science teaching*. New York, NY: Springer.

Bastien, B. (2004). *Blackfoot ways of knowing*. Calgary, AB: University of Calgary Press.

Battiste, M. (1995). Introduction. In M. Battiste & J. Barman (Eds.), *First Nations*

education in Canada: The circle unfolds. Vancouver, BC: University of British Columbia Press.

Battiste, M. (2002). Indigenous knowledge and pedagogy in First Nations education: A literature review with recommendations. In INAC, *National working group on education, our children: Keepers of the sacred knowledge*. Ottawa, ON: Indian and Northern Affairs Canada, February.

Battiste, M. (2005). *State of Aboriginal learning: Background paper National Dialogue on Aboriginal Learning*. Ottawa, ON: Canadian Council on Learning.

Battiste, M., & Barman, J. (1995). *First Nations education in Canada: The circle unfolds.* Vancouver, BC: UBC Press.

Brown, J. S., Collins, A., & Duguid, P. (1989). Cognition and the culture of learning. *Educational Researcher*, *18*(1), 32-42.

Bourke, C. J., Burden, J. K., & Moore, S. (1996). *Factors affecting performance of Aboriginal and Torres Strait Islander students at Australian universities: A case study*. Canberra, Australia: Report of Commonwealth EIP program, AGPS.

Burns, G. (2001). Toward a redefinition of formal and informal learning: Education and the Aboriginal people. Report no.: NALL Working Paper, 28. *Center for the Study of Education and Work*, OISE/UT. Retrieved from http://hdl.handle.net/1807/2742

Cajete, G. A. (1994). *Look to the mountain: An ecology of Indigenous education*. Skyland, NC: Kivaki Press.

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

Cajete, G. (2000). *Native science: Natural laws of interdependence.* Santa Fe, NM: Clearlight Publishers.

Canadian Council on Learning. (2006a). *What are the factors that facilitate and*
impede post-secondary access and participation of Aboriginal students? Ottawa: Government of Canada. Retrieved from http://www.ccl-cca.ca/CCL/Reports/LessonsinLearning

Canadian Council on Learning. (2006b). *What factors facilitate Aboriginal postsecondary success?* Ottawa: Government of Canada. Canadian Council on Learning. Retrieved from http://www.ccl-cca.ca/CCL/Reports/LessonsinLearning

Canadian Council on Learning, (2007a). *The cultural divide in science education for Aboriginal learners.* Ottawa: Government of Canada. Retrieved from http://www.ccl-cca.ca cca.ca/CCL/Reports/LessonsinLearning

Canadian Council on Learning. (2007b). *Report on learning in Canada: Redefining how success is measured in First Nations, Inuit and Métis learning*. Ottawa: Government of Canada. Retrieved from http://www.ccl-cca.ca/CCL/Reports/LessonsinLearning

Canadian Millenium Scholarship Foundation. (2007). *Aboriginal peoples and post-secondary education: What educators have learned.* Retrieved from http://www.milleniumscholarships.ca/images/Publications/aboriginal_en.pdf

Carson, T., & Sumara, D. (1997). *Action research as living practice*. New York, NY: Peter Lang Publishing.

Chambers, C. (2008). Where are we? Finding common ground in a curriculum of place. *Journal of the Canadian Association for Curriculum Studies, 6* (2), 113-128.

Corsiglia, J., & Snively, G. (1995). Global lessons from traditional science of long-resident peoples. In G. Snively & A. MacKinnon (Eds.), *Thinking globally about mathematics and science education*. Vancouver, B.C: Centre for the Study of Curriculum and Instruction, University of BC.

Council of Ministers of Education Canada. (2002). *Best practices in increasing Aboriginal post-secondary enrolment rates.* Retrieved September 28, 2007 from http://www.cmec.ca/postsec/malatest.en.pdf.

Council of Ministers of Education Canada. (2006). *Best practices in increasing Aboriginal post-secondary enrolment rates.* Retrieved from http://www.cmec.ca/postsec/malatest.en.pdf

Council of Ministers of Education Canada. (2006). *89th CMEC meeting: Ministers renew their commitment to Aboriginal education*. Retrieved from www.cmec.ca/postsec/malatest.en.pdf

Council of Ministers of Education Canada. (2009). *Ministers of education open CMEC summit on Aboriginal education*. Retrieved from www.cmec.ca/postsec/malatest.en.pdf.

Dick, B. (2002). *Action research: Action and research*. Retrieved from http://www.scu-edu.au/schools/gcm/ar/arp/aandr.html

H-duke, M. (2004). *The chemistry of education: A periodic relationship.* (Unpublished master's thesis). University of Lethbridge, AB.

H-duke, M. (2009) Understanding the life-world journey of aboriginal individuals through the liminal spaces of post-secondary science education. *CSSE/CSSHE, 2009 Conference.* Carleton University, ON.

H-duke, M. & Sterenberg, G. (2008). Bridging Aboriginal and Western worlds in science and mathematics education, *CSSE/CSSHE 2008 Conference,* UBC, BC.

Indian and Northern Affairs Canada. (1994). *Aboriginal education: The path to empowerment*. Ottawa, ON: Government of Canada.

Indian and Northern Affairs Canada. (1997). *Implications of First Nations*

demography. Final report. Ottawa, ON: Government of Canada.

Indian and Northern Affairs Canada. (2005). *Aboriginal post-secondary education and labour market outcomes Canada 2001.* Retrieved September 18, 2007 from http://www.ainc-inac.gc.ca/pr/ra/pse/01/01_e.pdf

Kirkness, V. (1997). Our people's education: Cut the shackles; cut the crap; cut the mustard. *Canadian Journal of Native Education, 22*(1), 10-15.

Kirkness, V. B., & Barnhardt, J. (1991). First Nations and higher education: The four r's - respect, relevance, reciprocity, responsibility. *Journal of American Indian Education, 30*(3), 1-15.

McLellan, H. (Ed). (1996). *Situated learning perspectives*. Englewood Cliffs, NJ: Educational Technology Publications.

McNiff, J. (2002). *Action research for professional development.* Retrieved from http://www.jeanmcniff.com/booklet1.html

McTaggart, R. (1991). Principles of participatory action research. *Adult Education Quarterly*, *41*(3).170.

O'Brien, R. (2001). *An overview of the methodological approach of action research.* Retrieved from http://www.web.ca/~robrien/papers/arfinal.html

Ogawa, M. (1995). Science education in a multi-science perspective. *Science Education, 79*(5), 583-593.

Reason, P., & Bradbury, H. (Eds.) (2001). *Handbook of action research: Participative inquiry and practice.* Thousand Oaks, CA: Sage.

Statistics Canada. (1996; 2005). *National tables: Aboriginal data*. Retrieved from http://www.statcan.ca

Statistics Canada. (2008). *Aboriginal peoples in Canada in 2006: Inuit, Métis and First Nations (*2006 Census. Vol. 8). Ottawa. ON: Government of Canada.

Statistics Canada Demography Division. (2005). *Projections of the Aboriginal populations, Canada, provinces and territories: 2001-2017*. Ottawa, ON.

Sterenberg, G., & Hogue, M. (2011). Reconsidering approaches to Aboriginal science and mathematics education. *Alberta Journal of Educational Research,57*(1),1-15.

Thunderbird, S. (2010). *Medicine wheel teachings*. Retrieved from http://www.shannonthunderbird.com

Wadsworth, Y. (1998) What is action research? *Action Research International* Paper 2 . Retrieved from http://www.aral.com.au/ari/p-ywadsworth98.html#Anchor-44169