Towards a BC Science Curriculum Inclusive of Indigenous Knowledge: Challenges and Recommendations for Reform

by

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Introduction

In the last few decades, Indigenous knowledge has continued to gain attention among educational researchers and provincial education systems across Canada (Aikenhead, 1997, 2001, 2002a, 2006; Aikenhead & Elliot, 2010; Aikenhead & Jegede, 1999; Alberta Education, 2013; BC Ministry of Education, 2013; McConney,A., Oliver,M., Woods-McConney,A., & Schibeci,R, 2011; Mckinley, 2005; Ontario Ministry of Education, 2011; Saskatchewan Ministry of Education, 2011; Snively & Corsiglia, 2001). In British Columbia, the Ministry of Education has established its support for Indigenous knowledge in the British Columbia's school curriculum, and it also emphasizes the value of Aboriginal science in coexistence with Western science. The introductory sections of the science K-10 curriculum documents state that, "The incorporating of Aboriginal science with Western science can provide a meaningful context for Aboriginal students and enhance the learning experience for all students" (Sciences Curriculum Documents, 2013). The notion of opening the boundaries of science to include multicultural sciences is not new, and was once an issue of much debate (Cobern & Loving, 2000; Snively & Corsiglia, 2000; Stanley & Brickhouse, 1994). More recently however, Indigenous knowledge has become widely accepted as a form of science. Snively and Corsiglia (2001) maintain that Indigenous knowledge has made significant contributions to science and suggest that every culture views the world differently and has developed different scientific activities that have met their specific needs over time.

Another important reason in integrate Indigenous knowledge into the science curriculum is that keeping the status quo of science education is what Battiste (2009) describes as forcing a Eurocentric curriculum on Aboriginal students and thus continuing the colonization of the past. Aikenhead advises that a science framework which recognizes Indigenous knowledge as a component of science will move us beyond our colonial past and better represent the Aboriginal students in high school science classrooms (2006).

On the surface, in the integration of Indigenous knowledge in the science curriculum is clearly supported by Ministry of Education in British Columbia, however, in actuality, this is not the case. It is underrepresented and is often taught as an 'add on' to the curriculum rather than an equal component of the curriculum, with equal value and worth to the rest of the science content. A genuine integration would include Indigenous knowledge as another valid worldview, and thus include a significant, rather than negligible, amount of representation in the curriculum. There are several obstacles impeding the genuine inclusion of Indigenous knowledge in science in British Columbia. Conceptions of science, teacher worldviews and beliefs, as well as the content and educational goals of the current science curriculum must be reformed before an authentic integration of Indigenous knowledge is possible.

Before discussing the challenges our current education system brings to the inclusion of Indigenous science, my experiences as a science teacher will provide insight to the realm of science education in British Columbia. Then a closer look at the meaning of the concept of worldview, science as we know it, and Indigenous knowledge, will explain why our current science education system must be reformed before authentically implementing an integrated curriculum.

Before I continue my experiences as a science teacher, I will define a few key terms. In this paper I use the term Indigenous to refer to all of the peoples worldwide, who are native to a particular geographical region, who have a long-term connection, relationship and occupancy with that region. This includes the Aboriginal peoples of Canada, which are comprised of the First Nations, Métis and Inuit peoples. Aboriginal science refers to science interweaved into the

Indigenous knowledge of Aboriginal peoples. Indigenous knowledge includes the collective experience, relationships, wisdom, and ways of knowing, accumulated over thousands generations, and represent the fundamental ties to land, culture and people. It is usually holistic and thus is not easily sub-divided into domains of knowledge such as art and science. Consequently, Aboriginal science, like other forms of knowledge including Traditional Ecological Knowledge (TEK), is not an isolated category, rather a science that is interlaced with all aspects of Indigenous knowledge (Cajete, 1999, 2000; Little Bear, 2009). It is within a Western context that this knowledge is categorized or labeled with Western terms, such as Aboriginal science. Since it is interweaved into Indigenous knowledge, throughout this work I use both Aboriginal science and Indigenous knowledge as interchangeable terms to denote science within Indigenous cultures.

Experiences as a Science Teacher

The following sections are life experiences and personal reflections and inferences based on my career as a science teacher, alongside other science teachers within British Columbia's education system. British Columbia's Science 9 curriculum (Science 9 Integrated Resource Package, 2006) reads:

> It is expected that students will: describe traditional perspectives of a range of Aboriginal peoples in BC on the relationship between Earth and celestial bodies. Students who have fully met the prescribed learning outcome are able to: identify passages related to the relationships between the Earth and various celestial bodies within specific traditional stories of BC Aboriginal peoples.
>
> (p.48)

"Why are we are we teaching Aboriginal stories in a science classroom?" These were the words I can remember uttering to myself the first time I came across this section of the Science 9 curriculum. Although it had been 5 years since I had taught secondary science, I couldn't recall learning the connection between Aboriginal culture and science during the four years of completing of my biology degree. I had no memory of a learning of its relevance in science during my secondary science teacher education, my practicum teaching high school science or during my four years as a Grade 6 teacher. "Aboriginal stories belong in the socials studies curriculum, definitely not in science," I would say with frustration to my colleague. I was not the only teacher who expressed these sentiments about Indigenous knowledge in the science curriculum. Teachers often consider science a discipline separate from other domains of knowledge, such Aboriginal science, and they commonly consider science to be incompatible with Indigenous knowledge (Blades, 2002; Ogunniyi, 2007; Tsai, 2002).

Schooling Experiences

Today, I realize that these views were a consequence of growing up and being educated in a Western culture, whose history of colonization and assimilation has devalued and disregarded other forms of knowledge deemed inferior. In recent years the value Indigenous knowledge been slowly gaining recognition, however, my initial perceptions of science and Indigenous knowledge remain a similar reality for many science teachers today. In Canada, teachers have all been molded by the same traditional, Eurocentric, Western education system. Throughout my schooling, I learned science within this same traditional model. In preparation for university entrance, I took high school biology, chemistry and physics. I knew the next phase after high school would be university, and all of my courses were in preparation for it. Classroom lessons consisted of note-taking, some discussion, practice exercises, quizzes and tests. Science in high school was presented as a source of reliable facts about the world. There was not much of an opportunity to discuss or learn about the nature of science, or the history of science, or any questions about science as a discipline. Values, human subjectivity, imagination and inquiry were not central to the science courses I took.

Each science course involved a race against the clock to finish learning the course material so that we would all do well on our final exams and provincial exams. The same preoccupation with content and overlooking of fundamental and philosophical questions about science transpired during my time at university, as I completed my Master of Science degree, and then my post- secondary teaching degree. Much of my time was spent memorizing concepts and facts without ever questioning them. I did not question science as a discipline or its role in the education system. Each of my university science courses was comprehensive and effective in achieving its goals and objectives however, each one lacked connections to Indigenous knowledge or Aboriginal science. Each one was void of the nature, history or philosophy of science. Neither of these sub-topics of science was mandated as a required course for my Bachelor of Science degree or my post-degree professional teaching program.

Discussions about curriculum theory, pedagogy or the philosophy of science were also absent in my education courses, as the realities of the teaching world, classroom management, and creating lesson plans were, justifiably, prioritized. Thus, my original bewilderment of the introduction of Aboriginal perspectives in science is not surprising. I lacked the understanding of the nature of science, as well as any grasp of an association between Indigenous knowledge and science. Thus, the uncertainty of incorporating Aboriginal science experienced by other science teachers, whose Western schooling produced similar experiences to mine (Blades, 2002; Ogunniyi, 2007; Ryan, 2012; Tsai, 2002; Winschitl, 2004), might not be a surprise.

Teachers' Voices

In my experience working within the science education system in British Columbia, several notions about science are apparent. The first notable assertion often voiced by teachers is that Aboriginal science is not science. Through these discussions with peer teachers, some teachers have additionally argued that teaching Aboriginal science is a wasted effort. These perspectives are a result of an understanding that science, based on a Western definition, has a universal essence and is distinguished from other forms of knowledge. This definition of science as being objective collection of verifiable facts, diminishes the legitimacy of Indigenous knowledge as a form of science, in the same way its definition excludes art, religion and history. Story-telling, spirituality, and the metaphysical lay at the core of Aboriginal science, features that teachers caution, are not a form of science. It is argued that Aboriginal science should be taught in social studies, within a more relevant subject, or by itself.

My peer teachers also express concern over teaching spirituality and mythical stories in the classroom, when religion and other domains of spirituality are not allowed to be used in science or in any other subject in public schools as established explanations for the natural world. For instance, spiritual stories relating to the constellations in the Science 9 curriculum are questioned by teachers who worry that this inclusivity could apply to other religious forms of spirituality, such as Christianity or Islam. As such, teaching Christianity's version of creationism as science is feared to be the next step.

This unease stems from the responsibility teachers feel to their students. Teachers are the judge of what their students will accept, understand and benefit from. Some may believe the contrast between Aboriginal science and Western science is deemed to be confusing to students. In addition, learning Indigenous perspectives within the current context of science means only a few examples of Aboriginal science are shared. This gives the sense that while it may have merit, it is still inferior to the rest of the science curriculum. Although the separation between the two domains of knowledge is made clear, some teachers expressed they value the contributions Aboriginal science makes to science. The notion that Indigenous knowledge is of value, yet distinct from science, is not a new idea. Cobern & Loving (2001) suggested that Indigenous knowledge is better off maintaining its independent position, separate from science.

Some teachers acknowledge the importance of critical discussions about Indigenous knowledge and science. However, this same suggestion has been coupled with the affirmation that those discussions would not be included in student assessment. This translates to a belief in a hierarchy of knowledge domains that places Indigenous knowledge at the bottom and science at the very top. Scientism, the profound belief in science and its methods of discovering truth, is a dominant, yet tacit, element emerging from the opinions of teachers. Believing that Western science is superior to and more valuable than other knowledge systems is reflective of a colonial frame of mind. In addition, views that Aboriginal science has had less significance to the modern world than Western science reinforces the scientistic and colonial attitudes among science educators.

Yet, I do not believe it is the intention of any teacher to hold a Eurocentric or colonial attitude towards Indigenous cultures. Part of the reason that this exists could be because of a normalization of privilege. The characteristics of the privileged define the societal norm which all else is measured against. In our society, Western science is the societal norm which all other forms of science are measured against. Wildman and Davis (2002) claim that privilege is rarely seen by the holder of that privilege. Teachers of Western science are affiliated with this privileged group, thus they are unaware that they are unduly judging Aboriginal science.

The absence Indigenous knowledge or Aboriginal science education has made teachers ill-equipped to teach it. Teachers lack confidence, resources and the know-how required to engage in Aboriginal science. Teachers have expressed their willingness to teach Aboriginal science if more of it embedded in the science curriculum, and as long as the knowledge was relevant to the current themes taught in science. Although the superiority of science still exists for many teachers, there are teachers who have voiced their complete support for Aboriginal science. However, they do not feel educated enough to incorporate it into the curriculum themselves. Teachers need support structures such as concrete curricular links to Aboriginal science, as well as content and instructional suggestions embedded into the curriculum documents.

Many of these opinions were once the same as my own. I did not reflect on my beliefs until I began my masters of education degree. The inattention to this type of reflection is common, as Tobin, Tippins and Gallard (1994) argue that science teachers often move through 15 to 20 years of education without ever being induced to think about their own beliefs about science or what experiences and influences have shaped them. Through reflection and professional development, I have changed my initial attitudes of Aboriginal science and realize that it indeed should be a fundamental part of our science curriculum. A pluralistic definition of science recognizes that different cultures have their own form of science that arises over time through the needs of survival and understanding nature. Common processes and ways of thinking do exist among different forms of science however, many of these differ, as well as the perspectives that are the driving force behind it. For instance, Aboriginal science discovers an understanding of nature so that relationships and interdependence with nature are developed and better understood.   Western science's endeavour of understanding nature is to establish truths about the reality, which often are used benefit human kind and its place on Earth.

In the next chapter, an exploration and examination of Western Modern Science and Indigenous knowledge makes it clear as to why Indigenous knowledge should be genuinely integrated into British Columbia's science curriculum. A genuine integration includes Indigenous knowledge as another valid worldview and an equal component to the rest of the science curriculum, thus including a significant representation of it in the curriculum. Nevertheless, its successful, authentic inclusion comes with challenges, including the curriculum and teachers' worldviews and beliefs. The subsequent chapters will examine these challenges, followed by recommendations for a genuine integration of Aboriginal science.

Chapter 2: Worldviews and Knowledge

Western Modern Science

The science curriculum of most conventional schools enculturate students into the value system of a Eurocentric, Western science, complete with its canonical knowledge, techniques and values (Aikenhead, 2002a, 2006; Aikenhead & Elliot, 2010). Western Modern Science (WMS), often termed as "Western science," or "modern science," is based on scientific philosophies, knowledge and practices originating from Europe and dominating schools worldwide. Cleminson (1990) explains the historical progression of WMS, starting with the Middle Ages when science was blended into the study of philosophy. Once science was recognized as its own distinct study and method of reaching truth, other advancements and developments took place. The possibility for "objective" observations of nature arose from Descartes' dualism, which assumes the mind and matter are separate entities. As two distinct and independent parts, matter or the natural world, is devoid of all elements of the mind, including spirituality, emotion, and human perceptions. Mind and matter are non-interacting, and when objective observations of the natural world are made, the scientific result is a universal one. The concept of objectivity and Francis Bacon's method of inductive reasoning led to the emergence of 'the scientific method,' a single, step-by-step method which is used to investigate the natural world. (This myth of a single, prescriptive scientific method still exists in science classrooms, schools and within the general public.) Scientific knowledge became grounded in the facts of sensory experience and supported by an empirical philosophy. Its success relied on the influences of positivism, which is exemplified by a strict adherence to objectivity and empirical methods, which could produce universal, value-free, reliable knowledge. The material gains of science enhanced its status and it was perceived to be an advancement over other sources of knowledge (Cleminson, 1990). This universalist epistemological basis of science has shaped the practice of science education in the last century (Stanley & Brickhouse, 1994).

The Eurocentric nature and universalist underpinnings of our curriculum has not gone unchallenged. Many researchers have called into question the universal assumptions of WMS, including influences of positivism. Positivists claim that knowledge and truth can only be achieved through empirical means, or sensory experience that has been scientifically verified, mathematically or logically. Essentially, positivism states that there is only one reality and there is only one way to come to know that reality (Little Bear, 2009). In the past century, several pillars of positivism have been challenged and re-evaluated by philosophers of science such as Popper, Kuhn, Toulmin and Lakatos (Cleminson, 1990; Stanley and Brickhouse, 1994). Karl Popper opposed positivism's use of scientific experimentation to verify theories, arguing that theories could only be *falsified*, or shown to be false through experiment or observation. Soon after, other limitations of positivism were identified. Among these limitations of positivism are, the universal conception of scientific language and method, the assumption that theory and observation (as well as the observer and observed) could be kept separate, the assumption of a value-free method and separation of facts and meanings, and the temporal and contextual independence of observations (Stanley & Brickhouse, 1994). It is now widely acknowledged that the observer and the observed are not separate entities, instead they are connected by the influence of the individual who is observing on what is being observed. Each individual observes the natural world with his or her own lens, thus one cannot eliminate subjectivity.

Cleminson (1990) stresses that science education must be represented "as it really is," and not the impersonal, objective, and value-free subject it is portrayed as. He uses the following assumptions as the foundation for a new direction in science curriculum:

1. Scientific knowledge is tentative and should never be equated with truth. It has only temporary status.
2. Observation alone cannot give rise to scientific knowledge in a simple inductivist manner. We view the world through theoretical lenses built up from prior knowledge. There can be no sharp definition between observation and inference.
3. New knowledge in science is produced by creative acts of the imagination allied with the methods of scientific inquiry. As such science is a personal immensely human activity.
4. Acquisition of new scientific knowledge is problematic and never easy. Abandoning cherished knowledge that has been falsified usually occurs with reluctance.
5. Scientists study a world of which they are a part, not a world from which they are apart. (p. 437)

Even with reform, the traditional, Western approaches to science are still dominant in our current science curriculum. School science is seen as a body of facts. Science lessons are often in the form of lectures in which students accept the information and facts provided by the teacher and textbook as unbiased. Scientists are portrayed as impersonal and unproblematic (Cleminson, 1990), and as detached observers of the world. This is a contradiction of how science is really practiced. Scientists do not follow a singular, prescriptive method in making their discoveries, yet the scientific method is portrayed this way in the science curriculum. Teachers often expect students to adhere to the defined steps of the scientific method when completing experiments and laboratory activities.

The universal conception of science has been an issue of debate over the last few decades. Universalists believe that science is universal thus immune to culture, gender, and race

(Stanley & Brickhouse, 1994) and embodied by WMS (Irzik, 2001). A negative consequence of this universal view of science is that anything outside of the WMS definition of science is considered superstition or myth. This adherence to scientism, or the belief that science is the only access to truth, leads to the dominance of scientific knowledge over all other systems of knowledge. This poses a particular problem for the position of other knowledge systems, especially with society's acceptance of science at the top of the epistemological hierarchy. Science is often used to dominate the public forum as though all other discourses were of lesser value (Cobern & Loving, 2001). In a science classroom, other forms of knowledge become relevant only when they have a relationship to science. There is no doubt that scientific progress has made contributions to medicine and good health, as well as benefited modern life economically, socially and culturally. Cobern and Loving (2001) emphasize that science is one of many factors in these successful developments, but not the only factor. They also revealed that the science community has often portrayed science as the key factor in these successes.

History has shown the ramifications of Western ideologies dominating those viewed as inferior. Entire cultures, including the Indigenous cultures in Canada have been destroyed because of colonization. Indigenous science and agriculture were replaced with Western science and agriculture (Stanley & Brickhouse, 1994), and traditional fishing practices comprised by Western aquaculture. Western culture suppressed Aboriginal language and culture resulting in a generation of youth that cannot communicate with or be educated by their Elders (Kawagley, Norris-Tull and Norris-Tull, 1998). Today, diverse students within Canadian classrooms, particularly Indigenous students, continue to be marginalized with a curriculum that privileges the perspective of WMS.

Science continues to be Eurocentric in that contributions from non-Western cultures are often ignored or not acknowledged (Hodson, 1993; Lewis & Aikenhead, 2001; Snively & Cosigilia, 2001). Research confirms that Chinese, Islamic, Indian and African scientific achievements have been devalued or falsely attributed to Westerners (Battiste & Henderson, 2009; Hodson, 1993). Paper making and printing, gunpowder and the compass were invented by the Chinese several hundred years before their discovery by Westerners (McGinn, 1991; Needham, cited in Hodson, 1993). Pulmonary circulation and the heliocentric theories of the solar system, discovered by Islamic scientists, are either ignored or attributed to Europeans (Sardar, cited in Hodson, 1993). Indigenous contributions to science have also been underrepresented and are not held in the same regard as WMS (Aikenhead, 2002a; Aikenhead, 2006; Aikenhead & Elliot, 2010; Battiste & Henderson, 2009; Little Bear, 2009; Snively & Corsiglia, 2001).

Multiculturalists argue that WMS is only one perspective among many of the natural world (Aikenhead, 2002a; Aikenhead, 2006; Aikenhead & Elliot, 2010; Battiste & Henderson, 2009; Little Bear, 2009; Snively & Corsiglia, 2001.) Multiple cultures, including indigenous cultures, contribute a rich resource of knowledge. Snively and Corsiglia (2001) argue that Indigenous knowledge has made significant contributions to science. The pluralistic standpoint recognizes that every culture views the world differently and has developed different scientific activities that have met their specific needs over time. Multiculturalists take on a relativistic position in which truth is relative and dependant on one's perspective, rather than being absolute and universal. A culture's way of knowing and thinking about the natural world, as well as their science development, is a product of their worldview.

The Concept of Worldview

A worldview is the lens we use to perceive and make sense of the world in which we live. It shapes our perceptions and ways of creating knowledge (Keane, 2008). Kawagley et al. (1998) suggest that worldview is a way of conceptualizing the principles and beliefs, including the epistemological and ontological constructs, which people have developed to make sense of the world around them. Hart (2010) describes worldviews as the cognitive, perceptual, and affective maps to making sense of the world. These maps are a complex organization of the principal beliefs about the world and reality (Yalaki, 2004). They are developed throughout a person's life and are influenced by the environment, culture, religion, education and social interaction (Hart, 2010; Yalaki, 2004). They provide a framework for people's behaviors and actions and are generally taken for granted as the way things are. Keane (2008) explains that there is a general unconscious acceptance of one's beliefs about reality, and little awareness of how they shape conceptions of the world. Contradictions and inconsistencies do exist within the framework of worldviews. For instance, if discrepancies between one's worldview and what is observed become too apparent to ignore, an individual might rationalize the discrepancy instead of changing his or her worldview. Despite that worldviews are not easily altered, they can change slowly over time (Hart, 2010; Parajes, 1992).

The ethnic and cultural diversity of Canada's population is mirrored within Canadian classrooms. Students carry with them a diverse range of worldviews, and not necessarily only the Western or scientific worldview that underlies a WMS curriculum. Students whose worldviews do not resonate with those of the science curriculum can become alienated. This alienation is even more serious for Aboriginal students (Aikenhead, 2001). For much of the same reason, Stanley and Brickhouse (1994) believe that teaching a universalist conception of science is miseducative. Aikenhead (2001) claims that most students experience a change in culture when moving from their life-worlds into the world of school science. Solomon (1993) discusses how children construct and store knowledge into two different compartments or worlds, the life-world and the scientific world. Certain triggers, such as scientific words or phrases used in a science classroom, will move children between the two domains of knowledge. Solomon (1993) even found that the lack of success on science questions was due to a failure to cross over from their life-world domain to the appropriate scientific domain. This was due to the absence of science triggers in the wording of the question. This strengthens Aikenhead's (1996, 2001, 2002a, 2006) notion of students experiencing a change in culture when entering a science classroom. He describes learning science as a cross-cultural event, and the moving between worldviews as border-crossing.

Aikenhead (1996) explains that border-crossing can be as effortless and smooth as moving between the cultural borders of work and home. He also explains that if the culture of science corresponds with a student's life-world culture, the student will experience a smooth border crossing because the curriculum already supports that student's worldview. However, many students find it difficult to cross over the borders of their life-worlds to the world of science (Aikenhead, 1996, 2001, 2002a, 2006; Aikenhead & Jegede, 1999). If science is at odds with a student's worldview, it could distort the student's worldview by forcing that student to compartmentalize, reject or marginalize his or her life-world concepts and form new scientific ways of understanding in the place of their life-world beliefs. This assimilation can alienate students from their life-world culture and cause social disruptions (Aikenhead & Jegede, 1999). Since there is a greater gap between WMS and Indigenous culture, Aboriginal students are at greater risk of alienation. Science teachers need to act as "tour guides", or cultural brokers who guide and assist students in border-crossing (Aikenhead, 1997) and help students gain access to WMS without losing sight of their cultural identity (Aikenhead, 2002a).

Battiste (1986) asserts that forcing a Eurocentric science on Aboriginal students, is a continuation of the colonization of the past, a process of "cognitive imperialism." Aikenhead (2006) maintains that a pluralistic multi-science will lead us towards decolonizing our Canadian science curriculum, and many studies have discussed the success of using cross-cultural teaching strategies when teaching an inclusive science curriculum to indigenous students (Aikenhead, 1997, 2001, 2002a, 2006; Aikenhead & Elliot, 2010; Aikenhead & Jegede, 1999; Mckinley, 2005; Snively & Corsiglia, 2001). Hart (2010) describes the dominance of Eurocentric thought as the "blinding" of Indigenous worldviews. He also asserts that when Indigenous worldviews are acknowledged they are most often analyzed thought a Eurocentric lens. The dominance of Eurocentric thought also exists in non-aboriginal students, resulting in their resistance of Indigenous worldviews when presented in the science classroom. Recognizing Indigenous knowledge as an element of school science, understanding and respecting Indigenous worldviews, as well as incorporating Indigenous perspectives into teaching, is essential to achieving an inclusive science curriculum. And equally imperative is the border-crossing of non-aboriginal students into Indigenous worldviews.

Indigenous Worldviews

Indigenous worldviews are grounded in the close relationships that people have with the environment and each other (Hart, 2010; Little Bear, 2009; Fixico, 2003; Hatcher, Bartlett, Marshall, & Marshall, 2009). Survival is dependent on the connection and support of living and non-living beings. All things are animate, and of energy and spirit, thus all are alive and linked together (Little Bear, 2009). This linkage has to do with the philosophy of the circle, which is inherent in Indigenous cultures (Fixico, 2003; Little Bear, 2009). The world is seen as a circle with all the things that are Mother Earth, including rocks, trees and humans, connected around the circle as equals. A Westerner's perspective of this circle would be the same except for the position of humans, which would be in the centre of the circle, above all things (Fixico, 2003). All aspects of life and time are represented by cycles, rather than a linear system of Western worldviews. These cycles are part of Aboriginals strong connection to the environment, and as a result they have been able to respect and maintain it. This relational worldview also reflects reciprocity and the understanding that humans must honour the relationships with other forms of life (Cajete, 2000; Hart, 2010). All things have a role in keeping the balance and harmony of life (Fixico, 2003; Hart, 2010). The mutual reciprocity means a give-and-take relationship with the natural world, which assumes a responsibility to care for, sustain, and respect the rights of other living things and the place in which one lives (Cajete, 2000). Like Western learning, Indigenous knowledge is sequential and builds on previous knowledge, however building on learning and traditions is never a linear or direct path. The Indigenous worldview builds on knowledge by following a meandering path, over obstacles in a roundabout way, through fields of relationships and establishment of a sense of meaning, territory, and range of context (Cajete, 2000).

The relational, cyclical worldview emphasises spirituality, community and respectful individualism (Hart, 2010). A group identity is more meaningful than the identity of one person (Fixico, 2003). Cooperation and community are fundamental aspects of Indigenous culture. The interrelationship between humans and the environment create their "communal soul," and the actions of members within the community are always, "for the good of the people" (Cajete, 2000). Western values of competition and acting on self-interest are considered inappropriate behaviour (Fixico, 2003; Inuit Women's Association of Canada, 2006). Westerners function in a linear society, with a linear concept of time and a focus on progression, where it may be more difficult to recognize the need for balance and inclusivity of all things. The competitive nature and celebration of individual successes present in our Western society and education system, clashes with Indigenous worldviews.

Indigenous Knowledge

Hart (2010) emphasizes the close connection between Indigenous knowledge and Indigenous worldviews. His research reveals characteristics of Indigenous knowledge as being personal, oral, experiential, holistic and local. Battiste & Henderson (2009) define Indigenous knowledge as a:

> Part of the collective genius of humanity of Indigenous peoples that exists in the context of their learning and knowing from the places where they have lived, hunted, explored, migrated, farmed, raised families, built communities, and survived for centuries despite sustained attacks on the peoples, their languages, and cultures. (p. 6)

Battist (2009) points out that the holistic nature of Indigenous knowledge defies Western approaches of defining categories. Unlike Western culture, which separates science from other realms of knowledge, and then further subdivides science into numerous categories, Indigenous knowledge embodies a broader perspective. For example, in the Yupiaq culture of Alaska, science is not separated from daily life, instead it is blended in with art, storytelling, hunting and craftsmanship (Kawagley, et al. 1998). In indigenous cultures, knowledge and learners are intimately connected. This also contrasts with a Western worldview that requires a separation and objectivity when learning (Hatcher et al. 2009).

Indigenous knowledge is adaptable, dynamic, and changes over time depending on environmental changes (Battiste & Henderson, 2009). Little Bear (2009) states that Indigenous knowledge must be understood from an Indigenous context. She stress that it is not a tangible thing, although its manifestations may be tangible. It is not a body of knowledge, but a methodology (Little Bear, 2009), or process of *coming to know* (Aikenhead & Elliot, 2010). *Coming to know* is a personal, experiential, holistic journey toward gaining wisdom. It is a process, journey, a quest for understanding and knowledge (Cajete, 2000). *Coming to know* contrasts with the Western idea that knowledge can be passively learned and accumulated. The Yupiaq see themselves as producers of knowledge, rather than as explorers of knowledge (Kawagley et al. 1998). There are no special gatekeepers of knowledge, rather repositories of knowledge such as Elders, dreams, experiences, stories, ceremonies and language (Kawagley et al. 1998; Little Bear, 2009).

The repositories of Indigenous knowledge allow for experiential learning processes which are closest to the educational paradigm of constructivism (Little Bear, 2009). Indigenous learners construct knowledge and their own realities. This differs from the positivist foundations of WMS existing in current science curriculums, which emphasis a singular method (the scientific method) of discovering a universal reality. Another major difference in the learning process of Indigenous cultures is that knowledge has been preserved orally (Hatcher et al. 2009; Kawaglety et al. 1998; Little Bear, 2009; Snively & Corsiglia, 2001). Historically, the preservation of knowledge and the survival of the next generation depended on effective strategies of learning. Seasonal and long-range weather patterns, salmon migration patterns, fishing, and hunting are some examples of the knowledge and skills that would be passed down by oral traditions, close observations and by working closely with each other. Kawagley et al. (1998) describes these essential strategies in Western educational terms as a modeling, guided practice, cooperative learning, peer-tutoring, and hands-on learning.

There is no translation for the word science in the North American Indigenous languages (Cajete, 2000). Indigenous expressions of science and science thinking are woven into all aspects of Indigenous culture (Snively & Corsiglia, 2001; Kawagley et at. 1998). This lack of a distinct designation for science within the Indigenous knowledge does not mean Indigenous knowledge lacks scientific knowledge. Expressions of scientific thinking are plentiful throughout astronomy, navigation, engineering, military science, ecology, medical practices, mathematics and indigenous agriculture. In addition, processes of science, such as observation of natural events, classification, and problem solving are woven into all aspects of Indigenous cultures (Snively & Corsiglia, 2001). The vast technology used in the survival of the Indigenous cultures is convincing of an application of scientific knowledge by Aboriginal peoples. Kawagley et al. (1998) understand that some argue that technology is not science, however, they make the point that technology does not come from a void. Scientific observation and experimentation are often carried out before technological advancements arise. The kayak, river fish traps, hunting and fishing gear are examples of the technology that was invented with the scientific study of the flow of currents in rivers, the ebb and flow of tides, and the feed, resting and migratory habits of fish, mammals, and birds (Kawagley et al., 1998). Kawagley et al. (1998) describe more examples:

> Each item of fishing gear is typically developed to capture a particular species of fish in a particular type of water (in a river, under the ice, on the shore of the bay, or in the open ocean). To make the appropriate traps and nets, the fisherman has to have significant scientific knowledge of the behaviors of each species of fish, tidal patterns, and the patterns of flow of water in rivers. In remote villages, most food is still retrieved from the wild. Therefore, all young men must have extensive knowledge of migration

> patterns, mating habits, and feeding behaviors of a wide range of wildlife (including seals, walrus, several species of whales, moose, caribou, ptarmigan, and many species of waterfowl). (p. 136)

Indigenous peoples in North America have a vast knowledge of local wild plants, both edible and medicinal, as well as navigation of open seas, rivers, constellations, seasonal positions of constellations, climate, seasonal changes and temperatures, cloud formations, air pressure, wind direction and speed (Elliott, Poth, & School District No. 63, 1983; Kawagley et al. 1998; Snively & Corsiglia, 2001) . The Yupaiq also have knowledge of the snow-covered tundra and the behaviour of snow and ice (Kawagly et al. 1998).

As with WMS, Indigenous knowledge also highly values observation, however they do not consider direct observation as the only way of *coming to know*. A spiritual orientation is integrated into the understanding of the universe. There are interconnections between the human world, the spirit and inanimate entities (Hart, 2010), so observing one's inner spirit, as well as the outer environment contributes to emergence of knowledge. Snively and Corsiglia (2001) point out that the spiritual base of Indigenous knowledge is the reason many scientists fail to recognize it as science, and instead regard it as being superstitious. Spirituality within the Indigenous worldview does not have the same connotation as it does in a religious sense (Aikenhead & Michell, 2011; Cajete, 2000). Since all things on Earth are animate, consisting of energy and flux, they are all connected, interrelated, and imbued with spirit (Little Bear, 2009). Kawagley et al. (1998) suggest that the absence of spirit in Western science is also one of its shortcomings. The incorporation of spirit in the Yupiaq worldview has resulted in an awareness of the interdependence of humanity with the environment, as well as a respect for and a sense of responsibility for protecting it. The acceptance of this spiritual realm within a Western worldview could develop the same sense of reverence and responsibility for nature within Western cultures. The absence of such reverence for nature in Western society has led environmental destruction, and loss of ethical values in exchange for technological progress, and human gain.

Chapter 3: The Dynamics of Teachers' Worldviews, Belief and Conceptions

Beliefs

Worldviews are the framework for making sense of the world (Kawagley et al., 1998), filtering knowledge before it is accepted, rejected or modified (Kagan, 1992). Worldviews are made up of multiple belief systems, and beliefs. Belief systems are made up specific beliefs. For example, the belief in dinosaurs might be part of a greater belief system in evolution. This belief system could perhaps be one of many that make up the framework to perhaps, a scientific worldview. Yalaki's (2004) study supported the notion that the beliefs people hold are attached to a larger belief system. He also found that science teachers prioritized their beliefs based on the structure of their worldviews, which concurrently influenced their values, feelings, practices and relationships. Beliefs determine behaviour and how people make decisions. For example, an individual who believes in driving safety will ensure that he or she is always wearing a seatbelt when driving. Many researchers have emphasized the importance of studying the influence of beliefs on teacher decisions, behavior and actions (Bryan & Atwater, 2002; Parajes, 1992; Ryan, 2012; Tsai, 2002; Yalaki, 2004).

Beliefs are not to be confused with knowledge, which is easily modified and developed. Knowledge is the awareness or comprehension of an idea, whereas a belief is the mental representation of a truth-value associated with that knowledge (Griffin & Ohlsson, 2001). Essentially, a belief is knowledge that has been shaped by personal feelings and judgement (Nespor, 1987; Parajes, 1992). Belief systems are more unchanging, inflexible, and less dynamic than knowledge systems (Parajes, 1992). They are strongly held and not open to evaluation and critical examination like knowledge systems are. Nespor (1987) asserts that beliefs are far more influential than knowledge in determining how individuals organize and define tasks and problems. Parajes' (1992) synthesis of findings reveals that beliefs play a critical role in defining behavior.

The Nature of Science

Generally, The Nature of Science (NOS) has been used to refer to the epistemology of science, or the values and beliefs characteristic to the development of scientific knowledge (Abd-El-Khalick, Bell, & Lederman, 1998). Although a specific definition for NOS agreed upon by scientists, science educators, historians and philosophers of science does not exist, there is a general consensus of agreement on aspects of NOS relevant to K-12 education (Lui & Lederman, 2007). The principles of NOS contrast with those of Western science depicted in schools and understood by the general public. The seven general aspects of NOS defined by Abd-El-Khalick et al. (1998) include views that scientific knowledge is tentative (subject to change), empirically based (based on and/or obtained from observations of the natural world), subjective (theory-laden), partly based on human inference, imagination, and creativity, and is socially and culturally established.

Understanding NOS is considered to be an important factor in science education (Abd-El-Khalick, Bell, and Lederman, 1998; Brickhouse 1990; Lederman, 1992), especially in improving students' understandings of science. The development of an adequate understanding of NOS must develop within teachers before we can expect it to development in students. Consequently, it is important to recognize the interplay between people's worldviews and their understanding of NOS. Ryan (2012) suggests that worldview is the framework within which teachers view NOS. Lui and Lederman (2007) explored the relationship between worldview and the conceptions of science and found that there was in fact congruence between understandings of NOS and worldviews.

Teacher beliefs about teaching and learning science are also closely aligned with their beliefs of NOS (Tsai, 2002). In this study, teachers who had traditional beliefs about teaching science also had traditional beliefs about learning science and about NOS. The same consistency existed with teachers who had 'process' or 'constructivist' beliefs. Tsai (2002) describes these closely aligned belief systems as 'nested epistemologies'. These 'nested epistemologies' are teachers' pedagogical beliefs of teaching and learning science, as well as their epistemological beliefs towards science. Tsai (2002) also discovered that the proportion of nested epistemologies in teachers seemed to increase with teaching experience. The implications of this finding on teacher reform are clear, as it will be more difficult to alter the nested epistemologies of experienced teachers. Embracing Indigenous knowledge may require not only changing teachers' beliefs about science, but also their beliefs about learning and teaching.

Science Teachers' Worldviews, Beliefs and Conceptions of NOS

With the emerging changes to our BC science curriculum we must recognize the critical role teachers will have in implementing Indigenous knowledge, especially if a new science curriculum does not fall in line with the already deep-seated worldviews, beliefs and conceptions of science held by teachers. Teachers ultimately have control of whether Indigenous knowledge is taught to their students. The hesitation, resistance, opposition and/or neglect to teach Indigenous knowledge in science, is a foreseeable challenge resulting from teachers whose worldviews, beliefs and conceptions of NOS differ from those related to Indigenous knowledge.

Countries, including Australia, New Zealand, Africa and the United States have started implementing Indigenous knowledge in their science programs (Aikenhead & Michell, 2011). The introduction of Indigenous knowledge in South Africa starting in 2005 generated debate and teacher opposition (Ogunniyi, 2007). These teachers were schooled in Western science and were more familiar with the Western worldview of science. The study revealed that teachers view science and Indigenous knowledge as two systems of thought that are separate and incompatible. Teachers regarded science as being universal and the process of discovering absolute truth, and Indigenous knowledge considered irrelevant to science. Tsai (2002) found that the majority of science teachers in his study held a traditional, empiricist or positivist views of science. These traditional beliefs were characterized by a perception of scientific knowledge as correct answers or established truths, teaching science as presenting the factual content of science and transferring it from teacher to students. In addition, learning science was described as acquiring or reproducing knowledge from credible sources.

Similar conceptions of science were observed by teachers in Canadian and American schools. The universal view of science was one of the strongest themes revealed from interviews with secondary science teachers (Blades, 2002). Teachers considered science to be culturally neutral or ‘culture free’ (Blades, 2002; Ryan, 2012). Teachers had a strong tendency towards scientism, the epistemological belief in empiricism and a lack of understanding of the nature of science, which Ryan (2012) suggests, leaves little room for the consideration of multicultural science. Guerra-Ramos, (2012), warns that stereotypical images of science, such as the scientisitc view of scientific knowledge, as well as limited perspectives of the world of science, are a ‘double-edged sword’ for teaching practice.

Stereotypical Images of Science

One stereotype or oversimplification of science exemplified by science teachers is the idea of a scientific method of inquiry that is linear, procedural and universal (Windschitl, 2004). The orderly, step-by-step quality of laboratory exercises that have predetermined outcomes creates the illusion that there is a universal method of science providing a fixed, non-negotiable body of scientific knowledge (Hodson, 1998). In Windschitl's (2004), this technical approach to the scientific method was subscribed by teachers who held degrees in science and were part of a highly regarded master's program in secondary science teaching. This type of scientific method lacks the epistemological bases of inquiry (Windschitl, 2004) and the complex, creative, and imaginative nature of the scientific endeavor (Abd-El-Khalick & BouJaoude, 1997; Lederman, 1992). In Tsai's (1999) study, a student viewed the purpose of laboratory exercises as ways to memorize all of the scientific truths. This misrepresentation of the scientific method in school science can only encourage a very restricted view of science (Guerra-Ramos, 2012) that dismisses that scientific inquiry can in fact take a variety of forms.

Impact of Teachers' Worldviews, Beliefs, and Conceptions of NOS

These worldviews and ideas about science are reflected in the discourse and actions of science teachers (Zeidler & Lederman, 1989) and have been found to be significant to the teacher's decisions about classroom strategies (Waters-Adams, 2006), including the role the teacher adopts in the classroom, the activities and assessment criteria they provide, as well as the way they organize and manage their classroom (Guerra-Ramos, 2012). In Waters-Adams' (2006) study, it was found that the practice of teaching science was shaped by a complex web of influence. Teachers' understanding of NOS, and their beliefs about teaching, learning and the curriculum, all impact their teaching practice.

Teachers' beliefs also influence their recognition of success and confidence in teaching. Their confidence in science practice exists when there is accordance between their beliefs about teaching and the understanding of the NOS (Waters-Adams, 2006). The study revealed that confident and effective teaching was not a matter of adequate knowledge, but the resonance of the knowledge within the individual. If Indigenous knowledge doesn't resonate with the belief system of a teacher, he or she will not be confident or effective in teaching it.

Waters-Adams (2006) also discusses a 'battleground' between espoused and tacit ideas of NOS that work within the complex web of influences. In normal practice, a teacher's tacit understanding had more effect on their teaching than their espoused ideas of NOS. With the time, support, and the reflexivity of action research in the study, the espoused understanding of teachers did change, however it did not become a dominant factor in their teaching. Guerra-Ramos' (2012) study revealed that the stereotypical images of science tend to be tacit and are rarely scrutinized or questioned by teachers. The study also established that these stereotypes are spread among teachers and their impact on teaching practices in science education need to be examined (Guerra-Ramos, 2012). This emphasizes the great importance of self-reflection and professional development programs that will work to transform both espoused *and* tacit understandings of NOS.

Teacher Language

These implicit conceptions of NOS are even embedded in teachers' language and are conveyed to students through regular classroom discourse (Zeidler & Lederman, 1989). Thus, language and discourse consistent with universal conceptions of NOS could reflect subsequent changes in students' understanding of NOS. Even if a teacher's espoused conceptions have changed, and he or she chooses to teach Aboriginal science, the discourse in which that science course is built upon may already convey a universal, empirical conception of science that is incompatible with Indigenous knowledge. A student who picks up on this conception will not consider Indigenous knowledge to be believable and will likely be unable to incorporate Indigenous knowledge into their established worldview. This suggests how important it is for teachers to reflect on the impact of both tacit and espoused worldviews, beliefs and conceptions of NOS.

The Formation of Teachers' Worldviews, Beliefs and Conceptions of NOS

Teacher Schooling and Education

A part of this reflection must consider how these worldviews and beliefs of science were formed. Researchers have found that it is teachers' schooling and pre-service teacher education that influence their beliefs and views about science (Hodson, 1998; Tsai, 2002; Windschitl, 2004). Teachers may hold traditional views of science because of their own school science experience reflected the same views. The instructive teaching styles and confirmatory laboratory exercises that teachers experienced during their education would have imposed traditional views (Hodson, 1998; Windschitl, 2004) of teaching, learning and of science (Tsai, 2002).

Teachers' science experiences also come from their years in pre-service education. Windschitl (2004) found that standard college science courses had little influence on teachers' understanding of NOS and did not prepare them to engage in the discourse of science. Tobin, Tippins and Gallard (1994) explain that teachers experience many years of schooling without being evoked to think about their own beliefs about NOS and how scientific knowledge has influenced them.

Research suggests that pre-service education and professional development programs are a necessity in the reform of teachers' worldviews, beliefs, and the understanding of the NOS (Blades, 2002; Hodson, 1998; Little Bear, 2009; Ogunniyi, 2007; Ryan, 2012; Tsai, 2002; Tsai, 2006; Waters-Adams, 2007; Windschitl, 2004). A successful implementation of Indigenous knowledge in British Columbia's science curriculum will also require, pre-service and in-service teacher education. However, research also suggests long-standing belief systems may not be easily altered by education and training (Ogunniyi, 2007; Parajes, 1992; Tsai, 2006). In Ogunniyi's (2007) study of effectiveness of a Practical Argumentation Course, several teachers reverted back to their original conceptions of science in the delayed post-tests. Parajes' (1992) synthesis of research revealed that the earlier beliefs are formed, the more difficult they are to alter. His findings also suggest that people hold onto beliefs that are based on incorrect or incomplete knowledge, even if reason, time, education, and experience contradict their beliefs. It will take carefully created and implemented instructional and educational teacher programs to successfully enhance teacher understanding and acceptance of other worldviews.

Background and Culture

Culture, family, social interactions, religion and education form the core beliefs of worldview. Yalaki (2004) uses a suitable analogy to describe this relationship between worldview, beliefs and culture:

> If worldview is the tree, beliefs are the branches and the forest is culture… To understand the branches, we need to be able to see the tree and even the forest as a whole. (p. 30).

A teacher's culture therefore has significant influence their beliefs and worldviews. The majority of teachers in Canadian schools are white (Ryan, Pollock, & Antonelli, 2009). The typical elementary school teacher is: female, white, middle class, heterosexual, able-bodied, Christian and Canadian-born (Bascia, 1996). Ryan et al. (2009) found that there are proportionally many more students of colour than there are educators of colour. The diversity represented by our student population is thus not represented by our teachers. Surprisingly, the gap between the groups appears to be widening (Ryan et al., 2009).

These findings suggest that the majority of educators in Canada belong to the same dominant Euro-Canadian culture represented in the Canadian science curriculum. This synchronization between the dominant teacher culture and the science curriculum indicates it may not be an easy task for teachers to change their beliefs and worldviews of science. They are secured in their beliefs, and safe within a culture dominated by Western, Euro-centric tradition. This also explains why teachers do not recognize the impact of their own culture. In Ryan's (2012) study teachers appeared to be unaware of their own cultural stance, white privilege and the nature of structural racism.

Teaching Indigenous knowledge within science will require teachers to examine their worldviews, beliefs, conceptions of NOS and cultural positions. Only then will teachers be able to recognize the significance of teaching a class of diverse students with multiple worldviews. The diversity of worldviews held by students does not necessarily resonate with the traditional views of represented by their teachers and the curriculum, and consequently many students become alienated.

As already discussed, Aikenhead (20010) describes learning science as a cross-cultural event, and the moving between worldviews as border-crossing. Students need to view science as one way of viewing the natural world, rather than the only way. Teachers have the critical role of assisting students they cross these borders (Aikenhead, 2001). However, teachers themselves need assistance in border-crossing. This points out the necessity of professional development programs in assisting them in that transition.

Chapter 4: An examination of BC's Science Curriculum

British Columbia's Science Curriculum

In the last few decades, Indigenous knowledge has continued to gain attention among educational researchers and provincial education systems across Canada (Aikenhead, 1997, 2001, 2002a, 2006; Aikenhead & Elliot, 2010; Aikenhead & Jegede, 1999; Alberta Education, 2013; BC Ministry of Education, 2013; McConney,A., Oliver,M., Woods-McConney,A., & Schibeci,R, 2011; Mckinley, 2005; Ontario Ministry of Education, 2011; Saskatchewan Ministry of Education, 2011; Snively & Corsiglia, 2001). In British Columbia, the ministry of education has established its support for Indigenous knowledge in the British Columbia's school curriculum, and it also emphasizes the value of Aboriginal science in coexistence with Western science. This is evident in the introductory sections of British Columbia's science K-12 curriculum (Table 1).

Table 1. Introduction to Science K to 12 (Sciences Curriculum Documents, 2013)

Aboriginal Content in the Science Curriculum – K-10 Curriculum Documents
The science curriculum guide integrates prescribed learning outcomes within a classroom model that includes instructional strategies, assessment tools and models that can help teachers provide all students with an understanding and appreciation of Aboriginal science. Integration of authentic Aboriginal content into the K to 10 science curriculum with the support of Aboriginal people will help promote understanding of BC's Aboriginal peoples among all students. The incorporating of Aboriginal science with Western science can provide a meaningful context for Aboriginal students and enhance the learning experience for all students. The inclusion of Aboriginal examples of science and technologies can make the subject more authentic, exciting, relevant and interesting for all students.
Science K-7 Curriculum Documents
Numerous difficulties arise when trying to incorporate indigenous knowledge and world views into the Western science classroom. The participants of the Ministry of Education Aboriginal Science meetings therefore suggest a model involving a parallel process, where Aboriginal and Western understandings exist separately, yet side-by-side and in partnership with one another.

Each side is enriched by the contrasting perspective that the other brings to any discussion. Aboriginal peoples are calling for this type of relationship with Canadian schools in a variety of settings (e.g., Ministry documents, science textbooks and curriculum materials, and teaching methods).

Working with the Aboriginal Community
Science K-10 , Senior Science Curriculum Documents

The Ministry of Education is dedicated to ensuring that the cultures and contributions of Aboriginal peoples in BC are reflected in all provincial curricula.

The recognition of Aboriginal science by the ministry of education is a significant development however, a closer look at British Columbia's K-12 science curriculum Prescribed Learning Outcomes (PLO's) gives a better indication of how well Aboriginal science is being supported by the curriculum. PLO's are the legally required content standards for British Columbia's education system. They set out the required skills, attitudes and knowledge, as well as, what students are expected to know and be able to do by the end of the course. The PLO's for science K-10 are grouped into the following organizers: Processes of Science, Life Sciences, Physical Sciences, and Earth and Space Science. The curriculum document points out that the organizers are not intended to suggest a linear delivery of course material, and that the Processes of Science PLO's are to be integrated into the curriculum throughout the year. While the organizers are the same for all grades, the topics within the curriculum organizers are different for each grade. For instance, the topic for Life Science in Science 9 is reproduction and in Science 10 it is sustainability of ecosystems. Along with each of the PLO's are suggested achievement indicators, which are statements that describe what students should be doing to demonstrate that they fully meet the expectations set out by the PLO's. Table 2 shows an example from Science 9.

Table 2. Grade 9 Physical Science: Atoms, Elements, and Compounds (Science 9 Integrated Resource Package, 2006, p. 45).

Prescribed Learning Outcomes	**Suggested Achievement Indicators**
It is expected that students will:	*The following set of indicators may be used to assess student achievement for each corresponding prescribed learning outcome.* *Students who have fully met the prescribed learning outcome are able to:*
C1 use modern atomic theory to describe the structure and components of atoms and molecules	▪ describe the development of atomic theory, including reference to Dalton, Rutherford, and Bohr ▪ distinguish between atoms and molecules ▪ identify the three subatomic particles, their properties, and their location within the atom

Aboriginal Content in British Columbia's Science Curriculum

The introduction to the K to 12 science curriculum clearly advocates for Aboriginal science and provides a notable explanation for teaching Aboriginal science alongside the Western curriculum (Table 1). However, the prescribed learning outcomes indicate that only a few outcomes actually contribute to achieving the overall goals of Aboriginal science defined in the introduction (Table 3). Only 1 of the 23 PLO's and 2 of its 79 suggested achievement indicators in the Science 9 curriculum make reference to Aboriginal science. In Science 8, none of the PLO's refer to Aboriginal science, and 1 of its 86 achievement indicators includes an Aboriginal science outcome. The same is similar for all of the Science K-12 curriculum documents (Table 3). This is a small number to make an adequate presence within the curriculum. Aboriginal content in all of the senior courses, with the exception of the sustainable resources course, is nonexistent.

Table 3. Aboriginal Content Within the Science K-12 Curriculum

Course	**Total Number of PLO's**	**Number of Aboriginal PLO's**	**Total Number of Suggested Achievement Indicators**	**Number of Aboriginal Suggested Achievement Indicators**
Science K	10	0	21	0
Science 1	10	1	20	2
Science 2	12	1	30	2
Science 3	11	1	29	2
Science 4	11	1	26	1
Science 5	13	1	29	3
Science 6	12	0	34	1
Science 7	12	0	40	1
Science 8	24	0	86	1
Science 9	23	1	79	2
Science 10	22	0	95	2
Biology 11	17	0	91	0
Biology 12	29	0	146	0
Physics 11	18	0	94	0
Physics 12	22	0	134	0
Applications of Physics 11	35	0	157	0
Applications of Physics 12	20	0	100	0
Earth Science 11	16	0	84	0
Geology 12	21	0	104	0
Sustainable Resources 11	30	0	110+	10
Sustainable Resources 12	81	0	110+	10
Science and Technology 11	40	2	140+	4

In this existing framework, the PLO’s for Aboriginal science appear to be ‘add-ons’ and interpreted as optional or negligible or left out altogether. Although clearly visible in the introductory sections, there is little evidence for the existence of Aboriginal science in the curriculum framework itself. There is not enough Aboriginal content in the curriculum for it to be considered a meaningful integration of Indigenous knowledge and Western science.

The infrequent inclusion of 1 or 2 Aboriginal science PLO’s also contradicts the holistic nature of Indigenous knowledge. Adding a few Aboriginal PLO’s to the existing checklist of

PLO's is not inclusionary of the Aboriginal science or any Indigenous worldview if the structure of the curriculum still reflects that of a WMS worldview. Both the framework and content of the curriculum reflect a Eurocentric worldview. The framework of the curriculum lends itself to pedagogical practices reflective traditional WMS, rather than experiential, purposeful, relational practices of Indigenous knowledge. Teachers are responsible and accountable for teaching a vast amount of content within tight time frames. The use of standardized assessment methods, add pressures of teacher accountability. To this end, teachers often rely on the use of textbooks and lectures to ensure all material has been covered by exam time. Inevitably, students end up memorizing enormous amounts of information to satisfy the demands within classroom learning. These pedagogical practices are at odds with Indigenous teaching and learning. Gaining knowledge through intuition and personal experience runs counter to the Western science perspective, which values objectivity, linear ways of thinking and the categorization of knowledge (Cajete, 2000). Experiential and holisitic ways of knowing, characteristic of Aboriginal science, are less likely to occur with the framework of the current curriculum. If the Ministry of Education is genuine in its advocacy of Aboriginal science, then bigger reform of the curriculum is necessary. A science curriculum whose structure and content reflects and support Indigenous worldviews is essential.

Goals for Science Learning

British Columbia's Ministry of Education's goals for science differ from that of Aboriginal science. The science curriculum's rationale for science includes preparing students for further education and for their adult lives. It is designed to develop scientific knowledge, skills and attitudes that will be relevant to their futures and their everyday lives. The introductory section of the science curriculum also promotes Aboriginal science and TEK, however, the PLO's of all of science curriculum documents do not as Aboriginal science makes up less than 1% of the curriculum content. Most of the curriculum is comprised of Western scientific content that is more preparatory of a future career in science than it is of everyday life.

This emphasis on careers in science is evident throughout the country. Chin, Zanibbi, Dalgarno, Poth, Ayala, Hutchinson & Munby's (2007) analyzed the objectives and goals of all the science curriculum documents from the 13 Canadian provinces and territories. There were 108 curriculum documents analyzed, and 747 statements found that reflected life after school. The largest single group of statements pertained to careers in science at 43%. Less than 3% of the statements made direct reference to the workplace and about 9% of the statements referred to the importance of being life-long learners, the majority of which were in the preamble sections and provided no specific teaching or learning strategies. These findings were reflected in British Columbia's documents as well, however reference to life-long learning was worse than the national average, having zero reference statements.

Why is there such a focus on science careers rather than the future workplace, or the application of science in other fields, or on Aboriginal science? The senior science courses offered, including biology, chemistry and physics are courses that are required for university entrance. The focus on a career in science originates from a curriculum that was formed in response to the cold war and Russia's launch of Sputnik, which both initiated the promotion of military, economic and technological developments (Blades, 2000; Gaskell, 2002). These interests also coincided with the interests of university scientists who wanted to update the science curriculum (Gaskell, 2002). Scientists believed that science would lead to future inventions and medical advances that would benefit the physical and mental health of the population. To meet these needs, the science curriculum was reconstructed to encourage science careers (Blades, 2000; Gaskell, 2002). However, the former Science Council of Canada (1984) conducted a study that found that students weren't drawn to science careers. In fact, students were ignoring science related careers and were developing poor attitudes towards science while enrolled in science courses (Blades, 2000).

A science curriculum that was only relevant to a few future scientists proved to be ineffective. It was also not enough to address the personal or societal problems involving science and technology (Gaskell, 2002). As a result, a new approach to science education, known as science, technology and society (STS) was initiated and met with enthusiasm across the country. Nevertheless, the programs and efforts resulted in little change to the curriculum (Blades, 2000; Gaskell, 2002). A science education that had been rooted in the mastery of content proved to be inflexible because teachers had difficulties accepting any of the STS programs and resources offered (Blades, 2000). Blades (1997), Fensham (1993, 1998) and Glaskell (1989) reveal another obstacle which was that universities made it clear that any courses that deviated from the traditional models of science would not be accepted for university acceptance (as cited in Glaskell, 2002, p. 62) This unfortunate attempt to realize curriculum change warns of the difficulties there will be to realizing a curriculum that authentically integrates Aboriginal science.

Gaskell (2002) investigates how the power of a few university scientists can have over the science curriculum of secondary schools, even with-government pressures to reform. This power rests on the ability of university scientists to control what is accepted for university entrance. Since possessing a university degree has a high correlation with future income and social status, parents and students are easily persuaded by their control. Fensham (2002) argues that societal experts rather than scientists need to be the drivers of science curriculum, so that a science for all future citizens, rather than for possible future scientists, can be established. He contends that scientists and science educators have a biased judgment of what science with ordinary citizens is like. Societal experts, such as applied scientists who work in an industry that puts them in contact with the public, have a better understanding of what the science interface with society is really like (Fensham, 2002).

To compliment Aboriginal science in the curriculum, a shift needs to occur from our current focus on preparing for a career as a scientist, to a focus on the development of responsible citizenship. Western standards of competition, rivalry, and survival of the fittest lie beneath the current goals of our education system. In Aboriginal learning, the value of individual learning cannot be separated from its contribution to the collective well-being (Canadian Council on Learning, 2009). A science curriculum focused on life-long learning, community involvement, relationship building and responsible citizenship would harmonize with Indigenous knowledge (Little Bear, 2009).

Assessment Methods

Another obstacle to Aboriginal science in the curriculum is the reliance on conventional teaching and assessments methods that recognize success as a measure of quantitative indicators on standardized assessments. In British Columbia teachers must provide formal reports that indicate the student's level of performance as it relates to the learning outcomes for each subject or course and grade (Reporting Student Progress: Policy and Practice, 2009). The letter of performance in Grades 4-7 are represented by letter grades and in Grades K-3, a performance scale. Other standardized assessments required by the Ministry of Education in British Columbia are the annual province-wide Foundation Skills Assessment test, which is administered in Grades 4 and 7, as well as the provincial exams administered in grades 10, 11, 12 for designated courses, including Science 10, and up until September 2011, Biology 12, Physics 12, Chemistry 12. These provincial exams are the provincial large scale assessments designed to allow individual students to demonstrate they have met provincial graduation requirements (Handbook of Procedures for the Graduation Program, 2012). Other standardized assessments used in British Columbia include national and international assessments, such as the Pan-Canadian Assessment Program (PCAP), the Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA).

Standardized instruction and assessment is known for its many shortcomings in reaching the diversity of students and learning styles (Cappon, 2008; Ginsberg, 2005; Jenkins & Keefe, 2001; Making a Difference, 2010; Subban, 2006, Tomlinson, 2000), and it is at odds with Indigenous learning. Current standardized assessment methods fail to take into account the diversity of learning styles, learning needs, experience and backgrounds of students (Making a Difference, 2010) and well as the Indigenous view of learning (Cappon, 2008). Cappon (2008) believes that standard assessments are not the only way to measure achievement, as they:

> Tend to emphasize learning deficits of Aboriginal people, while ignoring positive outcomes. They often overlook the special economic, health and social barriers to learning experienced by Aboriginal communities. They focus on high school or postsecondary education, rather than on the full spectrum of lifelong learning. They stress years of schooling and performance on standardized assessments, but ignore holistic learning that engages the physical, spiritual, mental and emotional dimensions. They ignore the importance of experiential learning and traditional activities outside the classroom. The result is that conventional reporting on learning

> success of Aboriginal people provides only a partial picture and therefore does not support effective policy development. (p. 61)

Knowing student background, culture, history, values and beliefs are important in differentiating instruction so that all students are reached (Making a Difference, 2010). Differentiated assessment is based on the reality that the needs of students cannot all be met in the same way, yet our education system continues to use standardized forms of assessment. Using multiple forms of assessments, rather than standardized ones, would not only meet the needs of Aboriginal students, but the diversity of all students.

British Columbia's science curriculum poses several obstacles to the authentic incorporation of Aboriginal science. Its structure, content, goals and assessment methods continue to reflect a Eurocentric worldview. This poses a greater threat to the incorporation of Aboriginal science if teachers' scientific worldviews and beliefs struggle to accept Indigenous science as valid within Western science. Teachers need a curriculum that will assist them as they open up their worldviews, beliefs and conceptions of NOS, to support Aboriginal science. Reform to the content, structure, goals and required assessment methods of the current science curriculum is vital if Aboriginal science is to be represented with integrity.

Chapter 5: Towards a Genuinely Inclusive Science Curriculum

Recommendations for an Inclusive Science Curriculum

Paradigm Shift

British Columbia's Ministry of Education's effort to include Indigenous knowledge in its science curriculum is step in the right direction, however, more needs to be done to genuinely integrate Indigenous knowledge into the curriculum. The first step to a successful and genuine implementation of Indigenous knowledge in the science curriculum requires a paradigm shift from worldview that embodied by a universal perspective, to a worldview that embraces a multicultural perspective of science. To initiate the shift, science education must first be represented as science really is, revealing the elements of NOS, rather than preserving the fallacies of WMS depicted in school science. Stereotypes of science continue to perpetuate inaccuracies and misconceptions that ultimately prevent any acceptance of other science perspectives. Cleminson (1990) claims that the portrayal of science as an impersonal and unproblematic subject of study must be deserted. He extends this sentiment by asserting that " if real scientists have so little in common with the stereotype [a scientist as a rather eccentric, bespectacled, and white-coated male living in a world apart from the one in which the rest of the population lives] projected by the science curriculum, it is high time that this stereotype be abandoned" (p. 438). Osbourne (2007) shares a similar standpoint on the portrayal of science and points out several fallacies of the foundation on which our science curriculum rests. These fallacies parallel Cleminson's foundational assumptions for a new science curriculum outlined already in chapter 2. A synthesis of some of Cleminson's (1990) and Osbourne's (2007) assumptions of science should be the foundation of a science that is true to itself:

1. Scientific knowledge is tentative and should never be regarded as universal truth.

2. Science is not objective, detached and value free. The view that a scientist is a detached observer of the world is false. Scientists study in a world of which they are a part of, not in one from which they are apart.
3. Science is a socially-situated product of culture, as well as and the values, interests and prior knowledge of scientists.
4. The existence of a singular scientific method is false. Scientists have rarely used such a prescriptive method to make significant discoveries. Different methods are practiced in different subsets of science.
5. The bounds of science are too vast to try to teach all of it in a science curriculum. The quality of the science experience is more important than quantity.
6. Diverse people in diverse places are not best served by a homogenous curriculum. Students should be offered a variety of science courses to meet their different needs.

Understanding science, as it really is, makes it more compatible to Aboriginal science. This paradigm shift that recognizes the coexistence of multiple worldviews will have to transpire on more than just a theoretically and scholarly level. This paradigm shift must become visible within all levels of society. This can only be achieved with the transformation of teachers' worldviews and notions of science, as well as with actual curriculum reform.

Reform of Teachers Worldviews, Beliefs and Conceptions of NOS

Pre-Service Teacher Education

Inclusion of Indigenous knowledge in the science curriculum entails philosophical as well as practical changes that go beyond the simple addition of a few PLO's to a dominantly Western science curriculum. Fundamental changes in the worldviews of a dominant Western culture can be modified with a combination of a curriculum's reformed conceptual framework and the alignment of teachers' beliefs with that conceptual framework. Worldviews, beliefs and ideas about science are reflected in the practice of teaching (Guerra-Ramos, 2012; Waters-Adams, 2006; Zeidler & Lederman, 1989). Teachers need to be aware that other forms of science exist and that their legitimacy as a science has been an issue of debate for some time. Blades (2002) found that teachers in his study had never considered science to embody elements of culture, much less represent Eurocentric elements. He suggested that secondary school teachers demonstrate a form of "cultural blindness" to the Eurocentric nature of their subject area. How can teachers become more cognizant to the limitations of Western science and their own worldviews?

This first step in changing teacher beliefs can be achieved with critical self- reflection of their own worldview, beliefs and ideas about science, as well as with an examination of the impact of their education, and beliefs on their teaching practices. Teachers also need to be aware of the elements that distinguish their own culture from that of the students, and uphold an affirmative attitude for both cultures (Friesen & Ezeife, 2009). Ryan's (2012) research indicated that significant progress will not be made in multicultural science education unless teachers recognize the role of their own worldviews, and cultural beliefs in the classroom, as well as the impact of their white privilege.

Peggy McIntosh (2002) discusses the concept of white privilege and describes it as an invisible backpack of unearned assets, which people are oblivious to. It is the power and privilege of whites to ignore their own race (Wildman & Davis 2002). McIntosh (2002) explains that whites are taught to think of their lives as normative, average and ideal, thus try to help those that are different by making 'them' more like 'us.' Given that the majority of Canadian teachers are white (Ryan, Pollock, & Antonelli, 2009), teachers may fail to recognize that they may be marginalizing students whose ethnicities, backgrounds and values differ from that of Western culture. By measuring Aboriginal and other ethnic students against Western standards, teachers may be unknowing putting them at a disadvantage. Before teachers can reconstruct this hidden power system, they need to know it is there, as well as their position in it.

Ryan (2012) also asserts that any school district attempting curriculum reform which encourages multiculturalism would unquestionably need to begin with a program of self-assessment for teachers, so that they can be assisted in examining and evaluating the impact of their own cultural beliefs in the classroom. This type of program will also support teachers as they cross their own cultural borders, which is essential if they are expected to support their students as they cross borders. Brand and Glasson (2004) emphasize the importance of teacher education programs in assisting pre-service teachers with border-crossing. They contend that by providing pre-service teachers with experiences that require them to assess their beliefs as related to their own identities, that they will enhance their abilities as effective teachers in diverse settings.

Teacher education programs need to do more than just make pre-service teachers aware of the diversity that exists. Informing them more about the ‘Other’ or providing them with strategies or tools for diverse classrooms is not satisfactory. Teacher education programs must focus on self-examination and engaging pre-service teachers to become of aware of the complexities of diversity. Pre-service teachers need to understand their position in hidden power systems and what it means to be seen as diverse. Johnston et al.’s (2009) action research project revealed that even when pre-service teachers we asked to consider a personal awareness of their own behaviors and beliefs, they avoided engaging in challenging and critical self-assessments.

In fact, the reflection on diversity served to contribute their need to feel good about themselves, and their openness to diversity rather than to critically examine themselves and their role in reinforcing incorrect perceptions of others. This makes it clear that engaging pre-service teachers in being genuinely reflective is complex, and that long-term programs might be a better context for deeper engagement in reflection and self-examination.

Pre-service teacher education courses in cultural studies and the philosophy of science are also essential. Some universities in Canada, such as the University of Victoria and the University of Saskatchewan, have already taken the step of including an Indigenous Education course as a required course for the teacher education program. Little Bear (2009) insists that if teachers are to respond to the needs of Aboriginal students, then teachers need to start by knowing something about the culture, history and social situations of Aboriginal students. This inclusion of Indigenous content at the university level must be implemented in the faculty of science as well. However, this must be facilitated in conjunction with implementing courses that will provoke pre-service teachers to explore the foundations and epistemological underpinnings of Western science and help them conceptualize science as a way of knowing the world rather than as a canon of content (Windschitl, 2004). Courses need to be dialogic, enable open-ended discussions, and enable students' meaning making about science in a reflective manner (Höttecke & Silva, 2011).

Making philosophy of science, history of science and/or NOS courses not just an option, and instead a graduation requirement for a Bachelor of Science degree, will ensure that secondary teachers with B.Sc degrees have been induced to thinking about the epistemological basis of science. Abell and Smith (1994) and Gustafson and Rowell (1995) consider the teacher's schooling to be the most crucial factor in the construction of understanding of science (as cited in Waters-Adams, 2006). Windschitl (2004) points out that pre-service teachers develop many ideas about science that are constructed over years of schooling, the most recent and most involved of which, come from their science experiences as undergraduates. He also claims that the model of inquiry that pre-service science teachers are exposed to in post-secondary education are not unlike the confirmatory laboratory experiences found in high school. Trumbull and Kerr (1993) found that typical undergraduate biology laboratory classes were highly scripted and controlled (as cited in Windschitl, 2004). As a result, students were unable to carry out the inquiry or even understand the reasons for collecting data because they had not been exposed to discussions about science as a discipline.

In order for teachers to incorporate multicultural and Indigenous worldviews, university science courses must provide an opportunity for pre-service teachers to become more critically aware of science as a discipline, as well as its connections in Aboriginal science. Teachers will need to come to know before they are able to incorporate Indigenous knowledge into their science classrooms. University science courses and teacher education programs must start preparing pre-service teachers for this task.

Professional Development

Since belief systems are harder to change the longer they are held (Parejes, 1992), professional development in these areas is essential for an integration of Indigenous knowledge into the science curriculum. Ogunniyi's (2007) study provides insight into the effectiveness of professional development programs whose purpose is to enhance teachers' understanding of and ability to implement Indigenous knowledge in the science curriculum. The South African Science-Indigenous knowledge systems (Science-IKS) curriculum introduced in 2005, was met with teacher opposition. Ogunniyi (2007) sums up four main reasons to the opposition:

1. The fact that teachers have been schooled in Western science and hence are more familiar with that worldview than that of IKS.
2. The new curriculum demands new instructional approaches and goals in terms of contextualization and indigenization rather than the mastery of a collocation of scientific information for examination purposes.
3. The top-down approach in which the curriculum was implemented seemed to underrate teachers' role in curriculum planning and implementation.
4. The lack of clarity on how a Science-IKS curriculum could be implemented. (p. 964)

All of these reasons are common to the challenges of implementing Indigenous knowledge into British Columbia's science curriculum. To equip science teachers with the knowledge and instructional skills needed to implement an integrated curriculum, Ogunniyi's study used a six month Practical Argumentation Course (PAC) to introduce a group of teachers to the process of implementing a Science-IKS curriculum. The instructional model provided the much needed intellectual or dialogical space for the teachers to voice their views and concerns about the new curriculum without feeling a sense of intimidation. It also gave the teachers an opportunity to critically examine the curriculum more closely, and develop instructional strategies compatible to the new curriculum. The study found that the course not only enhanced their understanding of Indigenous knowledge and the nature of science, it also increased their awareness of the need to implement Indigenous knowledge into their classrooms. At the end of the course, the teachers in the study expressed that without adequate training, followed by a long-term mentoring program, they would not have been able to implement the reformed curriculum successfully.

The implications of this study for professional development in British Columbia are critical. Not only do our teachers need a carefully and extensively developed program to be adequately equipped in integrating Indigenous knowledge, the program needs to be a long-term mentoring program. Many professional development programs in British Columbia consist of a two to three hour, or day long workshops, and mentoring programs at the provincial level not mandated. Abd- El-Khalick and Lederman (2000) claim it is highly unlikely that the views of science, which have been developed over 14 years of high school and university, will be effectively reformed during a few hours, days or even weeks. In fact, short-term professional development activities are unlikely to be successful in creating long-lasting effects since results are limited to a "honeymoon-effect" (Lindner, 2008 as cited in Höttecke & Silva, 2011, p.309). After completing workshops, teachers often feel excited about a new curricular idea, but the positive attitude and enthusiasm are often not long-term. Yoon and Kim's (2010) study found that personal reflection in combination with collaborative reflection among teachers, pre-service teachers and teacher educators creates healthy and interactive discussions in which participants can learn from each other and expand their perspectives. Both pre-service and professional development program must carefully be developed so that teachers can be successful in teaching Aboriginal science. These improvements however, are only part of the solution to a successful inclusion of Aboriginal science in the curriculum. The content and structure of the curriculum must also be reformed in order to support teachers.

Curriculum Reform

Changes to Curriculum Goals

Science education in British Columbia is "designed to provide opportunities for students to develop scientific knowledge, skills, and attitudes that will be relevant in their everyday lives and their future careers" (BC Science 9,2013, p. 11). Yet much of the content goes beyond what students need to know to be scientifically literate citizens. The science curriculum prepares students with a foundation in science needed to continue onto a career in science. Tests and standardized exams imposed on students leads to the memorization of scientific facts that practicing scientists do not bother memorizing. In the end, the needs of the minority (future scientists) are met, and the needs of the majority of students (future citizens), are not. Osborne (2007) stresses that the majority of students need "more than a knowledge of basic concepts of science, but also a vision of *how* such knowledge relates to other events, *why* it is important, and *how* this particular view of the world came to be" (p. 174). The goal of responsible citizenship runs parallel to the essence of Indigenous knowledge. The responsibility of group members to their community is a fundamental element in Indigenous cultures (Cajete, 2000; Fixico, 2003; Inuit Women's Association of Canada, 2006). Developing a worldview that is cognizant of other worldviews and perspectives of science should be foremost to memorizing scientific facts of WMS. Eliminating the pressure to train students in becoming future scientists, a greater focus can be placed on connecting Indigenous knowledge, as well as other forms of science, with WMS.

To aid the integration of Aboriginal science in high school courses, the current drivers of curriculum, university scientists, either have to accommodate to the curriculum reform by changing their entrance requirements and accepting a broader range of science courses, or cease their influence on high school education completely. Chin et al. (2007) indicated that curriculum documents across Canada reflected careers in science, with only a few referring to the general workplace, and in British Columbia, none referring to life-long learning. Societal drivers of education could have a positive effect achieving work-based and life-long learning goals in science for the majority of students who will not proceed with careers in science. These goals would also complement Indigenous knowledge. Universities can make a few changes to their entrance requirements that would support these goals while still maintaining an assurance of students that will head to universities. The majority of high school students are not secure in their plans after school, and so they want to keep as many doors open as possible. Admission requirements for the science department at universities in such as the University of Victoria are having completed two of the following: Physics 12, Chemistry 12, Biology 12, Geology 12, and Geography 12. Schools often only offer the first three courses listed. Courses, such as Sustainable Resources 12, are often not accepted for entrance. Attending post-secondary education is an option that students do not want to hastily close a door to by taking a non-admissible course. To keep their options open, students often take the admissible science courses even though they will most likely not continue on in a career in science.

Curriculum Content

One of the apparent flaws with the current science curriculum in British Columbia is the lack of content reflecting Aboriginal science. The support for Indigenous knowledge is clear in the preamble sections of the curriculum, but this is disappointedly reflected in the actual curriculum objectives themselves. Höttecke and Silva (2011) remind us that the curriculum is an instrument for moderating educational systems because it determines education goals, content and activities to be taught. Thus, they should support teachers by embedding concrete content, ideas, suggestions, activities and practice examples of Indigenous knowledge into the curriculum documents (see appendix for an example). This support will facilitate teachers in implementing Aboriginal science, rather than leaving it entirely up to them, especially when their beliefs and worldviews, lack of Indigenous knowledge and resources are already an obstacle.

Inclusive Teaching Practices

Another challenge to overcome is the differences in teaching styles reflective of Indigenous knowledge and our current curriculum. The Western model of transferring, and passively accumulating knowledge does not support the learning distinctive of Indigenous peoples. In fact, the one-size-fits all approach to teaching does not support the learning any group of students, given that classrooms are made up of a range of learning styles (Making a Difference, 2010). Reliance on textbooks, lectures, note-taking, memorizing facts are often the methods used in by teachers and students in science classrooms. Changing teaching methods to include multiple ways of learning, including experiential, cooperative, and hands-on learning, are not only long-awaited improvements to present teaching practices, they are be consistent with Indigenous ways of *coming to know*. To make these changes possible, teachers must be supported by a vision and curriculum that give them the time and flexibility to use a broader range of teaching methods. Teachers often complain that too much content and additional time restraints limit the variety of teaching and assessment methods. However, a curriculum that does not overload students with the science fundamentals needed to be a scientist will allow for the use of more teaching methods. Less content will also mean that teachers can differentiate their instruction to meet the needs of all of their individual students.

Differentiating instruction also means knowing every learner, providing choice in learning experiences, as well as being flexible in the assessment methods used (Making a Difference, 2010). For example, using oral learning and various methods of communication for assessment, including demonstrations, oral explanations, and storytelling, would be attentive to Indigenous traditions. Knowing student background, culture, history, values and beliefs are essential in differentiating instruction (Making a Difference, 2010) and are also critical in understanding the needs of Aboriginal students (Little Bear, 2009).

Science teachers will have to remember that they are cultural brokers or “tour guides” and assist students in border-crossing (Aikenhead, 1997). This will ensure that students gain access to other worldviews without losing sight of their own identity (Aikenhead, 2002a). This means that science teachers should be able to incorporate spirituality, dreaming, storytelling, ritual and ceremony without jeopardizing the integrity of either WMS or Aboriginal science. As cultural brokers, teachers can explain the meaning that comes out of these forms of experiencing and perceiving the world, and the inherent relationship and respect for the environment that ensues.

Culturally Valid Assessments

Friesen and Ezeife (2009) contend that in order to develop connections between Indigenous knowledge and the science curriculum, teachers need to be aware of the elements that distinguish their own culture from that of the students, and uphold an affirmative attitude for both cultures. They also attest that this will improve cross-cultural communication and assist in creating more culturally relevant assessments, as well as removing cultural bias.

Classroom science assessments that are developed from Western science perspectives, with little or no integration of Aboriginal science perspectives, will lead to Aboriginal students’ scores that are not a valid reflection of their scientific knowledge (Friesen & Ezeife, 2009). For example, time-limited tests penalize students from cultures that value reflection of thought over quick response (Common & Frost, 1992, in Friesen & Ezeife, 2009). This situation has led Solano-Flores and Nelson-Barber (2001) to propose that cultural validity should be a component of science assessment practices. They point out that people who are external to a cultural group tend to make overgeneralizations and rely on cultural stereotypes, thus creating assessments based only on cultural stereotypes or one cultural model will not achieve cultural validity. Instead assessments must be developed from a sociocultural perspective that combines both social and cultural contexts (Friesen & Ezeife, 2009).

Solano-Flores and Nelson-Barber (2001) describe cultural validity as the effectiveness in which science assessments address the sociocultural influences that shape student thinking and the ways in which students make sense of and respond to science. The sociocultural influences "include the values, beliefs, experiences, communication patterns, teaching and learning styles, and epistemologies inherent in the students' cultural backgrounds, as well as the socioeconomic conditions prevailing in their cultural groups" (Solano-Flores & Nelson-Barber , 2001, p. 555). Solano-Flores and Nelson-Barber (2001) emphasize that these socioeconomic influences should be used as tools for improving science assessments. They point out that not taking into account cultural differences in communication styles, for instance, may produce inaccurate perceptions of student performance.

Friesen and Ezeife (2009) emphasize that Canadian science educators require access to relevant Indigenous knowledge and meaningful community collaboration with Aboriginal Elders to develop culturally valid assessments. Solano-Flores and Nelson-Barber (2001) met with Yup'ik Elders to validate an assessment on making kayaks using body measurements. The first attempt was to have the Elders take the assessment individually, as if they were students, however, this was not successful. Working individually was inconsistent with the way Elders relate to each other. The meeting only became productive when the Elders were able to solve the kayak problem together as a team. Without the collaboration of educators with the Elders, they would not have understood the communication and socialization styles needed in developing a culturally valid assessment for the kayak activity.

Estrin and Nelson-Barber (as cited in Friesen & Ezeife, 2009) suggest that science assessments should use cultural resources that children are familiar with, use open-ended questions and avoid multiple-choice questions, true/false questions, and tightly timed formats. They also stress that teachers need to begin with what their students know, believe, and practice in their daily lives. Solano-Flores and Nelson-Barber (2001) demonstrate how student epistemologies can help assess the quality of science assessments in their investigation into the National Assessment of Educational progress (NAEP). An interview with a Latino girl who incorrectly answered a question about erosion, revealed that her sociocultural influences were most likely the reason she incorrectly answered the question, not because of an insufficient understanding of erosion. The erosion question shows two pictures, each with the same mountain and a river flowing through it. In one picture the mountains are low and round, and the river is wide, whereas the other shows the mountain with high pointy peaks and a narrow river. The question asks the student to choose which picture shows how the river and mountains look now in present day, as opposed to millions of years ago.

The Latino girl's reason for incorrectly picking the high peaked mountain was that it was the most familiar to her, as she had never seen a low mountain range in her experience. According to her epistemology, low mountain ranges were in the past because she had never seen them before. Solano-Flores and Nelson-Barber (2001) claim that this question privileges students whose first-hand experience is with low and round mountains over students whose first-hand experience is with pointy mountains. The example delineates how current approaches to assessment do not focus on understanding student epistemologies and the sociocultural influences that shape thinking.

British Columbia's current reliance on provincial standardized tests for assessment, as well as the reliance of standardized tests within science classrooms, are not valid assessment measures of students' whose cultural backgrounds differ from the dominant Western culture. Large-scale testing practices are not sensitive towards the subtle, yet important differences in the context in which individuals from the same cultural group live (Solano-Flores & Nelson-Barber , 2001). If educators were allowed to customize school-wide, provincial and national tests according to their student's cultural backgrounds and the culture in which they live, large-scale assessments would be more culturally valid. Solano-Flores and Nelson-Barber (2001) suggest that an educator's, school's or community's customization of large-scale assessments should include decisions concerning wording of questions, the contextual information included, and test administration time. The integration of Aboriginal science in the curriculum will not be successful unless the assessment methods used by educators in British Columbia are culturally valid to Aboriginal students.

Conclusion

Reflecting on our education system reveals the colonial underpinnings which have resulted in a disregard of Indigenous ways of knowing. It has shaped the worldviews of those who were schooled in it and marginalized those whose worldviews were different. Acknowledging other worldviews and combining Indigenous knowledge with Western science is important for all (Snively & Corsiglia, 2000) and particularly important for non- Aboriginals so that Indigenous knowledge can be brought into their epistemological framework (Friesen & Eziefe, 2009).

To assist in incorporating Indigenous knowledge into their epistemological framework, teachers need to recognize science "as it really is," and not the impersonal, objective, and value-free subject it is portrayed in science education. A paradigm shift in the understanding of science will lead to a better integration of Indigenous knowledge into the science curriculum. Teachers' worldviews and beliefs need to accommodate this curriculum reform, however it is paramount that they are given the support to do so. Without the capabilities of teachers an integrated Indigenous science knowledge system is a lost cause. Educational goals and curriculum content need to support teachers in their implementation of Aboriginal science. Concrete PLO's, resources and examples of Aboriginal science must be embedded within curriculum documents. In addition, pre-service and long-term professional development programs are essential in preparing teachers for this paradigm shift. With these changes to our education system, there is hope for an improved and authentic integration of Indigenous knowledge with Western science.

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Appendix

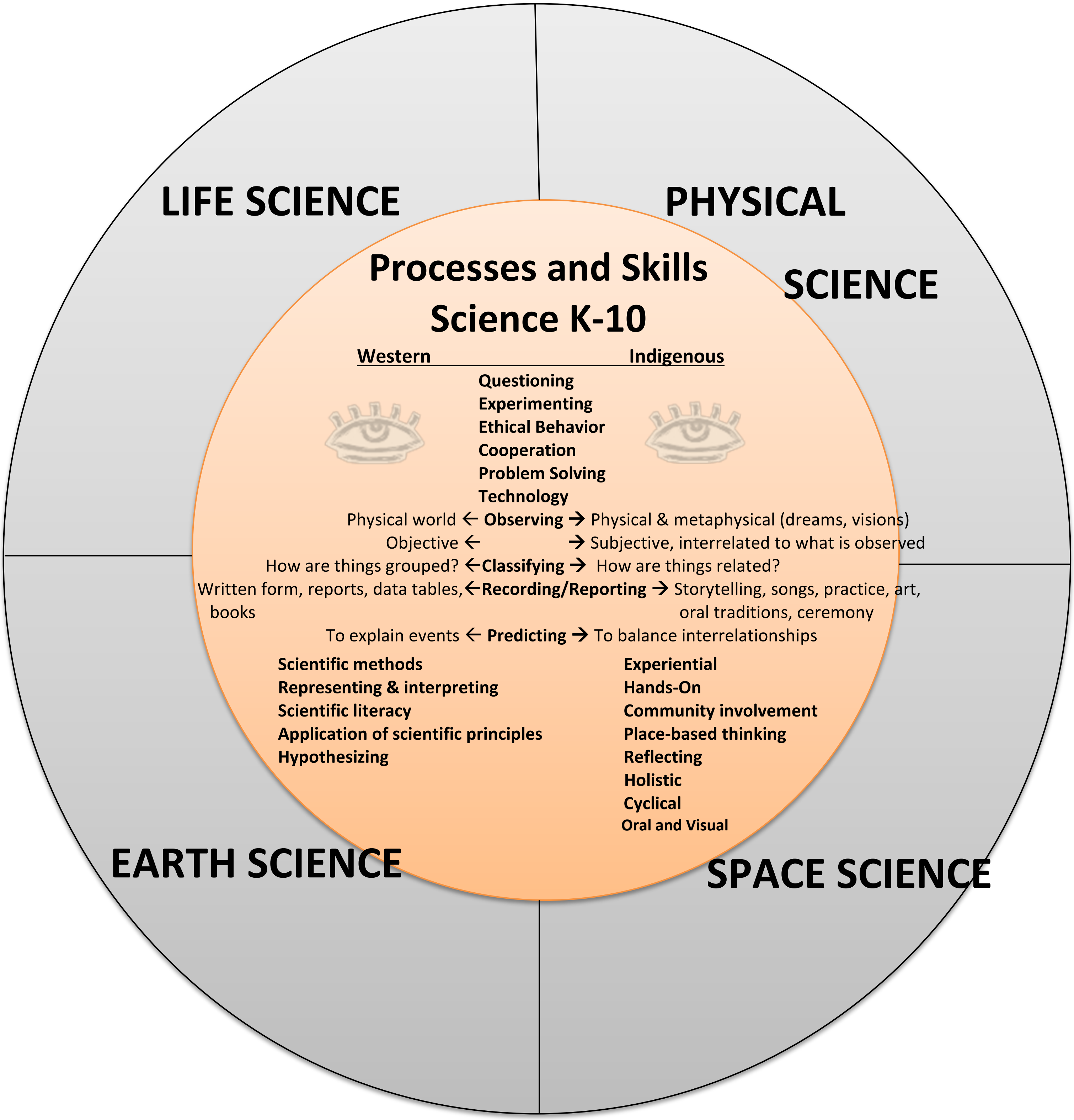
Remodeling of the BC Science Curriculum

The curriculum at a glance for science K-10 has been remodeled into a circle to reflect the cyclical significance of Indigenous worldviews. This circle emphasizes the connectedness of the curriculum units, physical, life, earth and space sciences, while allowing for Aboriginal science to be interweaved throughout.

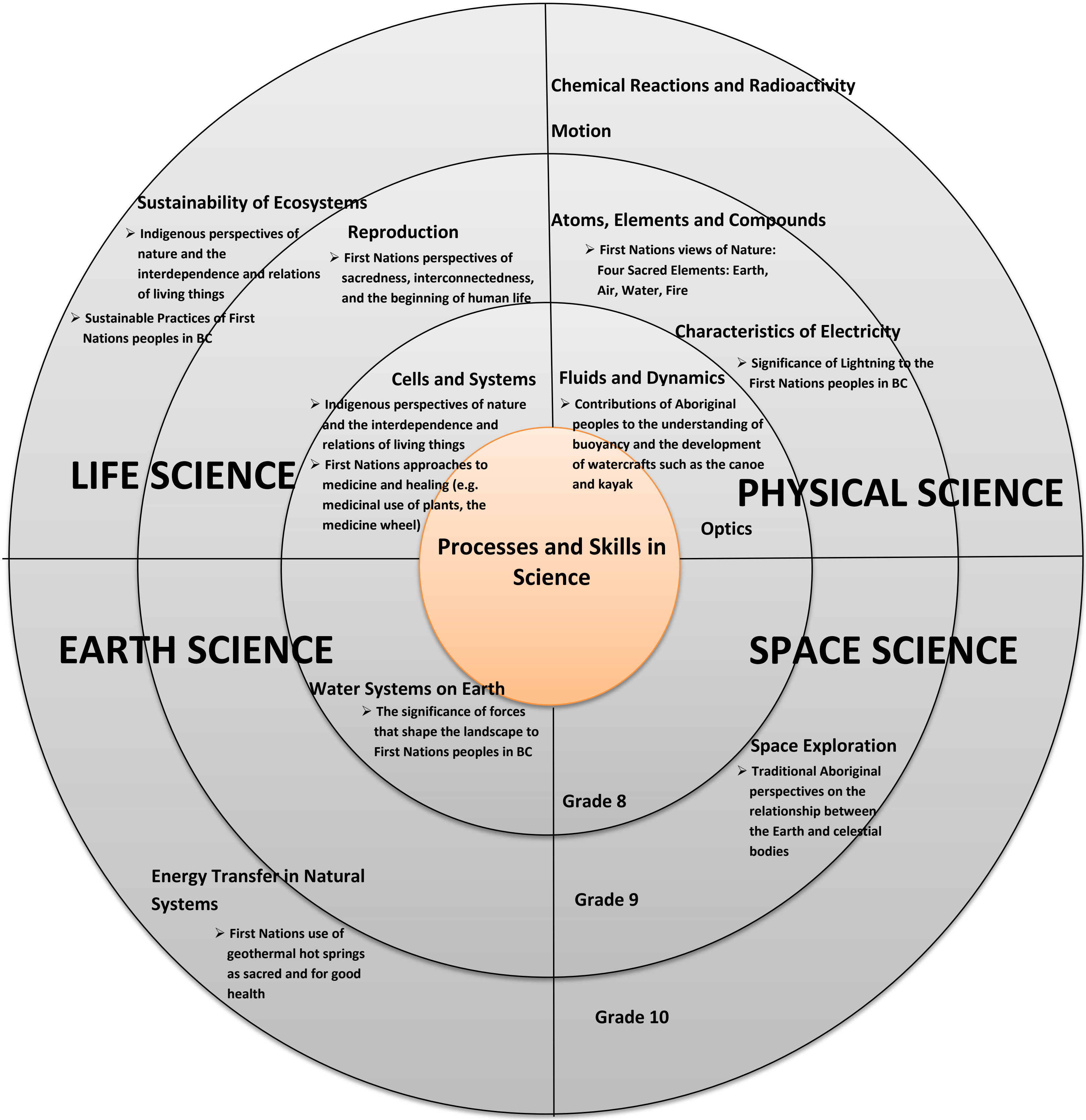
The processes of science in the centre of the circle are taught throughout the year in and include both Western and Indigenous process and skills. Both Western and Indigenous processes are used throughout each unit.

A remodeling of the curriculum incorporates a holistic approach of interweaving Aboriginal science Prescribed Learning Outcomes (PLO's) and Suggested Achievement Indicators (SAI) into the existing science 8-10 curriculum documents. This model represents the *beginning* of an improved integration of Aboriginal science in the BC science 8-10 curriculum. Further addition of Indigenous PLO's as well as a reorganizing, adding, removing of content and topics is needed for successful inclusion.

SCIENCE K-10 AT A GLANCE



SCIENCE 8-10 AT A GLANCE



Below is a list of PLO's in the current science 8-10 curriculum, with the new PLO's and SAI's representing Aboriginal science underlined. PLO's (or the SAI's of those PLO's) in the science curriculum that already represent Aboriginal science are marked with a *.

The **Processes of Science** PLO's have not been included below, however the Indigenous processes and skills are included on the Curriculum at a Glance model on page 69.

GRADE 8 PRESCRIBED LEARNING OUTCOMES

Life Science: Cells and Systems

It is expected that students will:

B1 demonstrate knowledge of the characteristics of living things.

NEW PLO (B1.1):

Describe Indigenous perspectives of living things (everything on Earth has spirit, so everything including rocks, animals, or mountains are considered living), interdependence, connectedness and the sacredness of life.

> NEW SAI: Describe the similarities and differences between Western views and Indigenous views of nature (e.g., In Indigenous cultures, such has BC First Nations, everything on Earth is interrelated and connected)

B2 relate the main features and properties of cells to their functions

B3 explain the relationship between cells, tissues, organs, and organ systems

B4 explain the functioning of the immune system, and the roles of the primary, secondary, and tertiary defence systems

NEW PLO (B5):

Describe First Nations approaches to medicine and healing (holistic and encompass body, mind and spirit)

> NEW SAI: Describe medicinal uses of various plants traditionally used by Aboriginal peoples. (e.g., Douglas fir pitch- heals wounds, Devil's club- healing medicine for coughs and colds)

> NEW SAI: Examine the First Nation peoples medicine wheel and its use in healing

Physical Science: Optics

It is expected that students will:

C1 demonstrate knowledge of the behaviour of waves

C2 explain the properties of visible light

C3 compare visible light to other types of electromagnetic radiation

C4 explain how human vision works

Physical Science: Fluids and Dynamics

It is expected that students will:

C5 explain the concept of force

C6 describe the relationship between solids, liquids, and gases, using the kinetic molecular theory

C7 determine the density of various substances

C8 explain the relationship between pressure, temperature, area, and force in fluids

C9 recognize similarities between natural and constructed fluid systems (e.g., hydraulic, pneumatic)

> NEW SAI: Describe the contributions of Aboriginal peoples to the understanding the principles of buoyancy and the development and design of canoes and kayaks and other watercrafts (whaling boats etc.)

Earth and Space Science: Water Systems on Earth

It is expected that students will:

D1 explain the significance of salinity and temperature in the world's oceans

D2 describe how water and ice shape the landscape

> NEW SAI: Explain the meaning and significance of the forces that shape the landscape to First Nations peoples in BC.

NEW PLO (D2.1):

Examine the significance of water to First Nations as an essential element of life, and examine the ways in which they traditionally valued, depended upon, and cared for aquatic wildlife.

D3 describe factors that affect productivity and species distribution in aquatic environments *

GRADE 9 PRESCRIBED LEARNING OUTCOMES

Life Science: Reproduction

It is expected that students will:

B1 explain the process of cell division

B1 relate the processes of cell division and emerging reproductive technologies to embryonic

development

B3 compare sexual and a sexual reproduction in terms of advantages and disadvantages

NEW PLO (B4):

Acknowledge differing cultural perspectives, including First Nations perspectives regarding the sacredness, interconnectedness, and beginning of human life

Physical Science: Atoms, Elements, and Compounds

It is expected that students will:

C1 use modern atomic theory to describe the structure and components of atoms and molecules

C2 use the periodic table to compare the characteristics and atomic structure of elements

C3 write and interpret chemical symbols of elements and formulae of ionic compounds

C4 describe changes in the properties of matter

NEW PLO (C4.1):

Describe First Nations views on the nature and structure of matter

NEW SAI: Examine First Nations four sacred elements: Earth, Air, Water, Fire

Physical Science: Characteristics of Electricity

NEW PLO (C4.2):

Examine how the importance of lightning to First Nations peoples is conveyed through stories and legends (e.g., The story of the thunderbird who carries lightning and thunder)

C5 explain the production, transfer, and interaction of static electrical charges in various materials

C6 explain how electric current results from separation of charge and the movement of electrons

C7 compare series and parallel circuits involving varying resistances, voltages, and currents

C8 relate electrical energy to power consumption

Earth and Space Science: Space Exploration

It is expected that students will:

D1 explain how a variety of technologies have advanced understanding of the universe and solar system

D2 describe the major components and characteristics of the universe and solar system

D3 describe traditional perspectives of a range of Aboriginal peoples in BC on the relationship between the Earth and celestial bodies *

D4 explain astronomical phenomena with reference to the Earth/moon system

D5 analyse the implications of space travel

GRADE 10 PRESCRIBED LEARNING OUTCOMES

Life Science: Sustainability of Ecosystems

It is expected that students will:

NEW PLO (B):

Describe Indigenous perspectives of living things (everything on Earth has spirit, so everything including rocks, animals, or mountains are considered living), interdependence, connectedness and the sacredness of life.

> NEW SAI: Describe the similarities and differences between Western views and Indigenous views of nature (e.g., In Indigenous cultures, such has BC First Nations, everything on Earth is interrelated and connected)

B1 explain the interaction of abiotic and biotic factors within an ecosystem

B2 assess the potential impacts of bioaccumulation *

B3 explain various ways in which natural populations are altered or kept in equilibrium *

NEW SAI: Describe the sustainable practices of First Nations peoples in BC

NEW SAI: Examine how various cultures view the relationships between living organisms and their ecosystems.

NEW SAI: Explain changes in the scientific worldview of sustainability and human's responsibility to protect ecosystems.

Physical Science: Chemical Reactions and Radioactivity

It is expected that students will:

C1 differentiate between atoms, ions, and molecules using knowledge of their structure and components

C2 classify substances as acids, bases, or salts, based on their characteristics, name, and formula

C3 distinguish between organic and inorganic compounds

C4 analyse chemical reactions, including reference to conservation of mass and rate of reaction

C5 explain radioactivity using modern atomic theory

Physical Science: Motion

C6 explain the relationship of displacement and time interval to velocity for objects in uniform motion

C7 demonstrate the relationship between velocity, time interval, and acceleration

Earth and Space Science: Energy Transfer in Natural Systems

It is expected that students will:

D1 explain the characteristics and sources of thermal energy

D2 explain the effects of thermal energy within the atmosphere

NEW PLO (D2.1):

Describe First Nation's use of thermal hot springs as sacred and for good health

D3 evaluate possible causes of climate change and its impact on natural systems

Earth and Space Science: Plate Tectonics

D4 analyse the processes and features associated with plate tectonics

D5 demonstrate knowledge of evidence that supports plate tectonic theory