The Sacred Tree: Weaving the stories of

Western science and Aboriginal ways of knowing

by

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Abstract

Instead of preparing for careers in science, some Aboriginal scientists believe they must instead train a new generation of "biologist warriors" in order to force the modern science community to value and respect all Indigenous knowledge systems. Other Aboriginal scientists have negotiated a shared vision of the world, instead of turning away from their own culturally rich and technically credible accounts of the world, to better position themselves in Western science careers. Both approaches identify challenges faced when a dominant culture overrides the value of Indigenous knowledge. I explored with participating Aboriginal scientists, how that negotiation (the decolonization of science stories) and how communicating new science stories can explain the world better and build cultural bridges. Interviewing Aboriginal scientists, as well as a science educator and non-Aboriginal scientists, yielded insights into core problems with how science is currently communicated, perceptions evolving, and recommendations for the future. Findings highlighted the pressure felt by Aboriginal scientists when they negotiate their places in science careers. One sentiment echoed by the participants was that they wanted to have a positive relationship with science. However, they were willing to drive towards a more political solution in view of the continued lack of Aboriginal representation in sciences. All participants identified family and cultural support systems as critical elements of flourishing in a hostile sub-culture of science. Many participants voiced a belief that Indigenous knowledge should be part of science in a broad sense—starting with the culture of science but reinforced in the classroom with teachers acting as cultural brokers. Findings indicated that without a respect for the larger body of knowledge available through non-Western sources, such as oral

storytelling, the systemic dismissal of Aboriginal ways of knowing will continue to undermine formal efforts to increase Aboriginal representation in science careers.

A cultural opportunity is created when Aboriginal scientists are encouraged to develop their unique understanding of both the Western scientific world-view and their own traditional world-views. They show it is possible to incorporate place-based Indigenous knowledge, passed along by Elders through stories, with confidence and passion while pursuing science careers outside of the colonizing society norms.

Key words: Aboriginal science, Indigenous knowledge, science education, Elder, warrior

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Introduction

In high school I saw myself as a writer—a creative, resourceful, and unpredictable storyteller. It should be no surprise that I found all things scientific and mathematical alien to me. My final mark in Grade 12 Biology was a whopping 39 percent and I spent several warm summers massaging "do-overs" in Algebra, thus my feelings of *otherness* (Littlejohn & Foss, 2008) were based in reality. For me, science was another world where my knowledge and views were not necessarily appreciated. A few years ago, I began communicating professionally in the science field, helping researchers and technology start-ups connect with funders and engaging stakeholders. I didn't feel unwelcome in this case, because communicating was my niche. However, I did sometimes feel like I was just visiting a hostile country. By being professional and using my own coping strategies, I avoided any impact on my success in science communications. This was my state of mind when I was invited to serve as a volunteer science fair judge. Even though I was not a scientist, I was asked to critique participants who were expected to present and communicate their projects clearly and passionately—my specialty. At this point, I noticed the lack of cultural diversity and the complete absence of Aboriginal[1] student participation, in particular. Since that first high school competition in Nova Scotia was sponsored by an international life science corporation and many projects were practically ready for commercialization, I considered my observation as unique for the level of competition, which was not very inclusive of me. The next science fair I judged was on the other side of the country with elementary to high school senior students participating—again, not a single

[1] For the purposes of this research, Aboriginal refers to First Nations, Inuit, Métis peoples and non-Western indigenous populations.

Aboriginal student. I wondered whether the constructed world of Western science, and how it was communicated, is as foreign to Aboriginal people as my own high school experience.

An unwelcoming subculture, the world of Western science, is at the root of an on-going lack of Aboriginal representation in the sciences and is reinforced by the absence of any research on the personal experiences of Aboriginal scientists. As a reasonable assumption, to find out why there were so few Aboriginal scientists, I thought I should talk to practicing Aboriginal scientists. As development and resource management concerns become more important to Aboriginal communities, the lack of a credible voice in planning their own future will focus even more attention on building Aboriginal science capacity. I think the disconnect between the Eurocentric, colonized way of seeing the world, has dominated learning systems to the detriment of the more holistic Aboriginal ways of knowing. There are opportunities to correct this imbalance and make the world of Western science connect with Aboriginal ways of knowing. The result will be an increased number of dedicated scientists able to see the wealth of knowledge available to them, without cultural restrictions. Thus, my research journey began by asking: (a) whether Aboriginal culture and ways of knowing had put Aboriginal science students at a disadvantage within the current school science curriculum, and (b) were there strategies in use to mesh or balance Indigenous[2] and Western sciences. Finally, could Aboriginal scientists share their insights to generate a more robust Aboriginal representation in the sciences in future? The best way to answer these questions using culturally relevant methodology is through storytelling or narrative inquiry, accordingly I invited Aboriginal scientists to tell me their stories.

[2] Indigenous refers to native or “place” based knowledge and culture.

One world view

The first step in exploring the subculture of science is to decipher the accepted definitions of science. Modern definitions of science are the products of a Western or Eurocentric approach, romanticizing or colonizing non-Western ways of knowing as less logical or credible, an indicator of the postcolonial influences on communicating science (Littlejohn & Foss, p. 344, 2008). A commonly accepted definition of science comes from the Latin *scientia,* meaning knowledge (*Science*, n.d.) and describes the effort to understand how the universe works through the scientific method, with empirical evidence as the basis of that understanding; a way of understanding (constructing) the world through thought and experimentation (Aronowitz, 1988, p. viii). In modern science education and in the Western scientific community, the definition of science only represents one Eurocentric view.

Today's science subculture uses systemically structured consistencies to construct explanations, which are a powerful way of understanding the world although this still constitutes just one way of seeing—not the *only* way. In 1995, Ogawa defined science as "a rational perceiving of reality, and in the case of Western science, the size of the collective group allows the effective communication of a shared representation of reality to be presented as preferred" (p.585). Most accepted the reality perceived by this one group of specialists. Ogawa and other researchers did not address the personal experience and history of Aboriginal scientists, their way of balancing the two worlds and whether their approaches could be duplicated.

Another world view

Indigenous science is an accepted term for inclusion of the beliefs and understandings of non-Western people, acquired through long-term association with a place (Corrigan, 2006; CCL, 2007). Ogawa (1995), explains out that Indigenous science as a perception of reality that is culturally dependent. Indigenous science might be "tacitly transferred from generation to generation through daily social and cultural events" (p.586). Snively and Corsiglia (2000), provided a definition of Indigenous science, too: "*Indigenous science* which interprets how the world works from a particular cultural perspective" (p.3). For Aboriginal people, learning has a single purpose—to honour and protect the earth and ensure the long-term sustainability of life. To them, learning is something that is always evolving and is never static (CBC, 2009). To illustrate the organic and self-regenerative nature of First Nations learning, the often used stylistic graphic of a living tree—the source of "Sacred Tree" in my research title—is in the holistic lifelong learning model. Bopp (1992) and Battiste (2009), both use the "tree" reference to explain Indigenous knowledge. Battiste also compares Indigenous science to a web, specifically a complex web of relationships in a constant state of flux with ecological context (place), local content and meaning, and implied responsibilities for possessing and sharing their knowledge (2009). Both visual depictions suggest an ever evolving educational system aligned with the rest of the world.

Previous anthropology-based research established that Aboriginal knowledge occurs by the sharing of storytelling and by Elder connections within the community (Aronowitz, 1988; MacLean & Wason-Ellam, 2006; Miller, 1996; Mitchell et al, 2008; Sutherland, 2002). Storytelling starts to build conceptual bridges between a science student's own experiences,

the passed on old knowledge, and newly acquired knowledge. For First Nations and Métis teachers, storytelling is a fundamental communicative model. Like their ancestors, they use a story as an analogy to explain the relationships between people and the natural world (MacLean & Wason-Ellam, 2006, p. 81). I conducted research with a readily available sample group of Aboriginal scientists and one science educator; and explored the strategies they used to build bridges. Their stories reflect different post-colonial coping strategies used to connect their knowledge of Western and Indigenous sciences while not compromising their respect for either. The results identified best practices by individuals already accessing both forms of sciences. Their approach could be used as a model to encourage better engagement in science for Aboriginal youth and future investigations into the Aboriginal student learning experience. Indigenous students are frequently raised in an oral culture and, consequently, more value is placed on spoken word (Aronowitz, 1988; Ignas, 2004). In an oral tradition-based community, books are not seen as "authorities" and Elders or older people are counselled about questions that need authoritative answers. To find information in an Indigenous community, you seek out an individual, such as an Elder, rather than a book (MacLean & Wason-Elam, 2006, p.17). Finally, interviews with potential role models with similar circumstances and their experiences both shared with the Aboriginal student may provide a better bond between Aboriginal scientists themselves (Taylor & Bogdan, 1984; Miller, 1996; CCL, 2007 & 2009).

As I explored the question of how stories connected the two worlds, I let a decolonization theoretical framework guide my research. From my point of view, the main source of Aboriginal student disconnect to science was the narrowly defined, colonized version of the world, in other words restricted to a Western perspective. All students, Aboriginal and

non-Aboriginal, suffer as result from curricula that do not broaden minds, but entrench truth systems from the dominant perspectives of Western epistemologies (Kulig, Duke, Solowoniuk, Weaselfat, Shade & Lamb, 2010, para. 2). Past, colonized, approaches to teaching science focused on the entrenched Western viewpoint and undermined genuine efforts to connect with Aboriginal science students, who were already accustomed to a way of seeing the world based on Indigenous family and community models (Ogawa, 1995; Aikenhead, 2008; Snively & Corsiglia, 1998). According to Ogawa (1995), those students formerly immersed in a world based on Aboriginal ways of knowing become aware of their own Indigenous science only when they live in a different or "foreign" culture. They feel "unsettled, likely in a negative way, expressed as 'this is not **our** feeling' or 'we **never** think like that'" (p. 586), without really being able to articulate the reason. Instead of identifying local knowledge and incorporating it, science communication in the classroom often either romanticizes local knowledge or discounts its validity (Ogawa, 1995; Sutherland, 2002). To succeed in creating a two-world perspective, the existence and value of each needs to be acknowledged, to the benefit all students. Aboriginal Elders share knowledge using legends to explain relationships with Nature. For this reason, I chose to use Aboriginal storytelling traditions to support my research approach, using participant narratives to illustrate the way they straddled the two knowledge worlds (Bopp, 1992; Berkowitz, 2001; Sutherland 2002; MacLean & Wason-Ellam, 2006). Honouring traditional ways of sharing knowledge is a critical part of the research and analysis.

I used thematic analysis and an open inductive approach to identify codes and emerging themes from raw data. Thanks to the small number of interview subjects readily available, I was able to conduct longer, more personalized sessions of at least 90 minutes and thereby generate

a richer experience (Taylor & Bogdan, 1984; Reissman, 2008). In addition, by concentrating on a small group of interviewees, I should be able to create relationships beyond initial interactions—building a foundation of trust for future follow-up. I am very grateful to the participating Aboriginal scientists and science educators. They are passionate about their scientific careers and continue to honour and respect traditional Indigenous ways of knowing. I noted pivotal moments in their lives and considered the impacts of people and experiences—the unique stories that defined their own personal relationships with science. The helpful and supportive strategies identified in the study not only demonstrate the way Aboriginal students can flourish in science careers but recognize the distinct advantages of weaving traditional knowledge with Western science to address progress challenges facing Aboriginal communities.

Literature Review

Historically, education in Aboriginal communities has caused controversy due to the political environment (Aikenhead, 2002; Battiste & Youngblood, 2009; CBC, TV, 2009). Many academics have explored the issues facing Aboriginal students in balancing Western standards with Indigenous values. In my review, I identified several scholars pushing for deeper and more committed research in this area. However, most research has focused on teachers, developing curricula, or policy development versus student experience (Aikenhead, 2001, 2002, 2006; Battiste & Youngblood, 2009; Belczewski, 2009; Berkowitz, 2001; McKinley, 2005; Ogawa, 1995). Even the very thorough and ambitious study, *Learning Indigenous Science from Place* (2008), produced as a combined research project with First Nations University of Canada, the Canadian Council on Learning, and the University of Saskatchewan, focused on the current pedagogy to support science education (Mitchell, Vizinia, Augustus & Sawyer, 2008). An in-

depth analysis of how *individual* Aboriginal scientists have accomplished a balancing act between their two worlds is missing from the literature to date. I found a gap existed in research on the scientific involvement of Aboriginal career scientists currently straddling work, their culture, and Indigenous knowledge (i.e., the missing voices). Many scholars discuss the struggle to respect Indigenous science or to include Aboriginal ways of knowing into modern science curricula, but none ask Aboriginal scientists how they negotiate the two worlds of science. I looked at ways research in this area had evolved, societal and cultural trends, major research to date, and major research figures: historic connections; colonization; ways of communicating science; scientific work, family and mentor influence, and science in the classroom.

Historic connections

Part of the underlying problem with the exclusion of Indigenous science from curricula can be found in the development of Western science itself, constructed over the past 150 years by Europeans. The "truth" of Western science communicated today relates to certain values and ideas. It is not necessarily objective, but another example of the legitimization of certain power structures and the colonizing practices of dominant nations (Aikenhead, 2002; Ogawa, 1995). Scholars have explored the evolving relationship between ways of interpreting the world (science) and studied science education in Indigenous populations around the world: Japan (Ogawa, 1995); North America (Battiste & Youngblood, 2009; Snively, & Corsiglia, 1998); Canada (Aikenhead, 2002 & 2006); Australia (Day & Nolde, 2008). Most acknowledge Indigenous knowledge reflects a larger understanding of the world and a more connected, holistic experience. Indigenous knowledge is not separated from the personal experiences and

relationships with nature. For an Aboriginal student, who has experienced a world view based on Aboriginal heritage, modern science may mean compartmentalizing how he or she sees the world in a way that does not feel truthful (Aikenhead, 2006, p.398) or just feels wrong (Ogawa, 1995, p. 586). Western science defines the world in a reductionist state where each piece of information must be testable to be confirmed as credible. Scientific reductionism is "the idea of reducing complex interactions and entities to the sum of their constituent parts, in order to make them easier to study" (Shuttleworth, 2008, p. 634). In contrast, Aboriginal ways of knowing or Indigenous knowledge consider the world as a series of intertwining relationships—a whole that is more than the sum of its parts. The former is historically considered "logical" while the latter is regarded by scholars as more spiritual and less factual. The absence of personal experiences of Aboriginal scientists from previous research allows the stories of these current scientists and their own explanations to yield new and useful insights directly related to the struggle taking place to decolonize science and communicate without bias (Aikenhead, 2006; Snively & Corsiglia, 2008; CBC, 2009). Since the early 1980's, researchers have been sharing and documenting possible bridges that teachers can build between Aboriginal learners with Western sciences while still respecting their traditional ways of knowing (Kawagley & Barnhardt, 1999; Aikenhead 2001; Haggan, Brignall, Peacock, & Daniel, 2002; Mitchell et al, 2008). Rather than examine the classroom and ways science is communicated, my research focused on the narratives of successful students themselves. Their stories and my findings reveal a set of strategies that give them the ability to move between knowledge worlds without compromising their cultural heritage or scientific goals.

Colonization

Comparisons between Western science and traditional knowledge systems identify various characteristics and opposing views. Western science favours analytical and reductionist (reductionist, n.d.; Shuttleworth, 2008) methods to examine the world, literally deconstructing a whole until the individual pieces can be examined and explained, whereas traditional knowledge is more intuitive and all-encompassing. While Western science is positivistic and materialistic in its approach, traditional knowledge is very spiritually founded and may therefore contribute to science classroom confusion for Aboriginal students (Nakashima & Roué, 2002). Studies have found that an important part of Indigenous science is the philosophy of inclusiveness, which views all of nature to be intelligent and alive, making the environment itself an active research partner (Reidlinger & Berkes, 2001). In his definitions of science, Ogawa (1995) uses the word “perceiving” thereby giving science a “dynamic nature” and acknowledging that “science can experience a gradual change at any time” (p. 588). By regarding a holistic and evolving knowledge approach to science as lacking validity, teachers create a potentially hostile learning environment for Aboriginal students. They thereby discredit a way of seeing the world that they do not fully understand.

Compared to Western time/space notions, Indigenous science collapses time and space resulting in fields of inquiry and participation that overlap past and present (ICSU, 2002, section 2). Fluid knowledge interpretation does not reflect modern Western science practice and creates more tension (CBC, TV, 2008). Indigenous science draws on all the senses (see Appendix C, Curricula 6), including spiritual and psychic, and is very concerned with relationships, attempting to understand and complete relationships with all living things (Mazzocchi, 2006).

Unfortunately, teachers that are heavily influenced by Eurocentric and Western perspectives instinctively consider modern science methodology superior, or "The only rational and objective way of uncovering truth and (the teachers) regard Indigenous knowledge and methods as primitive, archaic and irrelevant" (Binda & Calliou, 2001, p. 78). Past research identified the problem with the colonized view of science: Aboriginal students are taught science programs that do not respect or value the contribution of local knowledge (Hampton, 1995). My research discusses ways existing biases between Western and Indigenous sciences affect the development of Aboriginal scientists, but also includes successful coping strategies used by Aboriginal scientists who are comfortable in their careers and culture.

Communicating science

Canadian Glen Aikenhead is a key researcher on ways science is communicated in a classroom and how that process has alienated Aboriginal students. He explored gaps in teaching science that contribute to an underrepresentation of Aboriginal students in high school science and mathematics, and ultimately, underrepresentation in science careers (Aikenhead, & Huntley, 1999; Aikenhead, 2001, 2002, 2006). His seminal studies conducted in Saskatchewan, in particular *Teachers Views on Aboriginal Students Learning Western and Aboriginal Sciences* (1999) and *Towards Decolonizing the Pan-Canadian Science Framework* (2006), are important works of research. Scientific underrepresentation has been linked to economic, resource management and sovereignty problems for Aboriginal communities (CBC, 2009; Narine, 2011). The on-going dilemma in ensuring cultural influences are balanced in the classroom underlines the need for this research.

Different reasons have been examined (i.e., remote community location, family breakup, poverty and drug abuse) to explain why Aboriginal students do not succeed in high school STEM subjects (Science, Technology, Engineering and Mathematics). For the purposes of my research, I wanted to engage with people who had personally experienced the process to find the cause of the disconnect between the Aboriginal culture and Western science—that is, how did they cope as science students? The conflicting cultures in the classroom can result in "many (Aboriginals) feeling unwelcome in school science" (Aikenhead, 2006, p. 387). The traditional interconnected way of explaining the world is not included in formal school curricula offered to Aboriginal students. They do not feel their cultural knowledge has value (Aikenhead, 2001; Barker, 2004). That value disconnect may be the source of alienation in the science classroom for Aboriginal students, to the detriment of all students.

Science work

Why is having inclusive science education so important to Aboriginal communities and the people who live and work there? STEM[3] skills, and in particular science, are in high demand by employers in the emerging resource-based industry and environmental assessment and protection-based companies and can lead to many opportunities for the Aboriginal residents and their communities. "Employers are keen to plug into a young Aboriginal population but there are often education-based barriers to hiring and the lack of education is hurting community development" (Times-Colonist, 2011). According to Statistics Canada, 34% of Aboriginal people do not complete high school and only 8% have a university degree (Statistics Canada, 2006). A more alarming trend is the dropout rate for young Aboriginals. Between 2007

[3] Science, Technology, Engineering and Math

and 2010, the three-year average dropout rate among First Nations people living off-reserve, Métis and Inuit aged 20 to 24 was 22.6%, compared with 8.5% for non-Aboriginal people in the same age category (Statistics Canada, 2010). These numbers illustrate the need to find better ways to encourage Aboriginal students not only to continue school but become role models themselves and promote education. Role models are another example of the traditional role of Elders connecting the historical Aboriginal commitment to life-long learning with the present (Battiste, 2009; CBC, 2009). In British Columbia, Science Fair BC and BC Innovation Council members requested statistical overviews of all participants in their sponsored programs. Noticing the absence of Aboriginal youth (M. Griffith, personal communication, May 15, 2009), they began to work on new approaches. Local and traditional knowledge is an untapped resource and the decolonization of science education will go hand-in-hand to creating bridges for Aboriginal students (Aikenhead, 2003; Barker 2004; Battiste, Bell & Findlay 2002; Belczewski, 2009; Binda & Calliou, 2001).

Many other studies have found underrepresentation of Aboriginals in Western science sectors to be a root cause of fewer economic opportunities for their communities and youth (Haggan et al, 2002; Statistics Canada, 2006; Narine, 2011). My interest lay in finding ways to integrate the two ways of knowing via student experiences to achieve a long term result of increased Aboriginal representation in STEM careers. My research will add to the current body of work already promoting the value of respectful and practical integration of Western and Indigenous sciences for the benefit of all. Creating more robust Aboriginal representation in professional STEM careers could eventually preserve local knowledge for future generations. Aboriginal scientist Sonja Leonard discussed the value of integrating sciences in a podcast:

> Western science actually helps Indigenous people understand how their traditional knowledge of the environment is going to change with land use impact and potential impact from future climate change. And traditional knowledge helps inform western science about what some of these small- scale shifts are on the ground in remote areas where unfortunately western science did not have the capacity to be out there monitoring these impacts. (Kukolja, 2011)

Overall, past research by scholars around the world acknowledged the profound value of Indigenous science on current resource or development initiatives and studies where local voices need to be respected and included. However, many different ways of knowing exist and a post-colonial agenda requires bridges to be built between them (Kawagley, 1999). Local knowledge and an appreciation of interconnections can be a valuable asset for any community.

The story begins with family and mentors

Community, family, and group-belonging are recognized as an important social aspect of how people learn how to see the world (Fiske, 2004). For Aboriginal peoples, oral history or storytelling is the preferred delivery method used to share Indigenous knowledge (Aronowitz, 1988; MacLean & Wason-Ellam, 2006; Miller, 1996; Mitchell et al, 2008; Sutherland, 2002), while hegemonic, measureable education structures articulate how official government systems transfer information (Aikenhead 2006; Cajete, 1999; Hampton, 1995). A movement called “Two-Eyed Seeing”, started by a presentation in 2004 by Mi'kmaw Elder Albert Marshall, who believes Aboriginal youth need more support to understand ways of appreciating all perspectives of the world without surrendering one for the other more dominant view.

"*Etuaptmumk* or Two-Eyed Seeing refers to learning to see from one eye with the strengths of Indigenous knowledge and ways of knowing, and from the other eye with the strengths of Western knowledge and ways of knowing...and learning to use both these eyes together, for the benefit of all" (Bartlett, Marshall, M., Marshall, A., & Iwama, 2010). This strategy may help Aboriginal students cope with the confusing and conflicting versions of the world presented to them through family, school, and heritage (MacIvor, 1995). The historic ways of knowing can only make sense, if the two world views are felt to be in harmony, "When you force people to abandon their ways of knowing, their ways of seeing the world, you literally destroy their spirit and once that spirit is destroyed it is very, very difficult to embrace anything—academically or through sports or through arts or through anything—because that person is never complete. But to create a complete picture of a person, their spirit, their physical being, their emotions, and their intellectual being…all have to be intact and work in a very harmonious way" (Marshall, 2004). Part of the urgency in creating more harmonious ways of using knowledge comes from the lack of appropriate representation of Aboriginals in science, which starts in elementary classrooms and continues into high school.

According to the National Science Engineering Research Council (NSERC), under-representation of Aboriginals in professions that require formal Western science education follows a similar success statistics in Canadian classrooms (NSERC, 2008) where fewer than 6% of accredited scientists are of Aboriginal descent. Although other factors impact this outcome, for the purposes of this study, my focus was to determine whether underrepresentation of Aboriginals in science may be the result of how science is communicated wih subsequent student alienation from Western science understanding and curricula. According to education

researchers Day and Nolde (2008), the way students see the world, themselves, and how well they fit in appears to be very dependent on curricula that may not reflect their cultural upbringing (p vii). Families and teachers are critical influences on an Aboriginal student making the effort to tackle science.

Potential Aboriginal scientists need the support of family and community to flourish (McKinley, 2005: Mitchell et al, 2008). In parts of Canada, local knowledge-based Aboriginal school science fairs are taking place with the support of Elders and family members. This effort has resulted in a growing participation of students in Quebec and Manitoba, where Aboriginal Science Fairs have been operating for eleven years. Part of the future plans is to formally benchmark participation rates and track the winners, but a lack of funding has limited follow up studies to determine long term benefits for the Aboriginal science students who participated (M. LaLonde, personal communication, May 15, 2011).

Science in the classroom

For most Aboriginal students interested in science, the biggest challenge they face is being able to apply the disciplines of Western science without abandoning Indigenous knowledge in the classroom. Teaching science to Aboriginal students also presents challenges where the teacher contemplates their own objectivity and cultural sensitivity (Belczewski, 2009; Ignas, 2004). Both challenges, according to Aikenhead (1996), could be solved by creating an enhanced science framework that includes teachers acting as “culture brokers” (p. 398). He refers to educators as culture brokers who assist students to master repeated “border crossings” between their own everyday world and that of the science classroom (1996). Essentially, these guidances can help weave the different stories of science together in a way

that creates harmony. According to Ogawa (1995), every culture has its own science, so the act of learning science is actually culture acquisition, where students cross a "cultural border" from their everyday world into the subculture of science (p. 587). Aikenhead (1996) helped develop cross-cultural science and technology units with Aboriginal teachers in Northern Saskatchewan that used this approach. His contribution to the understanding of Aboriginal learning and impacts of colonizing knowledge culture is critical, often cited in international studies tackling similar issues (MacIvor, 1995; McKinley, 2005; Ogawa, 1995; Snively & Corsiglia, 1998).

By embracing modern science in school, young Aboriginals can become powerful community champions that help create better partnerships with the companies who want to do business in their communities (MacIvor, 1995). In a recent Globe and Mail article, SaskPower CEO Robert Watson described the importance of engaging local Aboriginal communities for the future, because he expected to see a talent crunch as retirements take place. He said "an essential part of our community is to get Aboriginals into more technical roles" (Fleece, 2011, p. B8). Thus, part of the discussion entails identifying long term benefits derived from robust representation of Aboriginal scientists - individual members and their communities.

As explained earlier, Indigenous science is a way of looking at the world as a whole, a way of knowing that embraces all aspects. Western science is not universal and yet usually taught as if it is neutral but the preferred way of knowing the world—part of the hegemony of a Eurocentric culture which diminishes Indigenous knowledge systems. What Aikenhead and many others unearthed was the absence of Aboriginal ways of knowing from science education curricula (Aikenhead & Huntley, 1999), resulting in a "non-relevant science perspective for Aboriginal students" (Kulig et al, 2010, para. 20). There may be new opportunities to decolonize

science in the classroom and see Western science in a type of relativistic perspective, “science is relative to the community of scientists who produced its knowledge” (Ogawa, 1995, p. 585). Documenting personal experiences of Aboriginal scientists may also provide clues to educators and those who develop curricula on approaches they can use to become better at presenting sciences inclusively, for all students.

Methodology

Research design

To produce primary data, I used narrative inquiry; interviewing seven subjects by asking open-ended questions regarding their family, community impact, historical understanding, science education, cultural and career challenges, and successes. The 60- to 90-minute interviews took place over the phone or via Skype®. A follow-up session was scheduled to ensure the data was correct. I coded data for analysis and a third party coded one interview excerpt to confirm my coding alignment. The findings and recommendations should assist future researchers on ways to make science more accessible for Aboriginal learners and provide non-Aboriginal students with the opportunity to share the special value of Indigenous knowledge.

In my research, I used the methods of inquiry and analysis developed by Catherine Reissman (2008). Her pragmatic approach most closely reflects my own understanding and interpretation of research and interview techniques. This qualitative, narrative inquiry method featured a small sample size intended to establish an acceptable level of trust with the subjects. I selected an approach that was supported by other researchers who studied similar situations within Aboriginal culture (Aikenhead, 2001; Ignas, 2004; Barker, 2004). Narrative inquiry is still

evolving, consequently, my approach was flexible, adapting to individual subjects as they shared their stories. I limited my own expectations to encourage results that may or may not align with my research (Reissman, 2008). Specifically, I did this by keeping my questions open and remaining flexible in my interpretation of data as I conducted interviews. Narrative analysis uses oral, first-person accounts of experience derived from interviews. The method is most appropriate for interpretive research, such as symbolic interaction analysis and studies that focus subjectively on identity, social-life, and cultures such as Indigenous. Narrative analysis examines the flow of participants' experiences in the stories they tell, with the objective of understanding how they obtain meaning from the events of their lives. Storytelling has its roots in the attempt to explain life or the mysteries of the world and the universe—to try to make sense out of things. A story could always be told to help a parent teach or explain some aspect of life or what the consequences of a child's behaviour would be. For Indigenous cultures, storytelling time was a time for the family to be together, a time for Elders to explain history to the children, and for learning, listening, interacting, and sharing. As Reissman explains (2008), narrative analysis is a continuum of different approaches to narrative texts rather than a standard method. I found this method to be the most current, culturally appropriate approach, to understanding how people think through events, identify with their values, and finally, how they see themselves. I believe that this method can be used to discover ways to encourage science education successfully with Aboriginal students.

In order to compare and balance the personal stories of the Aboriginal scientists with the historic, colonized perception of the two science worlds, I used a readily available sample within the social media in order to also engage scientists with little or no knowledge of

Indigenous science. Using research from existing literature on challenges to status quo versions of the level of "correctness" in sciences, I posted the following question to the Canadian Advanced Technology Alliance discussion board on LinkedIn® and directly through my Twitter® account, PR4Science: How is Indigenous (or Aboriginal) science different from Western science? I am researching this topic for my thesis and would appreciate comments or shared stories.

Participants and Timing

The participant selection process had to be based on convenience for two reasons: a very small number of Aboriginal scientists willing to participate and the time pressure of a short deadline. Seven subjects told their stories and shared experiences, six Aboriginal scientists following their scientific passion while still continuing to honour their Aboriginal heritage and one non-Aboriginal science educator. There were six males and one female; this is also representative of the current gender placement in science careers (CCL, 2009). The average age was 40 years, and tribal and geographical coverage encompassed the provinces of British Columbia, Quebec, Saskatchewan in Canada and Washington State in the United States. Tribal affiliations included:

- Algonquin-Anishnabeg Nation, Quebec,
- Cayuse Nation (Confederated Tribes of the Umatilla Indian Reservation), Washington State,
- Mohawks of Kahnehsatake (Oka), Quebec,
- Secwepemc Nation (Shushwap), British Columbia,
- Tahltan Nation, British Columbia,

- WSÁNEĆ (Saanich), British Columbia, and
- Wood Mountain First Nation, Saskatchewan.

Since my research depended on the cooperation of Aboriginal interviewees, I needed to obtain approval from the Royal Roads University Ethical Review Board and thus provided each participant with a release form and details on how I would use the information (see Appendix A). The search and invitation process for the interview subjects began in the fall of 2008. I conducted the interviews and follow-ups from December 2010 until the spring of 2011, with the final contact taking place on June 14, 2011.

Data

In addition to the primary data generated by the personal stories of interview subjects, the additional survey data from the broader science community regarding science validity helped to clarify how different perceptions of science could create possible conflicts. My interviews provided an examination of the events and stories, what people talk about and whose perspectives they draw on to make sense of the world. These open-question interviews invited subjects to tell their stories and share various aspects of their experience with science. It provided them the freedom to expand on their answers and suggest solutions or new approaches.

Narratives allow storytellers to adapt chaotic experiences in the world into causal stories that make sense, and to render them safe. To support subject interview data, I reviewed relevant literature, including the following subtopics:

- Features of Indigenous science,
- Colonization: Western science over Indigenous science,

- Aboriginal ways of knowing in school curricula,
- Science work—student preparation for a career, and
- Teachers as culture brokers.

These conversational sessions helped identify impacts of schooling, teaching and learning, life experience, career aspirations, mentor and family relationships, and cultural identity on academic success in Western sciences. It also clarified how the subjects viewed their aspirations for a future in science and how useful academic success was in achieving their vision of the future. I chose narrative inquiry based on my understanding of the importance of storytelling traditions in Aboriginal cultures, where the oral tradition is the basis for possessing and sharing Indigenous knowledge (Aronowitz, 1988; Mitchell et al, 2008). Miller explained that for Aboriginal Peoples "science education such as Creation, flora and fauna of different species was always learned through storytelling" (1996, p. 67). I felt that the strength of the research rested on the personal insights shared by people who have found or built bridges to make sense of the world and move forward in science.

Questions and rationale. The focus was on identifying and assessing the ways study participants worked within the parameters of a Western or colonizing science education system while managing their relationships with their Indigenous cultures (Aikenhead, 2006; Kulig et al, 2010). Interview questions included:

- Tell me about your favourite teachers and why?,
- Were you ever encouraged by teachers to incorporate local knowledge into your formal science classes and how?,
- Tell me about a time when you felt excited about science,

- Was there an event or a person who inspired you to pursue studies in science?,
- How did you see the principles and practice of Western science fit with Indigenous science?, and
- Do you volunteer to support Aboriginal students now and why?

These questions reflected earlier survey work carried out in the late 1990s in Saskatchewan (Aikenhead & Huntley, 1999).

Using in-depth narrative interviews and accessing existing literature such as Belczewski's (2009) and Aikenhead's (2003) research, which introduce the search for a balance in ways of knowing and Western sciences, I identified truths and trends about the adaptation strategies used by the subjects. Adaptation refers to the process through which people from a given culture "understand their surroundings and [within these learn to] function competently" (Fiske, 2004, p. 25). The strategies used are identified in the findings below.

As noted, I invited other (non-Aboriginal) scientists to tell me what they perceived to be the differences between Western science and Aboriginal ways of knowing. I distributed the question directly on my own science based network via email, as well as posting it on an online science discussion group, to which I belong (Linked-In: Canadian Alliance of Technology). Using professional contacts and social media, I received 18 online postings and responses from non-Aboriginal scientists and technologists. This secondary data was intended to provide a contrast to the personal account of my primary interview subjects. The types of responses on Indigenous knowledge ranged from negative to enthusiastically supportive—rejecting or embracing the idea of neutral knowledge value. The question used was based on literature review information that outlined the struggle for Aboriginal ways of knowing to be accepted in the international

science community: What do you see as differences between Western science and Indigenous or Aboriginal science? (see Table 2). The majority of responses did not completely dismiss local knowledge value but most saw “their” science (Western) as having the most credibility.

Method of analysis

I explored the interview subjects’ stories about science and the connections they created (or avoided) between their Indigenous learning and Western science education, focusing on identifiable themes and patterns of living and/or behaviour as illustrated by the four themes related to coping strategies used by the participating scientists (Table 1). There were two suitable theories to anchor my research: decolonization (Battiste, Bell & Findlay, 2002) and post colonialism (Littlejohn & Foss, 2008, p. 343-345) that examine how Eurocentrism and the processes of colonization contributed to the domination of Eurocentric ideology in science. Decolonization is an intellectual process that persistently transfers the independence of former-colonial countries into people’s minds (Shuttleworth, 2008). The basic idea of this process is the deconstruction of old-fashioned perceptions and attitudes of power and oppression adopted during the time of colonialism. Since formal education was the source of colonizing society norms being imposed, awareness of how teachers formally communicate science is critical to understanding opportunities to decolonize. Interviews were recorded and transcribed, and from the transcribed conversations, patterns of experiences were listed as original direct quotes or paraphrasing common ideas. Some of the theme categories reflected the underpinning of the decolonization theory, as well. The transcripts were manually coded by key concepts relating to the research questions and sorted into relevant coded categories. Open coding is a method of sorting data into categories to identify codes to use. Codes can fit

under more than one category and those categories evolved as the coding process was repeated two times to ensure rigour. Key concepts that relate to the research question (e.g., first science connection, Elder contact, formal education, approaches to ways of knowing) were important in defining categories. To further test the rigour of this analysis strategy, an independent colleague coded a passage from a transcript that was then compared to the same passage coded by myself (see Appendix B). The final step to a thematic analysis was identifying all data related to the already categorized patterns. Themes are defined as units derived from patterns, such as "conversation topics, vocabulary, recurring activities, meanings, feelings, or folk sayings and proverbs" (Taylor & Bogdan, 1989, p.131). The emerging themes are presented in Table 1 - Results/Findings are: School; Family/Community; Culture and Political.

Results/Findings

When Aboriginal scientists reflect on influences and obstacles to their careers in science that allows them to give something back to their communities, their stories can be categorized into four main themes and twelve subordinate themes. Areas of shared importance noted by interviewees during their efforts to pursue careers in science are outlined in Table 1.

Table 1

Emergent Themes: Aboriginal Scientists Tell Stories

EMERGENT THEMES	*School*	*Family/Community*	*Culture*	*Political*
Subordinate theme	Western science bias	Elder role	Loss of culture	Ways to fight back
Subordinate theme	Rebellion against dominant culture	Mentorship needed to help kids (role models)	Indigenous knowledge	Colonization
Subordinate theme	Culture brokers	Enable curiosity	Storytelling & connection to Earth	Threatened sustainability

Four main themes—school, family/community, culture and political

As noted earlier, past research had not fully addressed the experiences of Aboriginal scientists and their approaches to balance their cultural foundation with the parameters of Western science. To begin analyzing the results, I started with a larger more general observation. I asked scientists, both Aboriginal and non-Aboriginal, what they felt or saw as the differences between Indigenous or Aboriginal science and Western science (Table 2). The comments reflected a biased version of which science was “correct”, which I interpreted as a result of colonization. This can be considered as evidence of the pervasive nature of the bias in science education since most felt that current school science curricula reflect the best (preferred) knowledge system. From the response to the social media-based question, the perception appears to be that Aboriginal science is interconnected and has a more spiritual relationship with the earth and people. Western scientists unfamiliar with Indigenous sciences admitted their lack of detailed knowledge or understanding, but tended to categorize

Indigenous ways of knowing as primitive and less credible. On the other hand, Aboriginal scientists refer to a legend or story and see value:

> I think a lot of our history and legends, while they may be lessons; they are also probably explanations or hypotheses on why. I don't think it reduces anything, but rather is kind of neat really. It can serve as a reason, for one thing, why does a lamprey have no bones and why does the sucker fish have all of the bones? One story we have was that lamprey and the sucker were playing bones and it was a betting game that we have and still do today and they were gambling, the lamprey was losing and in the end he bet everything that he would win, and the sucker beat the game and that is why he has all the bones, and the lamprey has no bones. That is one of our stories about explaining morphological or physiological differences. You have that story about the lamprey and the sucker, but it also teaches you that the sucker has many bones and a different structure and so they have to be prepared differently. There are all kinds of lessons in there, but often when you boil it down, I view it as a hypothesis on why we see that difference. It doesn't reduce, or explain worse than regular science; it is just one way of explaining things. But there are other things that we also have as long term observations and patterns that are told by stories. (Participant 2)

Although most saw the way they could incorporate or weave the two sciences together, two scientists felt strongly about avoiding any connection between the two worlds and found it better to maintain separate, distinct relationships between both sciences and thereby honour family and culture. In Table 2, candid responses revealed a Western science bias but also a

willingness to learn. The responses were from a convenient sample gathered via social media invitations.

Table 2

Social Media Survey—Perceptions of Aboriginal and Western sciences

ABORIGINAL	WESTERN	SUPPORTING COMMENTS
Storytelling/oral history informs local knowledge and science	Written accounts, scientific methods are more logical	Aboriginals share knowledge by telling stories, explain the unexplainable.
Viewed as primitive but historical	Considered valid and credible	The Laws of Science represent an accepted international base, a common database to conduct research.
View place in world as one relationship which may not always make sense	View place in world as compartmentalized and subject to experiment.	Not all knowledge can be easily explained.
Mythical shares stage with reality	Logical, non-spiritual focus	An Aboriginal child asked me if the Earth was alive and I caught myself before I dismissed her question. I wanted to respect their culture.

Culture

All the scientists I interviewed identified strong curiosity in a person as a dominant personality trait for a future science career. Some cited a never-ending need to know how the world worked and why, while others noted they had an insatiable appetite for knowledge and badgered family and teachers, for example “I followed my father around asking questions about why he did something a certain way and his explanation usually involved a local story with mythical characters I knew from childhood” (Participant 5). The spark of creativity is also often associated with curiosity. The science teacher described how special it had been to take his students on trips into traditional lands accompanied by an Elder:

> We would travel to Seamus Island, a little island out here in the Saanich Inlet, we would travel by canoe, we would go out there and John or an Elder would tell the story about the place, and they would share their knowledge and then we would go on a walk about and this is where I would come in and talk about the native plants and this is what an ecosystem is and this is how it works for example. It was very exciting to witness the connections made. (Participant 6)

Each scientist recounted stories heard during their youth to explain the unexplainable: earthquake, flood, eclipse, lightning, storms, and animal migration. One story conveyed the reason his tribe originally adopted a plant for medicinal purposes, long term observations of a bear using it to cleanse internal organs before hibernation (Participant 2). Another story relayed historical migration routes of animals the tribes depended upon for survival (Participant 4). These stories present a hypothesis, a presumption why something happens, similar to the Western science approach in making educated guesses and then proceeding to prove or disprove them by testing. The difference lies in the Western science perception of oral history as being unreliable. Some stories told of mythical battles or mighty warriors, but among them were also detailed accounts of historical events and culturally significant meanings. One scientist described an epiphany he had when he finished his Masters at Oregon State University:

> So, that is where I really began (science), but it was always set up with the cultural background, too. So, if you look at it from a cultural, traditional cultural perspective, a lot of the things we observe in the world—you form those same kinds of questions, but sometimes they aren't formally tested. In that way, I

> probably was learning about science much earlier than my Master's degree, but it is not considered what we typically think as scientific method. Nowadays, I recognize it as an important foundation and understanding on how we gain knowledge. I would have to say that my earlier training (as an Aboriginal fisheries technician) was an important part of developing and becoming a scientist. (Participant 2)

In Aboriginal communities, Elders are respected for their wisdom and unique knowledge that they pass along to a young person when the time is right and the student is ready, the core of the Aboriginal approach to sharing knowledge. In Western science, the preferred means of knowledge transfer are more formal, with textbooks and teachers. These two different pedagogical approaches should have equal weight for Aboriginal students, but they often don't, which is when the gap or disconnect occurs. Teachers represent the role of the Elder in a formal education system, so it is important for them to understand how they can create a learning environment for future science involvement by Aboriginal youth.

Many participants shared common experiences in their lives that made a difference in being able to balance their interest in science with Aboriginal culture (Table 1). The experiences included actively working with mentors or concentrating on fields (such as environmental or food source based sciences) that would benefit their communities. They uniformly attributed their success in school with strong family support—even where their family didn't understand Western science or lacked experience in higher education, they were there for them. "My mother would drive hours from our reserve to deliver home cooked food for me while I was in university…it really helped" (Participant 1). The encouragement to be creative and curious is a

key element of Indigenous science and a driver for the desire to find balance, “the point of an Indigenous scientific process should be a known and recognized *place*—a balanced position. This place of balance is both peaceful and electrifyingly alive. In the joy of exact balance, creativity occurs, which is why Aboriginal ways of knowing are thought to be a life science” (Corrigan, 2006, p. 754). In fact, for many of the interviewees, their curiosity in the world was encouraged by a parent or other family member. Grandparents, parents, aunts, and uncles always had an oral story to put the world in context, to teach or share expectations about what lay ahead. Their stories framed cultural messages about qualities valued by their society—being loyal, responsible, or respectful—as well as passing along practical knowledge. To an Aboriginal Elder, the keeper of knowledge, they see themselves as partners with every living thing. Thus, it makes sense that chaotic systems, such as turbulence, weather patterns, and even people are difficult to explain by the process of scientific reductionism (Shuttleworth, 2008, p. 634), but reveal why other cultures use their own scientific approaches to make sense of the world and to share those with their children. When a young Aboriginal pharmacist (Participant 7) was interviewed in a Saskatchewan newspaper to talk about his new business, he acknowledged that he wouldn't be where he was without the support of his family encouraging him at a young age to set goals and refuse to let obstacles prevent him from attaining them. He was especially thankful to his mother who raised him in a single-parent home; "It was always instilled in me to shoot for your goals and never give up on what you want...and to never let anything get in my way” (Matte, 2010). Interviewees also agreed on the pivotal role of science teachers who acknowledged Indigenous knowledge as credible and interesting. Although two scientists kept

their culture and career very separate (Participants 1 & 4), the remainder worked hard to weave the sciences together when they could.

The Regina-based Aboriginal pharmacist felt insufficient numbers of Aboriginal youth attend university and hoped his role in the community would persuade them to look at the benefits of education (Matte, 2010). His plans include visiting schools and community centres to serve as a role model for First Nations youth. The non-Aboriginal science educator (Participant 6) pointed out that, although he felt it was not his place to direct value- and cultural-based education or to encourage political responses, in the absence of existing programs, he had launched several initiatives meant to reintroduce his students to studying the science of *place*. The next generation of Aboriginal science leaders realize their growing role in protecting the environment, because their way of life depends so much on a healthy ecosystem. Many hope to increase the number of Aboriginal students who decide to continue in science and, ultimately, create strong advocates for their culture. This was detected in the interviews as a way to enrich the capacity of their communities and ensure more Aboriginal students become active and involved scientists. The predominant strategy used by all interview subjects was building strong connections in their own personal relationships with family, teachers, tribal Elders, and community leaders. The analysis used narrative inquiry to identify important themes common to all seven subjects. Their personal success strategies can help the next generation of Aboriginal students learn how to successfully cross cultural borders while maintaining their connection to the natural world.

Discussion

Building Aboriginal science capacity

An online CBC Television news article explained how Canada's Aboriginal people have an array of experiences and opportunities that form part of their life-long learning philosophy—learning that goes beyond the classroom, a way of seeing the world that does not fit the colonized science perspective (CBC, 2009). The problem has been that educators continue to define science via Western "gate keeping" of knowledge, (i.e., only the colonizers' science is deemed universal) marginalizing local peoples and their own knowledge systems (Snively & Corsiglia, 2008, p. 2, Figure 1). However, the Francophone engineer with Oka ancestry saw this as a way Aboriginal students could carve out a special place for themselves; "We need to embrace [science] and do it really well. We have to do it better than other people, because we have a different perspective on a lot of things and can add to it [knowledge]" (Participant 2). The value (political and cultural) of becoming a respected scientist was demonstrated by the interview coding process. For an Aboriginal student, shutting out the traditional viewpoint removes a fundamental cultural component that usually helps them to see the world. Print records are not the only way to store and transmit information, as evidenced by the thousands of years of information collection and analysis used by storytelling cultures. Therefore, we ask ourselves how students can facilitate understanding, for themselves and educators, that science is more than just the sum of parts. Bridging the two sub-cultures by decolonizing science education can be an important factor for an Aboriginal student's academic success (Aikenhead, 2006). A driver for this research was the increasing need for more Aboriginal

scientists and in turn promoting research of other social scientists. According to the BC-based Aboriginal zoologist, it is vital for Aboriginal communities to increase their scientific capabilities:

> We have a responsibility, because of our culture and our understanding of our ancestors and the views and the relationships between us and the animal people. We made a promise, because they promised to take care of us, long, long time ago, we have made this vow to take care of them also. But unfortunately we are starting to fail, we are slipping. (Participant 2)

Personal connections to the world are what set Indigenous science apart from its Western science counterpart; it is connected to people through more than just objective observations. Most of us view our world through a lens formed by strict educational parameters that may exclude more historic place-focused or Aboriginal knowledge of the world (Aikenhead, 2006; Times-Colonist, 2011).

There has been progress within the science education community in creating new bridges between these worlds—of particular note is an exciting program established by the Science Alberta Foundation (see Appendix C). Members introduce Aboriginal ways of knowing into the classroom through an innovative "crate learning" approach, " the activities within this crate honour and acknowledge the traditional ways of First Nations people, while introducing students to the norms, beliefs, values, and conventions of Western science" (Science Alberta Foundation, 2011).

Aboriginal scientists must consider traditional values and ways to apply the tools (science), whether it is Indigenous knowledge or what is deemed to be science to protect community resources. Today's headlines often feature government, business, science, and non-

governmental organizations and corporations focused on harvesting resources located in remote or sensitive natural habitats where local culture and lifestyle may be vulnerable to unrestrained development (CBC, 2010; Fleece, 2011; Narine, 2011). To counter the pressures of development, five of the seven participants felt that a stronger political presence was needed, especially in Canada, where the residential school system created a void:

> We don't have programs here to foster our youth and develop with our First Nations younger people in programs like we have in the States. This plus the whole education system has failed Aboriginal students in Canada it is really pathetic and that is a systemic problem right, I mean, it feeds on itself and that is the problem I am having right now—trying to find students to encourage so that First Nations communities have at least a foundation to start but it is all over the place. It is really quite sad, but it happens from the whole cultural genocide thing that has gone in both the United States and Canada. (Participant 2)

A theme noted first by Participant 2, and then echoed by four more, is the political role being requested by Aboriginal scientists. Although not a primary focus of why they became scientists, many recognize how their credentials have had the power to influence decision makers and subsequently better the position of the communities where they grew up. There is an increased expectation of methods they can use to help. As Participant 2 noted in his answer to the reason Aboriginal communities need to build their own internal resources, "We can train biologist warriors to protect our world". The potential of moving towards a more aggressive Aboriginal position may have long-term effects on the relationship between the science community and organizations that want to do business with Aboriginal communities. Having

militant Aboriginal scientists pushing back on conventional scientific *wisdom* will create a different paradigm for those who aim to access resources within Aboriginal areas of control.

The Tahltan metallurgical engineer explained how she connected her science career and Aboriginal upbringing, "My goal as an engineer is to always protect our Mother Earth." She now owns her own environmental consulting firm, volunteers locally in her community, ran a summer science camp until recently, and actively encourages young Aboriginal students to go to university and pursue a degree in engineering or the sciences. She hopes they will consider her a role model and join her efforts to help protect our environment and work to create self-sufficient communities. All interview subjects voiced a commitment to sustainable futures for Aboriginal communities, even if that meant disputing the way science was interpreted. In particular, one subject repeated earlier comments about the need to become more political to promote sustainable communities, “That is the big thing that I think we need more of…to build that capacity and produce future *biologist warriors* to fight for the resources. That is what I view myself as doing, trying to train the minds so we can fight” (Participant 2).

Members of Aboriginal communities can make valuable contributions to the decision-making processes that have a direct impact on them. Although Canadian Federal and Provincial organizational policy mandates often require a consultation process with local Aboriginal communities, as a critical element of success in both planning and implementation. Nevertheless, this process doesn’t always take place without problems. Although local community members may not possess formal education credibility within an environmental study, they do have access to invaluable long-term generational local knowledge. If Western and Indigenous sciences were given equal consideration and respect, this could generate a

more meaningful, long-term relationship between local populations and resource development organizations.

Aboriginal ways of knowing embrace a variety of world views that may be at the source of conflict in the colonized science classroom, whereas teaching science in a way that promotes acceptance may solve that conflict (M. Griffith, personal communication, September 19, 2008). Snively and Corsiglia (1998), believed that "where Western modern science is taught, it is taught at the expense of Indigenous science" (p.3) and Ogawa (1995) saw Western science curricula "precipitating charges of epistemological hegemony and cultural imperialism" (p. 590). According to Ogawa, there is a causal relationship between the sciences. The incorporation of local knowledge into learning curricula, formerly biased against Indigenous science, is one step towards shaping a new vision. I hope the success strategies explored in my research encourages other interested academics to look more closely at the Aboriginal and non-Aboriginal student experience.

Leadership is needed

Aboriginal scientists employed in the corporate world can offer their unique understanding of methods local knowledge can use to support business and in turn the corporate world can protect and promote Indigenous cultures. Results from the coded interviews showed this to be a viable strategy. By enlisting the corporate world to support and value Indigenous knowledge, Aboriginal employees may eventually influence policy and direction and ultimately change the way the scientific community values Indigenous knowledge. Unfortunately, appeals to have more Aboriginal scientists appointed to boards and

commissions with a direct effect on Aboriginal communities have not always been successful. In March of 2011, the *Slave River Journal* reported:

> Chiefs Roxanne Marcel of Mikisew Cree First Nation and Allan Adam of Athabasca Chipewyan First Nation are calling for Aboriginal representation on the new oil sands monitoring panel. The chiefs sent a list of Aboriginal scientists to Environment Minister Rob Renner to fill the spot vacated by California ecologist Dr. Helen Ingram. Ingram resigned her position because of lack of Aboriginal representation on the panel. Adam said that having a First Nation person with on-the-land experience and traditional knowledge of Northeastern Alberta would go a long way toward reassuring downstream communities that the government is effectively monitoring the region's water and land. However, Renner has named University of Saskatchewan water scientist Howard Wheater to the panel. (Narine, 2011)

By rejecting the need for an Aboriginal scientist to serve on the Alberta oil sands monitoring group, the government demonstrated a lack of commitment and continues to reinforce a colonized viewpoint of Aboriginal science value. This kind of decision not only affects the degree of distrust for Western science that is held by Aboriginal people but also their feeling of having a diminished role in their own community. “We are responsible for guiding attitudes about science and Aboriginal kids—we have to show everyone how science is a good fit for our culture” (Participant 1). Discussing the challenges and bringing the issues to the attention of stakeholders, by putting pressure on governments and corporations to involve Aboriginal scientists, especially when sensitive relationships are involved, can prove to be effective.

Conversely, when corporations and governments make that commitment, there must also be accredited Aboriginal scientists available and ready to take these positions of authority.

When two worlds collide—the science community

Aboriginal storytelling traditions regard all experiences as worthy of sharing, for example, earthquakes are part of the oral history of the Aboriginal people of the west coast. Accounts of "ground shaking" have been found in many different tribal histories. The story of the last mega thrust earthquake (January 26, 1700) carved on an interior screen, taken from a Nuu-chah-nulth house, is now on display in the Canadian Museum of Civilization in Gatineau, Quebec. It is interpreted here in earthquake stories:

> The screen portrays two prominent Thunderbirds. Down each side of the screen are the tails of Killer Whales breaching the surface of the ocean. The creatures with large heads, protruding tongues and curled tails are likely supernatural Sea Serpents, Thunderbird's spirit helpers. The circle in the middle, with an oval centre, may signify a phase of the moon as well as a portal. The circles containing a cross probably symbolize the earth and the four sacred cardinal points of the compass. The US Naval Observatory Applications Department indicates that on the evening of January 26, 1700, sunset along the Washington coast was at 5:10 PM Pacific Standard Time and the Moon rose at 5:21 PM. The Moon was a waxing crescent with 36% of the Moon's disk illuminated. The Moon would have had pronounced "horns" pointing upward and to the left—just what is depicted in the Nuu-chah-nulth interior screen. Much of the information contained in

> Aboriginal art and stories is a faithful record of their observations and experiences. (as cited in J. Wynne, personal communication, April 22, 2011)

The records passed down through generations of Aboriginal peoples are local and specific, and provide useful and tested observations whose real value is just now being realized by Western scientists. As an interviewee explained: “A lot of our medicines actually come from our brother and sister animals, and plants. And so, that didn’t just happen, we didn’t just find out about those things, that took trial and error and testing and figuring out what worked” (Participant 2).

How is Indigenous (or Aboriginal) science different from Western science? Several non-Aboriginal scientists responded to the question I posed through social media with biased answers. Misinformation associated with science education has created a negative perception of Indigenous science that in turn affects how Aboriginal students see themselves. The following excerpt is an example of the type of resistant thinking to other or different ways of knowing from being accepted and embraced:

> It seems to me that aboriginal science would have been extremely limited without a written language and basic mathematics. One of the main reasons that European science advanced so quickly (Europe was a backwater 1000 years ago) was that literacy exploded and the ancient Greek and Roman knowledge was rediscovered—at least some of it. In particular, the rediscovery of the scientific method of the Greeks, testing observations against hypotheses was essential. Also, the development of mathematics in the west, particularly the independent development of calculus by Newton and Liebnitz, led to enormous

> breakthroughs. Also, aboriginal science would have been extremely limited in hunter gatherer societies (Anonymous, personal communication, May 3, 2011).

This account of a perceived superiority of Western science over Aboriginal ways of knowing demonstrates a systemic problem in communicating science within the sub-culture of modern science and the general public, especially at the expense of Indigenous knowledge. Many scholars, such as Carolyn Merchant, Theodor Adorno and E. F. Schumacher (Aronowitz, 1988, p. ii) considered the 17th century scientific revolution had shifted science from a focus on understanding nature, or wisdom, to a focus on manipulating nature (i.e., power), and consequently, science's emphasis on manipulating nature inevitably lead to the manipulation of people, as well. Science's current focus on quantitative measures has also led to criticism of its inability to recognize important qualitative aspects of the world (Aronowitz, 1988). The science community appears stagnant and cumbersome, unable or unwilling to recognize the opportunity of acknowledging a "multi-science" (Ogawa, 1995, p. 590) view of the world. Without becoming more flexible and recognizing the value of accepting non-Western views, a reduced capacity to rejuvenate the field is apparent. Aboriginal students interested in pursuing the sciences need a welcoming environment not only in the classroom but in society, because they may speak for the Earth someday. Henry Lickers, a biologist and member of the Turtle Clan of the Seneca Nation, stated:

> The First Nations people view themselves not as custodians, stewards or having dominion over the Earth, but as an integrated part in the family of the Earth. The Earth is my mother and the animals, plants and minerals are my brothers and sisters. (Cajete, 1999, p. ii)

Senator Lillian Eva Dyck, a Cree from Saskatchewan, is a neuro-psychiatrist, a recent appointee to the Canadian Senate and a believer in using Indigenous practices in her scientific work. She stated in an interview:

> The ways in which the sciences are taught in the Western tradition generally assume that science is neutral and that any knowledge generated by scientific enquiry is unaffected by the beliefs of the particular culture or the individual scientist, herself. Even today we tend to think of a scientist as being the epitome of an unbiased, logical expert—like a Star Trek character! Does this kind of image affect the kinds of people who are attracted into a science career? Does this kind of image affect how we teach science and how we retain science students? According to the beliefs of the Plains Indians, the Medicine Wheel teaches us that all things have four aspects; 'the spiritual, the emotional, the physical and the mental'. In order to attract and retain Aboriginals and women, to remedy their current under-representation in science careers, it is essential to focus not only on the mental and physical aspects of science as is done currently, we must also focus on the spiritual and emotional aspects of science. We need to find out what inspires interest in science and what motivates a person to enter into science careers. (Kitchikeesic, 2005)

It is the entire science community that has to promote a respectful inclusion of Indigenous views of the world. Several subjects noted the critical role played by their colleagues in changing the way science is perceived (see Table 2). Such a continued effort can drive

numerous initiatives at the education level. Ultimately, the science community will thereby grow and strengthen thanks to the inclusion of local knowledge.

Teachers as culture brokers

According to the Fraser Institute, British Columbia is one of only three provinces and territories in Canada identifyng Aboriginal students in a way that allows their academic results to be segregated for analysis. The gap in passing standard tests between Aboriginal and all other students is growing with fewer Aboriginal students completing their secondary schooling (Cowley, Easton & Thomas, 2011). This is seen as especially true in STEM subjects where Indigenous science cultural underpinnings are neglected or dismissed.

According to the metallurgical engineer interviewed, it was a dedicated math teacher who inspired her to pursue a career in a field with a low representation of Aboriginals and women. “I really felt connected to math; I was made to feel welcome” (Participant 5). Although scientists may admit that there are many ways of understanding the natural world, they believe that *their* science (Western) is the best approach, because it is “objective” testable. A less obvious aspect of the colonization of Indigenous science is the Western tendency to romanticize (colonize) traditional knowledge, instead of making it open to critical evaluation. The educator who teaches Aboriginal students pointed out that the efforts in BC to try and infuse science curricula with local knowledge end with mixed results:

> So every one of those science courses will have aboriginal content in there but it’s like a stuff sack, here is your camping equipment and sleeping bag and it is difficult to stuff it all in. Adding the aboriginal content: a) it is just an add-on, and b) the vast majority of the teachers are not aboriginal and do not feel very

> comfortable providing this information. What I do is to try and appreciate their own culture. So for example what stems from my own research was a program called SENĆOŦEN which was the language of WSÁNEĆ, the people here on the Saanich Peninsula and the Gulf Islands. ÁLENENEC means homeland, so I started a program with that ÁLENENEC (homeland) and invited Elders to tell the stories related to local places. (Participant 6)

In his efforts to support a more inclusive science curriculum, this educator became a *culture broker*, a term coined by Aikenhead (2006) to describe intuitive teachers who actively assist students to participate in both Indigenous and Western sciences. Those teachers recognize individual needs and situations, and help students create the best space for them to weave together the stories of their respective sciences. They also recognize the traditional Aboriginal perspective, where learning is never finished; but is a part of everyday living and a lifelong process. Encouraging Aboriginal youth is not an easy task, but there are educators committed to deliver a different kind of learning process for important cultural reasons. Stephanie Kelley, Native American Youth Organization (NAYA) said:

> Part of the reason I teach science at NAYA is to ensure that young Native American students have all the same opportunities as other students around the country. On reservations, they have to manage their own natural resources. It would be great if more people from their own tribe could have the scientific knowledge to help them be self-sufficient in managing their own resources. (Kukolja, 2011)

As this American Aboriginal science teacher explained, the practical and long term benefits of science education ensure a more sustainable future. Becoming comfortable in larger, more holistic approaches to science could also result in successful students being able to better help their communities, a sentiment shared by all the subjects interviewed.

As identified in the interviews, today's science ideology usually positions non-Western sciences as the "other" (Littlejohn & Foss, 2008, p. 345), another effect of the historic colonization of Indigenous culture. As perceived "others", young Aboriginal students feel unwelcome and alienated in the classroom. They may not even be fully aware of the reason for feeling uncomfortable, but the end result is often a rebellion against modern science—they reject learning the dominant cultural norms. Colonization is not just about imposing a dominant culture, sometimes colonization is the removal or devaluation of competing cultures, "Stories can show us whose histories have been authorized and whose have been silenced; whose lives have been acclaimed and whose have been devalued" (Maclean & Wason-Ellam, 2006, p.38). There is a need for successful Aboriginal scientists to lead by example by building new stories to counter the cumulative effects of Western science domination. As role models, Aboriginal scientists can drive change and increase Aboriginal representation in science careers and counter of the role of "otherness". A practical example for all students is the way interview participants have successfully integrated Indigenous science understanding with a formal career in Western science. This creates a practical, real-life career guideline for Aboriginal students. According to interview subjects, encouragement in the classroom to view science holistically is slow to change, and is explained by the sole woman scientist in the group: "Science in my classroom experience never included any connection to Indigenous knowledge, I hope we can

change that." Teachers need to rethink their role as a broker between Indigenous and non-Indigenous cultures. There should be possibilities for students to have the best of both worlds—admission to the mainstream culture of school, but also recognition for their own cultural values, traditions, ways of learning, and interests. "The use of a story in the classroom allows students to reveal their knowledge and have others recognize them for being knowledgeable. It also provides an opportunity for their ways of knowing to be honoured and respected in the classroom" (Maclean & Wason-Ellam, 2006, p. 13). When Aboriginal ways of knowing are part of the learning process, it creates a way for learners to move confidently in both directions, crossing borders in a way—to build skill sets that include both Western science and Aboriginal ways of knowing while making progress in addressing the issue of proportional representation (Belczewski, 2009; Caledon, 2010). Language is the intellectual means by which post-colonial communication and reflection takes place, and that relates to the potential strength of Aboriginal oral traditions in creating new ways of bridging the sciences without choosing one over the other. The subjects spoke eloquently about their experiences in school and society, and their stories made sense of the competing views. Science educators are taking a hard look at ways of engaging Aboriginal students in a respectful, relevant manner:

> How can we make science education more relevant, more in tune with WSÁNEĆ beliefs? I was really kind of looking for that sort of ecological world view, in terms of trying to create some form of curriculum or something. And so that was the main issue, how can I make science interesting more meaningful and more relevant, and then what is the role of the white person? The WSÁNEĆ people passed their history down in an oral tradition by telling stories in families and in

> the longhouse. By telling these stories, their children learned important lessons about who they were as a people, what they valued, and how they were expected to live their lives. Teaching from 'place' is about bringing people and place together, again as a white person, I don't really know the language that well, and I have heard the stories and have really learned about the culture but it is not my place to stand up and teach them their culture. (Participant 6)

Although employment is a strong motive for science education, the ability to understand complex scientific issues, as more resource development takes place in traditional territories, is a driver, as well. All of the scientists and educators interviewed described the need for the Aboriginal communities to aggressively build their own scientific capabilities as a political element. "Knowledge is power" comes to mind.

Role of the family and community role models

According to the participants, the best strategies to support their efforts in having successful science careers were robust personal networks – with family, mentors, teachers and community. The role of family members and community leaders is instrumental in encouraging young students to see beyond the classroom—for many scientists their family and community belief systems can be the deciding factor in managing to balance their personal needs and their studies. Elders are a source of wisdom and history in Aboriginal culture, whereas Western society often equates age with decay and loss of importance, as one subject shared "I do not forget the stories of my Elders just because I use technology" (Participant 4). They pointed out that Elders are not opposed to embracing Western science, just that it needs to be part of the balance. One explained: "My father asked me, what earthly good is it to ignore Western

science?" (Participant 1). This proves that Aboriginals recognize the value of all ways of knowing, but the on-going dismissal of different forms of knowledge can be demoralizing to those who are trying to create cross-border appreciation. In the comparison (see Table 2), the value of Elder communication counters modern science, because oral storytelling traditions have powerful personal meaning compared to Western arms-length observations. One non-Aboriginal scientist, Jane Wynne, shared her epiphany while presenting a science talk to a remote B.C. community school during National Science and Technology Week: "An Aboriginal child asked me if the Earth was alive and I caught myself before I dismissed her question. I wanted to respect their culture." (J. Wynne, personal communication, March 8, 2011). Participant 5 recalled a significant personal turning point in understanding her own cultural connection to the earth. When an Elder spoke at an open house, arranged by her employer, to discuss mining development, "He pointed at the mountains and said they knew where the water would come from; the community had faith in that knowledge. He asked me what I thought would happen when we changed the mountain so that the snow would not be there to send them water. I realized how important that connection to local knowledge is to our versions of the world". She now provides critical environmental advice on resource development issues to bands in British Columbia, while remaining well regarded by her scientific peers.

Honouring promises—past and future

Too many Aboriginals are living a second-class existence. Education is a critical building block to improving life for individuals, families and communities. Media coverage and negative statistics are evidence indicating we are not making the kind of progress that will bring a

brighter future (Cowley et al, 2008). Troubling statistics provided a compelling rationale for my investigation. Although the problem with a science disconnect has been recognized (CCL, 2007 & 2009), and various groups (NSERC, FSIN, NRCAN, NAAF) attempt to encourage young people from First Nations and Métis communities to continue their studies, there has been no significant increase in the number of Aboriginal high school graduates moving on to undergraduate work in science fields (Statistics Canada, 2006). There is a bias in the public school system towards dominant Western science approaches. I believe when Aboriginal science is not included or, more importantly, not respected within school science curricula, the result is student rebellion in the form of disengagement. The emergent themes identified in Table 1 illustrate and support the overall dissatisfaction with current curricula by Aboriginal scientists. The growing demand for better, more mindful relationships with Aboriginal communities has a side benefit, a growing value of local knowledge, and an opportunity to stop rebellious disengagement in the classroom. Leadership—in the science community, schools, businesses, government, and Aboriginal communities—needs to validate the importance of Aboriginal scientists to ensure future sustainability of Aboriginal communities. Their unique understanding of Western science and Indigenous science will provide a foundation of trust and cooperation embracing the mythical as well as the empirical, as shown in this quote:

> For all the people of the earth, the Creator has planted a Sacred Tree, under which they may gather to find healing, power, wisdom and security. Its roots spread deeply into Mother Earth, its branches reach to Father Sky. Its fruits are the good things that our Creator has given to all peoples, the path to love,

> compassion, generosity, patience, wisdom, justice, courage, respect, humility and other great gifts.
>
> The life of the Tree rests with life of the people, but if they forget to take its nourishment, many would grow sick at heart, lie, quarrel, and abuse the land, poisoning everything they touch. The people would be as in sleep, to awaken again to their search for the Tree, whose knowledge rests with the Elders. (Bopp, 1992, p.20)

Developing mutual respect for the two ways of knowing when communicating science is helpful and will support different educational approaches to science learning in school. If we weave together stories from Western science with Aboriginal legends and myths, all students will gain a sense of "place" and their role in it.

Far reaching benefits

According to Aikenhead (2006), a Eurocentric dominated world is an "ontologically impoverished world," (p. 398) so formally accepting and learning Indigenous knowledge can expand current perspectives and create better scientists. Teachers have the power to acknowledge the value and relevance of Indigenous ways of knowing by weaving Aboriginal stories and historic references into Western science curricula and thereby support each other. Understanding events in the past is integral to understanding means to move forward. Oral traditions are no less valuable than written studies and key elements in accepting and using the local knowledge passed down over thousands of years. Aboriginal ways of knowing can increase benefits and the eventual outcomes of major projects in Aboriginal communities as a Native American biologist interviewee explained:

> I became interested in using science to restore our traditional foods, specifically fish, for me that's what formed my world view on how, why it is so important. Why we have to use the tools of the non-native people and we have to do it better. (Participant 2)

The limitations of my research included underrepresentation of Aboriginals in science careers itself; finding willing participants who met the criteria within the time frame was extremely demanding. Another challenge was my own status as a non-Aboriginal investigating a serious dilemma facing Aboriginal communities. Furthermore, my own science education was delivered in a Eurocentric-focused curriculum that left me with a historic bias of my understanding of what constituted "science". Nevertheless, as explained in the introduction, my own feeling of not belonging to the world of science established a healthier appreciation of the obstacles faced by Aboriginal students. Although these research results came from a small sample group, with the aim to identify common perceptions and experiences among a group of relatively homogeneous individuals, Aboriginal scientists, it produced the results needed to advance to the next level of research. Corporations harvesting resources in areas located near Aboriginal communities must meet regulatory obligations to demonstrate community investment and employment opportunities and thereby engage in appropriate consultation processes. A review of postings for high-paying jobs in major resource projects quickly highlights the rate of demand for credentials—often in Western sciences. If corporations embrace Aboriginal ways of knowing into routine environmental assessments and remediation plans going forward, a shift in perception of the credibility of different knowledge systems and

the people who have shared it will have happened. The influence of business can create new perceptions where all parties benefit.

When reflecting on the analysis of my research of the Aboriginal scientists, who found their own unique path to success, I felt the following summed up the great value of recognizing the need to connect Western and Indigenous sciences: “Western science and traditional knowledge constitute different paths to knowledge, but they are rooted in the same reality. We can only gain from paying attention to our cultural history and richness” (Mazzocchi, 2006 p. 464). Each scientist worked to build a bridge to succeed in a STEM career without abandoning their Aboriginal ways of knowing. Developing Aboriginal scientists as interpreters, ambassadors, role models and mentors, who understand both worlds and can comfortably shift back and forth, will be invaluable.

Although my research did not identify a specific solution to the challenges facing Aboriginal scientists, there were many strategies shared that can be used immediately or researched further. Many other researchers have documented some of these ideas in an attempt to increase research participation. Part of the power of the on-going research is initiating positive change, by sharing and applying our research results.

My recommendations

- Explore the activist “biologist warrior”—the scientist as political activist.
- Track successful Aboriginal scientists—engage them in outreach activities:
    - Leverage with other professional organizations with Aboriginal members,
    - Create a speakers bureau,
    - Build and promote school/media appearances,

- Mesh the modern mentor model with the Aboriginal Elder traditions,
- Incorporate Indigenous storytelling into grade school science curricula,
- Pressure government to increase Aboriginal involvement in resource management,
- Develop school support systems for students in transition (e.g., UBC and UVic Longhouse programs),
- Recruit corporate sponsors to support new initiatives (e.g., Aboriginal Achievement Awards),
- Expand regional Aboriginal Science Fairs to national—using Quebec and Manitoba models,
- Research successful initiatives and share information (CCL, 2007),
- Engage Aboriginal students in curriculum development, and
- University of Lethbridge model.

This list offers hope, but as one subject noted: "It is not an easy balance [between the sciences], and I don't think we should necessarily incorporate traditional knowledge into Western science. That kind of implies that Western sciences are above other knowledge and I don't think that is a good way. Instead of integrating one directly into the other, I think what you have to do is *weave them and support them*" (Participant 4).

Parting words

If Aboriginal populations suffer by the way science is taught, which alienates them and creates obstacles, then fundamental change is needed; not only in the science classroom, but in the subculture of science itself, where perceptions and attitudes are shaped. Government needs to change their perceptions and cooperate with Aboriginal communities in planning for

the future. Aboriginal leaders must demonstrate to their young people that science can be a valuable asset for the future. Finally, educators and those who consider science their profession must change the way they personally perceive the world, to look past historical bias and see the remarkable knowledge out there, if they only widen their horizon. Society has a choice – change the way science is connected to Aboriginal ways of knowing in the worlds of education and science, or look forward to more active challenges via “biologist warriors” inspired to create change in a more confrontational format. I hope by telling the stories of how this group of dedicated scientists nurtured a healthy, balanced relationship within *both* worlds, the next generation of curious Aboriginal students can succeed in weaving all stories of science into a collaborative approach.

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Appendix A

Research Consent Form

My name is Robyn Quinn and this research project is part of the requirement for a Masters of Professional Communications at Royal Roads University. My credentials with Royal Roads University can be established by telephoning the Director of the School of Communication and Culture, xxx

This document constitutes an agreement to participate in my research project, the objective of which is to explore how successful Aboriginal scientists have managed their relationship between Western science and Aboriginal ways of knowing.

The research will consist of narrative inquiry and thematic analysis. I will listen and record your stories related to working in Western sciences and this stage should last about an hour for at least one session, maximum three. These may take place in face-to-face meetings or by phone or Skype. In addition to submitting my final report to Royal Roads University in partial fulfillment for a MAPC, I will also be sharing my research findings through presentations at appropriate conferences and publishing in academic journals. If you or your organization would like a copy of the report I can arrange to send it direct.

Information will be recorded and, where appropriate, summarized, in anonymous format, in the body of the final report. At no time will any specific comments be attributed to any individual unless specific agreement has been obtained beforehand. All documentation will be kept strictly confidential. The raw data assimilated for the purpose of the research will be held for one year after which it will be destroyed. If, for any reason, an individual must withdraw from the project all of the data related will be destroyed.

A copy of the final report will be published and archived in the RRU Library.

You are not compelled to participate in this research project. If you do choose to participate, you are free to withdraw at any time without prejudice. Similarly, if you choose not to participate in this research project, this information will also be maintained in confidence. Please feel free to contact me at any time on my cell phone at xxx or at the following email address should you have additional questions regarding the project and its outcomes: [redacted]

By signing this letter, you give free and informed consent to participate in this project.

Name: (Please Print): _____

Signed: _____Date: _____

Appendix B

Interview Coding Excerpt and Coding Example

Interview statements excerpt	Analysis Code
1. I don't believe in using just the reductionist method	SCH 2, FAM 3
2. it is good for answering questions and tearing things apart	CUL 2, SCH 3
3. but we still have the cultural effect that we need to apply to this and get things back.	POL 1, SCH 2, CUL 2
4. It (Indigenous science) is more of a conceptional (sp) view, helping with how we are connecting together	CUL 2, FAM 2
5. inherent problems with science but no reason to throw the baby out with the bath water.	SCH 1, POL 2
6. criticism of the use of the science of course, the philosopher {name} opened the doors for the natives to say, screw you, your science has been used in bad ways	POL 1, SCH 2, CUL 1
7. we need to embrace that [science] and do it really well. We have to do it better than other people because we have a different perspective on a lot of things and add to it[knowledge]	CUL 2, SCH 1, POL 2, FAM 3

EMERGENT THEMES	*School*	*Family/Community*	*Culture*	*Political*
Subordinate theme	Western science bias SCH 1	Elder role FAM 1	Loss CUL 1	Ways to fight back POL 1
Subordinate theme	Rebellion against dominant culture SCH 2	Mentorship Need to help kids (role models) FAM 2	Indigenous knowledge value CUL 2	Colonization POL 2
Subordinate theme	Culture brokers SCH 3	Enable curiosity FAM 3	Storytelling –connect to Earth CUL 3	Threatened Sustainability POL 3

Appendix C

Science Alberta Foundation "Aboriginal Ways of Knowing" School Crates

Crate	Curricula	Information
Aboriginal Ways of Knowing: Colour Talking Circle	1.Creating Color	Ever Wonder how colour can be extracted from plants and used to colour porcupine quills? This colourful crate is based on the Aboriginal talking circle. Participants are encouraged to share stories as they explore coloured materials and their properties.
Aboriginal Ways of Knowing: Lessons from the Sky	2.Sky Science	In seven beautifully illustrated activities students will use models and stories to develop their understanding of astronomical objects in the sky. Students will learn about the motion and characteristics of stars, and the Moon; explore the relative position and motion of objects in space; and model seasonal cycles and phases of the moon.
Aboriginal Ways of Knowing: Little Moccasin's Boat Adventure	3.Buoyancy & Boats	Hayley Little Moccasin is going on a boat trip with her Grandpa (*importance of Elder relationship*). Along the way, they meet with friends who teach them about building Voyageur canoes, umiaks and kayaks. Discover how to set a fishing net using floaters and sinkers.
Aboriginal Ways of Knowing: Sharing Our Environment	4.Learning About My Environment and Community	The activities within this crate honour and acknowledge the traditional ways of First Nations people, while introducing students to the norms, beliefs, values, and conventions of Western science.
Aboriginal Ways of Knowing: Stories of the Iinii	5.Building with Variety of Materials,Testing Materials & Designs	Gather around Hayley Little Moccasin's Great Grandmother as she tells the stories of the great iinii or buffalo. Understand and respect practical Aboriginal ways of knowing and link this knowledge with the science of testing materials and designs.
Aboriginal Ways of Knowing: The Senses	6. Senses	Traditional ways of knowing rely heavily on the use of senses to learn about the world. Students will use their senses to make observations throughout all the activities in this crate and learn how songs and music are linked to the traditions and histories of Aboriginal people.

Appendix D

Interview Participants Overview

1) Aeronautics Engineer, male, age 40's, Algonquin-Anishnabeg Nation, Quebec, Francophone
2) Research Biologist, male, age 40's, Cayuse Nation (Confederated Tribes of the Umatilla Indian Reservation) Washington, USA, Anglophone
3) Mechanical Engineer, male, age 50's, Mohawks of Kahnehsatake (Oka), Quebec, Francophone
4) Computer Technologist, male, age 30's, Secwepemc Nation (Shuswap), British Columbia, Anglophone
5) Metallurgical Engineer, female, age 30's, Tahltan Nation, British Columbia, Anglophone
6) Science teacher, male, age 30's, non-Aboriginal, WSÁNEĆ (Saanich), British Columbia, Anglophone
7) Pharmacist, male, age 30's, Wood Mountain First Nation, Saskatchewan, Anglophone