Chapter 6 - Indigenous Science: Proven, Practical and Timeless

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Indigenous Science (IS) in this book refers to the science knowledge of all peoples who, as participants in culture, are affected by the worldview and interests of their home communities and homelands. Ogawa (1995) proposes that every culture has its own science and refers to the science of a given culture as its "indigenous science" (p. 585). Ogawa quotes Yamada (1970), a Japanese historian of Oriental science, who writes, "every culture and every society has its own science, and its function is sustaining its mother society and culture" (p. 585).

The traditional wisdom component of IS—the values and ways of decision-making relating to science knowledge—is particularly rich in time-tested approaches that foster sustainability and environmental integrity. Western Science (WS) is the most dominant science in the world today and is widely thought of as "officially sanctioned science." However, because WS has been implicated in many of the world's ecological disasters—pesticide contamination, introduced species, dams and water diversions that have impacted salmon and other indigenous species—it seems that reliance on Western Science alone can be seen as increasingly problematic and even counterproductive.

Cultural diversity suggests that Western Science and Indigenous Science should be viewed as co-existing or parallel. Westerners freely acknowledge the existence of Indigenous art, music, literature and drama, and of political and economic systems in Indigenous cultures, but many fail to apprehend and appreciate the concept of Indigenous Science. Thus, when Western Science is taught without acknowledging Indigenous Science, this can be construed as assimilative science education.

This chapter explores different versions of what science is, and what counts as scientific. It provides many examples from the Americas of Indigenous peoples' achievements in a broad range of science disciplines, and describes a rich and well-documented branch of Indigenous Science formally known to many biologists and ecologists as Traditional Ecological Knowledge (TEK). The stories and testimonies of Indigenous peoples provide educators with important information about Indigenous knowledge, wisdom and accomplishments that can be used to develop new innovative curriculum resources for science education.

We take the view that since Indigenous cultures have made significant achievements in a broad range of science disciplines, then surely there are different ways of arriving at legitimate science knowledge claims. Since IS generally incorporates wisdom and holistic values, it raises opportunities to consider the long-term costs and benefits of actions that may affect the environment. Not surprisingly, instances of IS can be found imbedded in numerous existing knowledge categories: Indigenous Knowledge (IK), TEK, and Traditional Ecological Knowledge and Wisdom (TEKW). Without knowledge, there can be no science. Thus, the definition of science should be broadened to include IS as science. The intention of this chapter is to identify a vast body of Indigenous Science and science literature drawn from cultures other than Eurocentric western society that provides great potential for enhancing our ability to develop more relevant science education programs with which *all* students can identify.

Terminology: Indigenous Science, Western Science and Traditional Ecological Knowledge

In education literature there are numerous descriptions of what science is, and of what counts as scientific. The Latin root, *scientia*, means knowledge in the broadest sense. The standard account of science can be called "Western," given its historic origins in ancient Greek and European cultures. Terms such as "Western Science," "Modern Western Science," "Standard Science," and "Official Science" have been is use only since the beginning of the 20th century. Western scientific theorizing began toward the end of the 19th century, when scientists began to grapple with abstract theoretical propositions—for example, evolution, natural selection, and the kinetic-molecular theory. What confidence would one have in theoretical statements built from or based on unobservable data? Care was taken to develop logically consistent rules outlining how theoretical statements can be derived from observational statements. The intent was to create a single set of rules to guide the practice of theory justification (Duschl, 1994). Following accepted scientific definitions, science educators defined WS as people's attempt to search out, describe, and explain in natural terms generalizable patterns of events in the world (Good, Shymansky, & Yore, 1999). Yore (2008), further describes the process of scientific inquiry:

> The search is driven by inquiry, limited by human abilities and technology, and guided by hypotheses, observation, measurements, plausible reasoning and creativity, and accepted procedures that try to limit the potential influences of non-target variables by utilizing controls. (p. 11)

Educators in the west popularly like to say that scientific theorizing began towards the end of the 19th century, but the history of science and technology is both long and rich. In antiquity, independent of Greek philosophers and other civilizations such as those of Egypt, India, and Iran, the Chinese made significant advances in science, technology, mathematics, and astronomy. Among the earliest inventions were the abacus, shadow clock, hot air balloon, fireworks, iron casting, and the first flying machines such as kites. The four great inventions of ancient China—the compass, gunpowder, papermaking, and printing—were among the most important technological advances only known in Europe at the end of the Middle Ages.

In sharp contrast to the exclusivist definitions of science made by Yore (2008) and others, Ogawa (1995) defines science rather simply and inclusively as "a rational perceiving of reality," where "perceiving means both the action constructing reality and the construct of reality" (p. 588). The word "perceiving" gives science a "dynamic nature" and acknowledges "science can experience a gradual change at any time" (p. 588). Ogawa further contends that "rational" should be seen in relativist terms.

Cajete (1999), a Tewa educator and scholar, defines Indigenous Science as:

> a broad category that includes everything from metaphysics to philosophy to various practical technologies practiced by Indigenous peoples past and present … [and, like western science] has models which are highly contextual to tribal experiences, representational and focused on higher order thinking and understanding. (p. 81)

Cajete contends that IS includes exploration of basic questions, such as the nature of language, thought and perception, the nature of time, human feeling and knowing, interconnectedness and proper relationships to the cosmos. It is a philosophy that gives rise to a diversity of technologies such as hunting, fishing, plant cultivation, navigation, architecture, art, and healing. Hatcher, Marshall, and Marshall (2009, p. 15) describe IS metaphorically as a "living knowledge" that requires less dependence on knowledge transfer from books, and requires "knowledge gardening with living knowledge keepers," which differs from WS.

The process of generating or learning Indigenous ways of living in nature has been described as *coming to know* (Cajete, 2000; Peat, 1994), a phrase that connotes a journey. *Coming to know* differs from a Eurocentric science process *to know* or *to discover* that connotes a destination, such as a patent or published record of discovery. Indigenous *coming to know* is a journey toward wisdom or a journey of wisdom in action, not a discovery of knowledge (Aikenhead & Ogawa, 2007). For Michell (2005), *coming to know* includes the goal of living in harmony with nature for the survival of the community. "Nature provides a blueprint of how to live well and all that is necessary to sustain life" (Michell, 2005, p. 39).

We extend our discussion of terminology to include Traditional Ecological Knowledge (TEK), described by many scientists as a sub-section of Indigenous Knowledge or Indigenous Science. The term is in flux, and some authors use the term interchangeably with IS or IK. TEK combines current observation with wisdom, knowledge and experience that has been acquired over thousands of years of direct human contact with specific environments. A leading Canadian researcher in this field, Fikret Berkes (2012), defines TEK as:

> … a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment. (p. 7)

McGregor, an Anishnaabe-kwe scholar, goes further and defines TEK as "more than a body of knowledge … TEK also encompasses such aspects as spiritual experience and relationships with the land." It is a "way of life, rather than being just the knowledge of *how* to live, it is the actual *living* of that life" (2004, p. 78).

TEK interprets how the world works from the cultural perspective unique to a particular group of Indigenous peoples. Although the term TEK came into widespread use in the 1980's, TEK itself is timeless and predates written record (Corsiglia & Snively, 1997). The stories and testimonies of Indigenous peoples are usually related to a home place or territory. TEK embodies both remembered sensory information built upon repeated observation, and formal understandings that are usually transmitted orally in story form or ceremonial form with abstract principles and important information encapsulated in metaphor (Cruikshank, 1991; Turner, Ignace, & Ignace, 2000). Perhaps the most useful way to think about Indigenous Science is that it is complementary to Western Science and not a replacement for it. Rooted in different worldviews, Indigenous and Western Science are not easy to combine, and it may not be desirable to meld the two. Each knowledge system is legitimate in its own right. The two kinds of knowledge may be pursued separately but in parallel, enriching one another as needed (Berkes, 2012).

Thus, approaches to science seem to have proceeded along two fundamentally different courses: a) by the timeless procedure of relying on observation and experiment, and b) during the past two centuries through the theoretical examination of queries and assertions. We agree with Ogawa (1989) that "every culture has its own science … something like its own way of thinking and/or its own worldview" and that Western Science is only one form of science among the sciences of the world.

Because the labels "Indigenous Science" and "Western Science" often obscure the great richness and diversity found within each knowledge system, they can unfortunately lead to misunderstanding and stereotyping. The labels also mask important similarities. For example, both knowledge systems were developed from culture-based ways of experiencing and making sense of nature, and each knowledge system in its own cultural way relies on empirical data, observation, curiosity, experimental procedures, rationality, intuition, predictability and knowing of cause and effect relationships.

We agree with Vickers (2007), that Indigenous people have guiding principles that are passed down through the generations to assist humans in their relationship with each other, with animals, the land and water, and the supernatural world. As Vickers (2007) states, with respect to Western thinking, “Our method of relating to the land and the sea is ‘scientific’. The missing component in the teaching of science today is an intimate connection to the ‘subject’ that benefits the well being of the community” (p. 592). These principles will not only assist us to restore individual and collective balance, they will also assist the school system to deliver knowledge in a respectful way.

While we recognize the rich and important literature of TEK examples compiled by working scientists, we also acknowledge McGregor’s (2000, 2005) concerns regarding the power imbalance used by some scientists to enforce a Western cultural bias that controls decision making over local land, resource and animal issues. This issue of power associated with knowledge imbalance is often enacted outside the academy, that is, in the real world of economic progress, corporate profits, and political ideologies.

Although we agree with the above concerns related to how TEK is defined and enacted, for the purpose of this book, we believe that what counts is not so much the label, but more the content, intent, and practice, whether or not the information is correct and was obtained with permission, and that the information and ways of knowing be respected. We believe it is critical that educators become sufficiently familiar with ways to access the rich body of TEK knowledge compiled and indexed by Indigenous scholars and working scientists, many of whom have spent a lifetime respectfully learning from the Elders. Elders and knowledge holders are not always accessible and their numbers are dwindling. Teachers, Elders, curriculum developers and Ministry of Education officials may need to be able to locate and access sources of TEK and IS literature in order to introduce the world of Indigenous Science to all children in the science classroom. Increasingly, educators can access critical Indigenous concepts and information through literacy and digital storage translations, thus adding ancestral knowledge and wisdom to our understanding of how to live in harmony with Mother Earth.

The Wisdom Aspect of Indigenous Science

Traditional wisdom may be thought of as an aspect of IS that focuses on balancing human needs with environmental requirements. As Corsiglia and Snively (1997) note:

> Traditional wisdom usually begins with an understanding that spiritual essence infuses and defines all forms, and that all life forms must be respected as conscious, intrinsically invaluable, and interdependent. Respecting an animal’s body means honouring its spirit and using every part of an animal’s body. In practical terms, traditional wisdom extends the caring relationships associated with “family” life to communities and even to the environment. We are all related, it is wrong to exploit other life forms or take more than one’s share. The deep interest our children feel in animals, plants, water, and earth should be trusted and encouraged. All creatures can be our teachers and while humans may readily affect other life forms, we need not see ourselves as superior. (p. 29)

The proper forms of human conduct are set out in an elaborate code of rules. Deference is shown for everything in the environment, through gestures of etiquette and thanks, and by avoiding excessive use in the Nuu-chah-nulth culture (Atleo, 2004). Among the Nisga'a, for example, wolves and bears may be considered superior life forms because they "do not need to talk to communicate" (Harold Wright, personal communication to John Corsiglia, 1977). All life forms are conscious. Among the Kwakwaka'wakw, when the first salmon (coho) were caught by trolling, the fisherman's wife met her husband's canoe at the beach and said a prayer of welcome to the fish. Even today, some families continue to say a prayer to the first fish caught, while others honour the first fish by pulling their seine boat into a cove and enjoying a special family meal (Gilbert Cook, personal communication to Gloria Snively, July, 2001). Harmony can be preserved through respect, justice, and diligence. Wealth achieved without the respect for sustaining harmony or sharing simply indicates greed and selfishness. The truth of situations will always become known. As the Elders have often said, "there are no secrets" (Deanna Nyce, personal communication to Corsiglia, 1989). Thus, IS can be thought of as the joining of the technical aspects of traditional knowledge with the values and ethics of traditional wisdom.

In a backlash against excessive claims for the ecological wisdom of Indigenous peoples, some researchers point out examples of tribal people and ancient societies who did over-exploit local resources (Smith & Wishnie, 2000). However, some ecologists, notably Dasmann (1988) have pointed out that a distinction must be made between invaders and natives. When humans invade a new and unfamiliar ecosystem, their impact on the environment may be substantial initially. As Nisga'a chief Eli Gosnell related to John Corsiglia (1979), "When are the white people going to start behaving as if they live here?"

This initial relationship may change as the people develop a knowledge base, learn from their mistakes, and realize the limits of their new environment. Long-settled natives tend to co-evolve with their environment, and they often achieve a level of symbiosis with their environment (Berkes, 2012; Dasmann, 1988; Corsiglia & Snively, 1997). On the whole, this chapter takes the view that long-resident Indigenous peoples generally developed a relationship with their land and animals involving sophisticated systems of resource stewardship and respect.

Indigenous Science in the Americas

Numerous traditional peoples' scientific and technological contributions have been incorporated in modern applied sciences such as ecology, biology, medicine, architecture, engineering, geology, pharmacology, agriculture, horticulture, agronomy, metallurgy, navigation, astronomy, animal husbandry, fish and wildlife management, nautical science, plant breeding, and military and political science (Berkes, 2012; Turner & Peacock, 2005; Deur & Turner, 2005; Turner, 2014a, 2014b; Weatherford, 1988, 1991).

The ethno-pharmacological literature and anecdotal traditional knowledge reveals that many Indigenous peoples have a vast knowledge of the medicinal qualities of plants. Traditional American healers discovered and used quinine, Echinacea, Aspirin® (A.S.A) and Ipecac® (a drug still used in traumatic medicine to expel stomach contents), as well as some 500 other important drugs (Weatherford, 1988, 1991; Cajete, 2000). Studies have shown that the Mayans targeted specific illnesses using plant compounds that have now been corroborated using laboratory tests, for example, that plant species used to target gastrointestinal ailments actively do treat the symptoms (Berlin, et. al, 1996). In fact, "over 70% of all western drugs have come from isolating the active ingredients in plants and animals that the world's Indigenous people had already been using for medicinal purposes for centuries [prior to contact]" (Ross, 1966, p. 63). "Obviously," according to Berlin et al. (1996, p. 348), "experimentation is not exclusive to western science."

In the Americas alone, traditional knowledge and wisdom systems sustained populations estimated to be as high as 100 million (Wright, 1992), one-fifth of the world's population at the time of contact in 1492. To feed and clothe an expanding population, Meso-Americans developed some 3,000 varieties of potatoes (suited to different soil types, elevations, and climatic conditions), as well as squashes and pumpkins, yams, tapioca (cassava), vanilla extract, chili peppers, corn, sunflowers, tomatoes, quinoa, amaranth, wild rice, Jerusalem artichokes, avocados, peanuts, chocolate, strawberries, blueberries, papaya, pineapples, maple sugar and maple syrup, tobacco, cotton, and several varieties of beans (Cajete, 2000; Weatherford, 1988, 1991). Meso-American mathematicians and astronomers used base 20 numeracy to calculate calendars more accurate than those used by Europeans at the time of contact, even after the Gregorian correction (Kidwell, 1991). In the past four centuries, western Europeans appropriated and improved vast quantities of agricultural and medicinal products indigenous to the Americas, but this transfer of knowledge has largely gone unrecognized.

Weatherford (1988) describes how the Indigenous peoples of the Andes had been cultivating the potato in their mountain slope gardens for at least 4000 years. “Even before the Incas, these natives produced high yields of potatoes from small plots of land, and they developed different kinds of potatoes for every type of soil, sun, elevation and moisture condition. Colors ranged from whites and yellows through purples, reds and browns” (Cajete, 2000, p. 135). The date of the introduction of potatoes into Ireland is unknown, but according to Cajete (2000) they were a field crop before 1663.

According to Weatherford (1988), Andean farmers invented the first freeze-dry method of preserving potatoes by putting the potatoes out to freeze at night. The sun thawed out the potatoes and the farmers squeezed out the excess moisture, repeating this process several times. The result was a white chunk of potato the texture of Styrofoam. The Incas could easily store large quantities of dried potatoes for five or six years. Cooking the potatoes required soaking them in water, and the preserved chunks could be used in soups and other dishes (Weatherford, 1988).

Corn, a member of the grass family, was first domesticated about 9000 years ago from a wild grain by the Mayan Indians in south central Mexico. The first corn was a loose-podded variety that looked like the seed head at the top of wheat stalks. Historians believe the crop spread throughout Meso-America by 2500 BC. Central and South American peoples came to depend so heavily on corn that they devised some of the earliest calendars just to keep track of their corn planting and harvesting schedules (Dolores, 2011).

As a truly cultivated plant over thousands of years, corn cannot be propagated using other plant parts, can only propagate by its seeds, requires tending, and cannot survive in the wild. Unlike wheat and rice which have obvious relatives, the precise origin of corn remained a mystery to Euro-Americans ever since they first observed the plant in the new world in the late 14th century. We now know from DNA typing that corn was domesticated in southern Mexico from grasses as early as 9000 to 10,000 years ago. Teosinte is the common name for a family of grass plants that grow taller and have broader-leaves than most other grasses. Ancient farmers noticed that some teosinte plants were larger than others or had more kernels, or some kernels may have tasted better or were easier to grind. The farmers saved kernels from plants with desirable characteristics and planted them for the next season’s harvest, a process know as selective breeding (Carroll, 2010). Before they were domesticated, corn plants only grew small—25 mm (1 inch) corncobs and only one per plant. Many centuries of breeding and domestication resulted in the development of plants capable of growing several cobs per plant that were several centimeters long (Vigouroux & Marsuoka, 2013). The Spaniards called it maize. In the late 15th and early 16th century, European explorers and traders carried maize back to Europe. Maize spread quickly to the rest of the world because of its food value and its ability to grow in diverse climates and soils. Today, more maize is produced annually worldwide than any other grain (Dolores, 2011).

Indigenous practices of planting some crops were superior in comparison to European techniques of sowing seeds. Indigenous farmers learned that planting individual seeds for particular qualities, rather than strewing handfuls of seeds on the ground, enabled them to control the genetic diversity of their crops, resulting in a large variety of staple crops. “They thus became masters of plant hybridization long before the nineteenth-century botanical researchers George Mendel and Luther Burbank demonstrated the technique to the rest of the world" (Landon, 1993, p. 9).

Centuries before the arrival of Columbus, people of Meso-America and the Amazon Valley created stone ball courts and played games with rubber balls. Spanish conquistadors were astonished when they saw the remarkable way the rubber balls bounced. By treating the sap of several kinds of rubber, the Indigenous Americans developed a range of articles including waterproof bags and the original gumboots (Walker, 1943, cited in Cajete, 2000, p. 137). Traditional scientists were the first to discoverer the use of rubber, vulcanizing, the use of asphalt for waterproofing plank-hulled boats, petroleum jelly and also platinum metallurgy (Weatherford, 1988, 1991).

The Yup'ik people of southwest Alaska have an extensive technology for surviving the harsh conditions of the tundra. According to Kawagley and Norris-Tull (1995), "Their technology could not have been developed without extensive scientific study of the flow of currents in the rivers, the ebb and flow of tides in the bay, and the feeding, sleeping, and migratory habits of fish, mammals, and birds" (p. 2):

> Yupiaq people have an extensive knowledge of navigation on open-seas, rivers, and over snow-covered tundra. They have their own terminology for constellations and have an understanding of seasonal positioning of constellations. They have developed a large body of knowledge about climatic changes—knowledge about temperature changes, the behavior of ice and snow, the meanings of different cloud formations, the significance of changes in wind directions and speed, and knowledge of pressure. This knowledge has been crucial to survival and was essential for the development of the technological devices used in the past [and many still used today] for hunting and fishing. (p. 2)

The truth is, directly or indirectly, we are all benefiting from Indigenous scientific and technological innovations every time we dine, clothe ourselves, travel or go to the doctor.

Combining Traditional Ecological Knowledge and Western Science

TEK provides invaluable time-tested resource management practices that can be used alongside WS to develop more workable and effective approaches to current resource management strategies than either could accomplish alone. In fact, it has become a policy requirement in Canada, and in particular northern Canada, that TEK be incorporated into environmental assessments affecting wildlife management including: migratory birds, species at risk, forest practices, and fisheries management (Usher, 2000). The authors can only report on one project, as an example, in some detail.

The Nisga'a people of northern British Columbia live in the Nass Valley, near Alaska. Every spring, members of some Nisga'a families still walk their salmon streams to ensure that spawning channels are clear of debris and that salmon are not obstructed in their ascent to spawning grounds. Concerned with the multiple perils faced by their Nass River salmon, the Nisga'a have themselves implemented a salmon protection project that uses both the ancient technology and wisdom practices, as well as modern statistical methods of data analysis to provide more reliable fish counts than electronic tracking systems (Figure 6.1). The Nisga'a project, which earned a Department of Fisheries and Oceans Canada award, is described in the following account by Corsiglia and Snively (1997):

> Observing that electronic fish counters can be inaccurate, the Nisga'a have instituted an ingenious fish counting system in the Nass River that combines ancient fish wheel technology with modern statistical methods. The ancient fish wheel was made of cedar wood and nettle fibre mesh, and the elongated axle of the fish wheel was fitted with three parallel vanes constructed in the form of large, flattened dip nets. The swift moving downstream current turned the wheel by exerting force against the submerged vanes, and as the companion vanes rose in turn, they gently caught and uplifted the fish as they swam upriver. As each vane rose from the horizontal, the fish slid toward wooden baffles that guided them out of the side of the fish wheel and into submerged holding baskets. This technology provided the Nisga'a with an effortless fishing technique as well as a ready supply of fresh salmon. (p. 19)

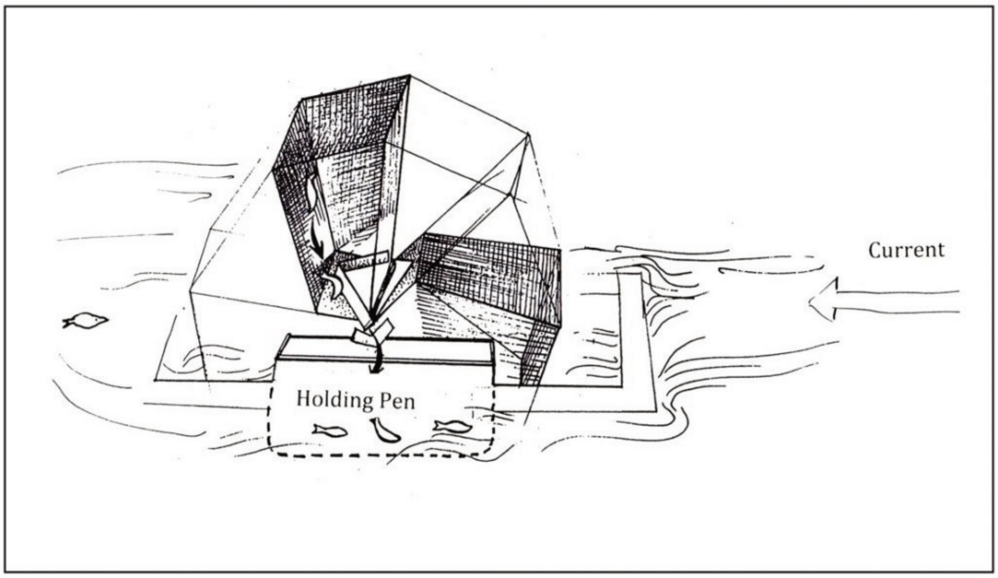

Figure 6.1 ▲ Nisga'a fish wheel showing holding pen. Illustration by Laura Corsiglia (1997).

Modern Nisga'a fishing wheels are made of aircraft aluminum and nylon mesh. Like their predecessors, these fish wheels allow fish to be captured live and held in holding tanks. This enables the Nisga'a to tag and count the fish by means of statistical analysis. Returning salmon are first caught using a fish wheel at a lower river station where fish are tagged. Fish are also caught at an upper fish station where the proportion of tagged fish is used to calculate returns. Reportedly, "this system provides more accurate and reliable data than that collected by electronic tracking systems alone" (Chief Harry Nyce, personal communication to Corsiglia, 1986).

Contributions of Traditional Ecological Knowledge and Indigenous Knowledge Scholarship

Some of the contributions of TEK and IK scholarship to contemporary environmental knowledge, conservation and resource management worldwide (acknowledged by Western scientists) are outlined below:

- Perceptive investigations of traditional environmental knowledge systems provide important biological and ecological insights (Berkes 2012; Houde, 2007; Turner & Peacock, 2005; Turner, 2014a, 2014b; Usher, 2000; Warren, 1997).

- TEK and IK can help locate rare and endangered species and provide cost effective shortcuts for investigating the local resource bases. Local knowledge makes it possible to survey and map in a few days what would otherwise take months, for example, soil types, plant and animal species, migration pathways, and aggregation sites (Berkes, 2012; Usher, 2000; Warren, 1997).
- TEK and IK provide knowledge of time-tested resource management practices, and can be used to develop workable approaches to current resource management strategies (Houde, 2007; Turner & Peacock, 2005; Usher, 2000; Warren, et. al., 1993).
- Provides time-tested in-depth knowledge of the local area (past and present) that can be triangulated with WS resulting in more accurate environmental assessment and impact statements. People who depend on local resources for their livelihood are often able to assess the true costs and benefits of development better than any evaluator from outside (Houde, 2007; Warren, et. al, 1993; 1997).
- Provides experienced based value statements about appropriate and ethical behavior with respect to animals and the environment (Berkes, 2012; Deur & Turner, 2005; Turner, 2014a, 2014b; Houde, 2007; Usher, 2000).

A key point here is that scientists who do much of their work in laboratories may be unable to understand the complexity of ecosystems, especially northern or distant ecosystems, through sporadic observations, as opposed to lived experience.

Recognition of the importance of incorporating IS and TEK in environmental planning is explicitly addressed in reports and agreements in Canada and internationally. The Brundtland Commission report, *Our Common Future* (WCED: World Commission on Environment and Development, 1987), recognized the role of TEK in sustainable development; and the *Convention on Biological Diversity, Agenda 21* (UN Conference on the Environment, 1993), declared that Indigenous people possess important traditional scientific knowledge. The document *Science for the Twenty-first Century: A new Commitment* (UNESCO: United Nations Educational, Scientific and Cultural Organization, 2000), set new standards for respecting, protecting and utilizing Indigenous Knowledge. Working scientists worldwide associated with hundreds of institutes are collaborating with Elders and knowledge holders to collect and document examples of TEK and IS knowledge; including institutes in the US, Canada, Middle and South America, Africa, Europe, Australia, New Zealand, India, Russia, China and Japan.

Towards Acknowledging Indigenous Science

There are a number of issues that make it difficult for scientists to acknowledge IS. Many scientists view IS as useful, but outside the realm of Eurocentric science. Of the debates which inhibit acknowledging IS and TEK as of the realm of science, two will be briefly articulated here: 1) the portrayal of Indigenous cultures as unscientific because they lack the benefit of Western scientific methodology and empirical observation; and 2) problems associated with recognizing traditional knowledge and wisdom as science because it respects and values all forms of life (its spiritual essence).

Indigenous Science as Science

Many educated people today believe that Indigenous cultures are unscientific because they are based on magical or spiritual beliefs and/or because they lack the benefit of the Western scientific method of empirical observation and experiment. Technology is not considered an applied science but rather people's attempt to address or alleviate issues of human need by adapting to the environment utilizing design and trial and error approaches (Yore, Hand, & Florence, 2004). The argument against acknowledging the legitimacy of IS as outlined by Yore (2008), is as follows:

> History of technology has examples of inventors producing innovations in advance of the scientific explanation. Frequently, the debates about science have not kept the differences between science and technology clear and, by doing so; confound the issues regarding the need for western science to move toward explanation utilizing physical causality rather than magic, mysticism, and spiritualism. (p. 13)

Thus, by defining both science and technology narrowly, and from a western worldview, all Indigenous innovations described in this paper would fall outside the realm of science because they are technologies that lack explanatory power utilizing physical causality. The argument for acknowledging the legitimacy of IS is best summarized by Cajete (1999):

> Whether there exists an Indigenous science in western terms is largely an incestuous argument of semantic definitions. Using western science orientations to measure the credence of non-western ways of knowing and being in the world has been applied historically to deny the reality of Indigenous people. The fact is that Indigenous people are, they exist and do not need an external measure to validate their existence in the world. Attempts to define Indigenous science, which is by its nature alive, dynamic, and ever changing through generations, fall short, as this science is a high-context inclusive system of knowledge. (pp. 81-82)

Central to the issue of the authenticity of IS is the controversial question of the existence of curiosity-driven inquiry among Indigenous peoples. Clearly, according to Berkes, "there is a great deal of evidence that Indigenous people do possess scientific curiosity, and that traditional knowledge does not merely encompass matters of immediate practical interest" (Berkes, 2012, p. 10).

Reconciling the Spiritual Base of Indigenous Science and Traditional Ecological Knowledge

One important point of difference between IS and WS is that Indigenous Knowledge systems include spiritual dimensions (beliefs) that may not make sense to scientists or fall outside the realm of WS. Academics and Western trained researchers generally view TEK as a "body of knowledge," but for Indigenous people, TEK (and IK) is a way of life and is an inextricable combination of knowledge practice and belief, as per the definition by Berkes (2012).

Respect is the fundamental law of Indigenous peoples. This basic tenant was described in the context of the Gitksan and Wit'suwit'en claims to their ancestral homelands by hereditary tribal Chief Delgamuukw to the BC Supreme Court in 1987, as follows:

> …for us, the ownership of territory is a marriage of the Chief and the land. Each Chief has an ancestor who encountered and acknowledged the life of the land. From such encounters come power. The land, the plants, the animals and the people all have spirit—they must be shown respect. That is the basis of our law. (Tyler, 1993, p. 225)

For some, the word "spiritual" is associated with religion or Christianity or some analog thereof. But for many people, spirituality means life with consciousness. Thus, the land, the plants and animals, and people all have their own spirit, integrity, and substance; they must be respected. By extension, spiritual stewardship of resources represents more than securing an economic commodity in order to earn a benefit. Spiritual stewardship represents a way of life, a vital process of socialization, moral education, respect for all forms of life, and responsibilities.

Gitksan and Wit'suwit'en worldviews, as with Indigenous worldviews generally, evolved without Aristotelian logic and Cartesian thinking, which have played a major role in shaping the value systems and conceptual frameworks of Western society. Gitksan and Wit'suwit'en cosmology does not exhibit the Cartesian division between mind (or spirit) and matter. As a consequence, "there is no conceptual separation between the spiritual and natural world, which makes their cultural worldview conceptually and symbolically different from Western thinking" (Tyler, 1993, p. 227).

Importantly, what many opponents of IK and TEK fail to recognize is that spiritual explanations contained in myths and stories often incorporate important ecology, conservation, and sustainable development strategies across the generations (Atleo, 2004; Berkes, 2012; Johnson, 1992). In reference to TEK, Johnson and Ruttan (1991) point out:

> Spiritual explanations often conceal functional ecological and conservation strategies. Further, the spiritual aspect does not necessarily detract from the aboriginal harvester's ability to make appropriate decisions about the wise use of resources. It merely indicates that the system exists within an entirely different cultural experience and set of values, one that points no more and no less valid a picture of reality then the one that provides its own (western) frame of reference. (as cited in Johnson, 1992, p. 13).

Furthermore, the spiritual explanation of TEK is a fundamental component and must be promoted if the knowledge system is to survive (Cruikshank, 1991; Johnson, 1992; Turner, 2005). Criticism of the validity and utility of IS and TEK misapprehend the structure of Indigenous oral information systems. "These systems simply do not assert that mythical-magical forces cause and control nature. Indigenous peoples observe, interpret and orally report nature exhaustively. Rather than writing about their findings, they may use metaphorical stories to compress and organize information so that it can be readily stored and accessed" (Snively & Corsiglia, 2001, p. 23).

False Assumptions of a Colonial Past

In an attempt to understand the origin of errors, false assumptions, and biases about Indigenous knowledge, the authors sketch our colonial past in the Americas. History books and various colonial papers have depicted Indigenous peoples as "hunters and gatherers," "affluent foragers," and "without agriculture." Europeans proclaimed the Americas as *Terra nullis*, meaning "unoccupied land." The cultural prejudices and the missionary, political, and academic agendas of the majority culture since the time of the *conquistadores* served to undermine actual Indigenous Knowledge and claims on the land and its natural resources. The vast majority of documentary information in the Americas was recorded by men of European background and culture—explorers, traders, settlers, colonial officials, and missionaries. It is perhaps not surprising that innovations such as Indigenous estuarine root vegetable gardens, clam gardens, and salmon enhancement practices went unnoticed or unrecognized. The claim of 19th century colonial surveyors that Northwest Coast peoples "have no aboriginal plant which they cultivate," or BC Governor General James Douglas' (1859) characterization of Indigenous people as "mere wandering denizen[s] of the forest," reveals more about the observers than the observed. Rather, these assertions served to devalue and dismiss Indigenous people's claims to entire regions of land and resources. "Together, colonial claims regarding traditional resource use provided a façade that served the extractive ambitions of colonial and frontier economies and the expansionist territorial agendas of colonial governments and the nation state" (Deur & Turner, 2005, p. 336). In this regard, it is instructive to note that WS grew up in the service of European empire building, which accounts, at least in part, for its portrayal of IK as outside the realm of "real science." It also helps explain the emphasis in WS on domination and control of lands, resources, and environment.

Conclusion

In these days of worldwide social, political, and environmental stress, we are all affected by problems associated with resource depletion, increasing human population, climate change, and environmental disaster. Only recently have Western scientists begun to wrestle with approaches that promise to improve our ability to mitigate the impact of human society upon the planet. The world's educators must recognize the paramount importance of the ecological crisis. Our challenge is not so much to seek ever more sophisticated technological solutions to environmental problems, as it is to re-establish a moral, emotional, and perhaps sacred, relationship with the biosphere.

The addition of IS examples into the science classroom allows it to be more widely recognized and respected for its validity and usefulness, adding interest and authenticity to the study of science. What is wrong with Nisg̱a'a, Kwakwa̱ka̱'wakw, Lil'wat and Coast Salish children learning about the science of their own cultures in the science classroom, and why shouldn't all children learn about the science of many cultures? Unless IS is given sufficient recognition in the science classroom, and unless Nisg̱a'a families continue to walk the streambeds each spring, invaluable IS and TEK may be lost forever.

Indigenous Science not only existed in the past, but in numerous cases, it exists today. For many science educators the first step is simply recognition of the validity of IS within the realm of science, and its importance in the science classroom. It is our hope that teachers will introduce both IS and WS as different but complementary ways of understanding the world to all students in the science classroom. Discussion should stress similarities rather than differences, and explore practical possibilities for combining the Indigenous and western frameworks in understanding nature and solving science, technology and environmentally related problems.

DISCUSSION POINTS

- Before reading this chapter, respond in writing to the question: "What is science?" Then share the definition with a neighbour and then share definitions with the larger group.
- Debate the proposition: Scientific theorizing began toward the end of the 19th century when scientists began to grapple with abstract theoretical propositions. Hence, "real science" is an exclusive invention of Europeans in the late 19th century.
- In a small group, brainstorm the following:
    - How the Indigenous peoples of Meso-America discovered medicinal uses of aloe vera and quinine.
    - How the Tainos of Meso-America developed corn.
    - How Andean farmers invented the first freeze-dried potato.
    - How Meso-American farmers developed 3,000 varieties of potato.
- Proponents of WS argue that "real science" is testable, evidence-based, has explanatory power, and is determined by consensus. When Indigenous peoples of the Northwest coast increased the production of edible root gardens by building rock terraces in the low intertidal zones, was their innovation the result of trial and error only, or can it be included in the realm of "real science?" Discuss.
- On average, 1 bushel of corn is required to produce 3 gallons of gasoline. In 2007, the global price of corn doubled as a result of an explosion in ethanol production. Research the unintended effects of ethanol production on world food production, world economies, environmental impacts, and the Indigenous people of Africa and the Americas.

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