Cult Stud of Sci Educ (2007) 2:539–620
DOI 10.1007/s11422-007-9067-8

ORIGINAL PAPER

Indigenous knowledge and science revisited

Glen S. Aikenhead · Masakata Ogawa

Received: 4 July 2007 / Accepted: 4 July 2007 / Published online: 23 August 2007

Abstract This article provides a guided tour through three diverse cultural ways of understanding nature: an Indigenous way (with a focus on Indigenous nations in North America), a neo-indigenous way (a concept proposed to recognize many Asian nations' unique ways of knowing nature; in this case, Japan), and a Euro-American scientific way. An exploration of these three ways of knowing unfolds in a developmental way such that some key terms change to become more authentic terms that better represent each culture's collective, yet heterogeneous, worldview, metaphysics, epistemology, and values. For example, the three ways of understanding nature are eventually described as Indigenous ways of living in nature, a Japanese way of knowing seigyo-shizen, and Eurocentric sciences (plural). Characteristics of a postcolonial or anti-hegemonic discourse are suggested for science education, but some inherent difficulties with this discourse are also noted.

Keywords Indigenous · Science · Knowledge · Nature · Worldviews · Metaphysics · Science education

Introduction

In this article we explore knowledge systems and ways of knowing nature colloquially known as Indigenous knowledge and science. These two labels belie the great diversity found within each category and mask similarities the two categories share, for example, empiricism, rationality, and dynamic evolution. We recognize that the literature is replete

G. S. Aikenhead (✉)
University of Saskatchewan, Saskatoon, SK, Canada
e-mail: glen.aikenhead@usask.ca

M. Ogawa
Kobe University, Kobe, Japan
e-mail: ogawam@kobe-u.ac.jp

with comparisons between Indigenous knowledge and science, but our project here does not continue the false dichotomy, Indigenous knowledge versus science, found in colonial discourse with its subtext of winners and losers (Macedo 1999). Instead, our project recognizes ways in which the two terms (*Indigenous knowledge* and *science*) become problematic and require more authentic categories such as the triad *Indigenous ways of living in nature* (plural), *neo-indigenous ways of knowing nature* (referring to a cluster of Asian cultures, including for instance, Islam and Japan, described in detail below), and *Eurocentric sciences* (plural). These descriptors reflect more complex and authentic concepts than those conveyed by the colloquial dyad *Indigenous knowledge* and *science*.

Our purpose in exploring similarities and differences among the three categories is to offer insights of value to science educators so they can build bridges between their own Eurocentric knowledge system and other ways of knowing, thereby spanning the colonial false dichotomy between science and Indigenous or neo-indigenous ways of knowing nature. Science educators can be guided by, for example, Battiste (2000), a Mi'kmaq scholar and international authority on Indigenous knowledge, who has "sought to find ways of healing and rebuilding our nations...by restoring Indigenous ecologies, consciousnesses, and languages and by creating bridges between Indigenous and Eurocentric knowledge" (p. xvii). Yupiaq scholar and educator Kawagley (1990) contends that strong bridges are built by examining the collective worldviews and epistemologies of Indigenous, neo-indigenous and Eurocentric knowledge systems. We agree.

In this article, school science delimits the scope of our exploration. Our intended audience comprises science educators open to, or at least curious about, cultural and postcolonial perspectives in their field. Our intended audience is not the professional scientist whose perspective on Indigenous or neo-indigenous knowledge is understandably much different than science educators' perspectives. Within our audience of science educators, a full range of reader viewpoints exists. At one extreme, a highly Eurocentric reader embodies Eurocentric knowledge and likely has little appreciation or understanding of Indigenous or neo-indigenous knowledge systems. At the opposite extreme are in-depth bicultural readers who embrace Indigenous or neo-indigenous knowledge systems and who appreciate and understand Eurocentric knowledge. A position in-between these two extremes is the reader who embraces Eurocentric knowledge but appreciates and understands Indigenous or neo-indigenous knowledge systems to some degree. With this full spectrum of readers in mind, we explore Indigenous, neo-indigenous and Eurocentric knowledge systems to expand readers' understanding of Indigenous and neo-indigenous ways of knowing nature.

Although school science delimits our project, our intention is not to explore a closely related topic: the place of Indigenous or neo-indigenous knowledge in science education. This topic is the focus of a recent research literature review (McKinley 2007) and is taken up in a future issue of *Cultural Studies of Science Education* (in volume 3).

Over the past three decades, science educators have become increasingly interested in Indigenous and neo-indigenous ways of knowing nature. This interest has generally been fuelled by a desire for social justice in the equitable representation and success in school science and mathematics by students conventionally marginalized within those subjects on the basis of students' cultural self-identities. Hammond and Brandt (2004) documented this motivation through their analysis of anthropological studies devoted to a cultural perspective on science education published in key scholarly journals.

Interest has also been stimulated for other reasons. First, some scholars (including some scientists) want to expand the content domain of science to encompass facets of Indigenous

knowledge for the purpose of improving the scientific enterprise's contributions to our planet's sustainable future (e.g., Cajete 2000b; Snively and Corsiglia 2001). They want to avoid, for instance, government officials making science-based decisions over resource management while ignoring highly relevant Indigenous knowledge. Such decisions can have devastating consequences (Castellano 2000; Glasson et al. 2006; Nadasdy 1999). To this end, for instance, the International Council for Science (ICSU 2002) includes "traditional knowledge" (Indigenous knowledge) as one of the branches of science in its organization.

Second, there is a movement to enhance the sovereignty and cultural survival of Indigenous peoples worldwide (e.g., McKinley 2007; Niezen 2003). A movement toward sovereignty is about healing and rebuilding Indigenous nations oppressed by colonization (as mentioned above), but it is also about surviving the biodiversity wars between, on the one side, Indigenous peoples who see themselves fighting biopiracy and globalization, and on the other side, commercial interests who see themselves providing new products for humankind and maximizing corporate profits. The meaning of intellectual property rights is crucial here.

Third, an increasing number of science educators want to understand the cultural influence on school science achievement by students whose cultures and languages differ from the predominant Eurocentric culture and language of science. These students may live in a non-Western country (e.g., Japan, Nigeria, or Saudi Arabia) or they may live in a Western country (e.g., USA, Australia, or UK), but in any case, they do not feel comfortable with the culture of Eurocentric science embedded in their school science classes.

The diversity of reasons motivating science educators' interest in Indigenous and neo-indigenous knowledge creates the many different perspectives found in the literature. Rather than review this diverse literature, we eclectically draw upon it according to three broad topics around which this article is organized: a characterization of science, a description of Indigenous ways of knowing nature, and a description of a neo-indigenous way of knowing nature (in our case, a Japanese way of knowing nature). We conclude with a discussion on three related topics: potential pitfalls to describing these three diverse ways of knowing nature, similarities and differences among these three ways, and a critical application of this article's content to science education materials. We begin with science because it is more familiar to most readers.

Science

Our brief characterization of science lays out some of its major features. Readers will contemplate these features through the lens of their own professional knowledge. In this section we clarify the term *science*, we sketch the diversity and some presuppositions that lie within science, and we recognize school science as a separate but related entity.

Clarification of the term *science*

The historical origins and evolution of science within Euro-American cultures naturally causes its practitioners (today's scientists) to embrace certain fundamental worldviews, epistemologies, ideologies, and values; all related to science's origin and evolution.

The origins of science go back to ancient philosophies (e.g., Egyptian and Greek), while its evolution can be marked by major social transformations in Europe. Understanding this evolution helps clarify the term *science*.

The first social transformation in Europe was the Renaissance movement. It eventually created the need for 17th century natural philosophers (e.g., Galileo, Kepler, Descartes, Wallis, Leibniz, Roberval, Huygens, Halley, and Newton) to establish a knowledge system predicated on the authority of empirical evidence, as opposed to the authority of the church and royalty. Natural philosophy was imbued with the value of gaining power and dominion over nature (Mendelsohn and Elkana 1981). Other values were added as window dressing to natural philosophy in order to appease the church and royal authorities of the day. This façade of values included objectivity and a disconnection with human implications of the knowledge generated by natural philosophers (Mendelsohn and Elkana 1981). Natural philosophy first became a social institution in England when the Royal Society was founded in 1662. Other countries followed. These historical events are known today as the Scientific Revolution.

A second social transformation stemmed from the success of natural philosophers at exercising power and dominion over nature. Their success attracted the attention of entrepreneurs who adapted the methods of natural philosophy to gain power and dominion over human productivity, in the context of various industries emerging across 18th century Britain (Mendelsohn 1976). This gave rise to the Industrial Revolution and provided a new social status for technologists. These industrialists spoke of natural philosophy as the handmaiden of technology. However, the independent-minded natural philosophers would have none of it. In the early 19th century, natural philosophers began to distance themselves from technologists, thereby precipitating the next radical transformation in the evolution toward modern science (Mendelsohn and Elkana 1981).

Natural philosophers, led by Whewell (an Anglican priest and natural philosopher of mineralogy at Trinity College Cambridge), set about to revise the public image of natural philosophy by portraying technologists—for example, James Watt of steam engine fame—as people whose success depended upon *applying* the abstract knowledge of natural philosophy. He and his colleagues succeeded in their revisionist project, and today there is a widespread belief in the erroneous notion that technology is solely applied science, thereby maintaining the ancient Greek philosophy (ideology) that holds "pure science" superior to practical knowledge (Collingridge 1989).

Revising history was only one step in the 19th century's radical advance toward modern science. A new social institution was required and it needed to secure a social niche in 19th century European society. In short, natural philosophy needed to be *professionalized* (Orange 1981). Very purposefully and politically, the name *science* was chosen to replace *natural philosophy* during the birth of a new organization in 1831, the British Association for the Advancement of Science (BAAS). Thus, the BAAS added a new meaning of science to the English lexicon, a meaning we primarily use today (Orange 1981). In archaic English, *science* simply meant knowledge (Latin: *scientia*). Given its BAAS origin, science in the Anglo world narrowly privileges an operational meaning defined, in part, by the Eurocentric science taught in universities.

The word *science* was politically chosen by the founders the BAAS because they required a label to set themselves apart from natural philosophers, from technologists steeped in the successes of the Industrial Revolution, and from members of the stogy Royal Society (MacLeod and Collins 1981). The BAAS also sought a privileged position from which to lobby financial support for the work of its members, and from which to establish an ideology of an emerging school science curriculum. Furthermore, the BAAS served as a

model for the American Society of Geologists and Naturalists when, in 1848, the Society established the American Association for the Advancement of Science.

As a consequence to this evolution of natural philosophy into a 17th century institution and then into professionalized science, modern science has often been associated with Western thinking. Some scholars follow the convention of labeling this Eurocentric knowledge system *Western science* or *Western Modern Science*. Others argue that this label diminishes the non-Western contributions to science's canonical knowledge and ignores the globalization of science that influences all countries today. Krugly-Smolska (2004), for example, proposed the term *transnational science* to avoid the connotative baggage she and others associated with *Western science*.

A different label altogether arises from considering *who* contributes to this knowledge system and way of knowing nature, and consequently, what kind of knowledge is generated. In this article, we focus our attention on 20th and 21st century people originally trained by university science departments worldwide and then employed, for instance, by business, industry, the military, government agencies, private foundations, and to a small extent, by universities. In short, these are people employed mostly in a social context of power and privilege associated with R&D (research and development), patents, economic progress, and globalization. These professionals are paid by their institutions to generate, transform, or use knowledge for the purpose of benefiting those institutions. Many of these people belong to professional scientific organizations that exist: for informal networking through "invisible colleges" (subject to censorship when national security or corporate profits could be at risk), for formal dissemination of knowledge through professional conferences and journals (also subject to censorship), and for political lobbying to influence funding policies to benefit its members. In professional science communities, people collectively work within a subculture that frames their thinking and practice in the context of that work (Traweek 1992). For most scientists, this subculture is Eurocentric in nature. Therefore, in this article we refer to these people's professional knowledge system and way of knowing nature as *Eurocentric science*. The heterogeneity that exists among these scientists (described below) will be represented by the plural *Eurocentric sciences*.

Eurocentric sciences possess a powerful way of knowing about nature, and this includes knowledge appropriated over the ages from many other cultures (e.g., Islam, India, and China). Such knowledge was modified sufficiently to fit Eurocentric worldviews, metaphysics, epistemologies, and value systems. Eurocentric science is also known as the culture of Western science in some fields of cultural anthropology (e.g., Kawada 2001; Pickering 1992) to emphasize the group's shared norms, values, beliefs, expectations, technologies, and conventional actions.

Our use of the term *Eurocentric sciences* creates the need to define the singular term *science*. Here we propose a pluralist notion of science for use in science education. We do not presume that scientists and their professional organizations will take up this definition because their identities seem to rest on their ownership of the word *science*, an ownership expressed in terms of a universalist viewpoint on Eurocentric science, as opposed to a pluralist viewpoint on science (Elkana 1971; McKinley 2007).

Ogawa (1995) conceived of science from a multi-science (pluralist) perspective that provided a meaning more encompassing than science's conventional Eurocentric meaning. He simply defined it as *a rational perceiving of reality*. The word *rational* does not signify a universalist rationality, but a rationality founded within the cultural context of use (Elkana 1971). *Perceiving* means both the process of constructing what is perceived to be reality through the participation of a group of people, and their resultant mental

constructions of reality. A rational perceiving of reality has three aspects: a process, a product (i.e., knowledge or action), and a cultural context defined by the people engaged in the perceiving. Ogawa (1995) considered three sciences: Eurocentric science (discussed here), indigenous science (discussed below), and personal science (a rational perceiving of reality unique to each individual, not discussed).

The notion of science proposed in this article reaffirms "a rational perceiving of reality," by which we mean: *a rational empirically based way of knowing nature that yields, in part, descriptions and explanations of nature*. This superordinate concept subsumes the Euro-American cultural perspective (Eurocentric science) and various non-Eurocentric perspectives, including Indigenous and neo-indigenous ways of knowing nature.

MacLeod and Collins's (1981) historical account of the foundation of BAAS placed the word *science* squarely in a political arena of elite social privilege. We revisit this political arena in this article, but in the context of 21st century science education, as we broaden the 1831 meaning of science by adopting a multi-science perspective. This shift in definition advances our project to help decolonize the discourse in science education by building bridges between a Eurocentric knowledge system and other ways of knowing. Our pluralist superordinate *science* forms one of those bridges between Eurocentric sciences and various Indigenous and neo-indigenous ways of knowing nature.

Eurocentric sciences

Before comparing Eurocentric sciences with Indigenous and neo-indigenous ways of knowing nature, we sketch in broad brush strokes some key features of Eurocentric sciences.

One of the most well-known, influential though somewhat controversial, description of Eurocentric science is Kuhn's *The Structure of Scientific Revolutions* (first edition 1962, second edition 1970). He expanded the notion of Eurocentric science from a rather narrow philosophical description to one that included a limited sociological and historical viewpoint. His concepts of paradigm, normal science, and extraordinary science introduced subjective human elements into scientific ways of knowing, and thus, into the fabric of scientific knowledge itself. These concepts help to characterize the great diversity within Eurocentric science. For example, many scientists engage in normal science—puzzle solving through the use of established science content within a paradigm (paradigm-directed)—while other scientists may at times engage in extraordinary science that could lead to challenging scientists' allegiances to a paradigm (paradigm-shattering). Moreover, paradigms can be so diverse that communication between them (e.g., between ecologists and biophysicists) is hampered or even incommensurate.

Scholars criticized Kuhn for not clarifying his concept of paradigm sufficiently, citing as many as 22 different definitions in his first edition (1962). In response, his second edition (1970) included a Postscript in which he delineated legitimate multiple meanings of paradigm. First, he reiterated that a paradigm is associated with a group of scientists who produce and validate scientific knowledge. "A paradigm governs, in the first instance, not a subject matter but rather a group of practitioners. Any study of paradigm-directed or paradigm-shattering research must begin by locating the responsible group or groups" (p. 180). Validation within a paradigm requires argumentation and consensus making by a group of practitioners.

Second, Kuhn replaced "paradigm" with "disciplinary matrix" to clarify another meaning of paradigm. A disciplinary matrix is a "constellation of group commitments"

(p. 181). This constellation comprises: (a) symbolic generalizations (e.g., vocabulary and equations); (b) metaphysical paradigms, represented by various types of models, from heuristic to ontological models; (c) values that guide a judgment concerning evidence and theories, as well as values that scientists draw upon to reach a consensus; and (d) exemplars that serve as concrete problem-solutions for students to construct knowledge shared by a community of practitioners.

A third meaning of paradigm expanded Kuhn's notion of exemplar into an "assimilated ... time-tested and group-licensed way of seeing" (p. 189). This tacit knowledge leads to his fourth point: scientists' perceptions and interpretations depend upon scientists' prior experiences and training (p. 198). The degree to which this tacit knowledge is shared often reflects the strength of a group's commitment to a paradigm. And lastly, Kuhn discussed the degrees of incommensurability found between different paradigms.

Kuhn demonstrated that Eurocentric science does not proceed in a purely logical and impersonal way. His detractors, however, accused him of undermining the epistemic authority of Eurocentric science by his placing Eurocentric science at the mercy of human emotions and intellectual fads. This criticism was countered by Bauer (1992) who pointed out that scientific consensus making most often relied upon critically analyzed, empirical data (not solely upon subjective group commitments to a paradigm), and that recent history of Eurocentric science "offers ample instances where science *did* incorporate false beliefs, sometimes under the influence of emotion and fashion" (p. 62, emphasis in original). Perhaps Kuhn's detractors were seeking a universalist descriptor of Eurocentric science, rather than the narrow pluralist descriptors offered by Kuhn.

The existence of multiple paradigms, some of which may be incommensurate, illustrate the extensive diversity within Eurocentric science. For this reason, we incorporate the more authentic term *Eurocentric sciences* (plural) into our discussion.

Even within a single field of a Eurocentric science, paradigms can be extensively diverse, for example, the origin-of-life research described by Hazen (2005):

> Scientists crave an unambiguous definition of life, and they adopt two complementary approaches in their efforts to distinguish that which is alive from that which is not. Many scientists adopt the "top-down" approach. They scrutinize all manner of unambiguous living and fossil organisms to identify the most primitive entities that are, or were, alive. For origin-of-life researchers, primitive microbes and ancient microfossils have the potential to provide relevant clues about life's early chemistry.
> ...
> By contrast, a small army of investigators pursues the so-called "bottom-up" approach. They devise laboratory experiments to mimic the emergent chemistry of ancient Earth environments. Eventually, the bottom-up goal is to create a living chemical system in the laboratory from scratch – an effort that might clarify the transition from nonlife to life. Such research leads to an amusing range of passionate opinions regarding what is alive, because each scientist tends to define life in terms of his or her own chosen specialty. (pp. 26–27)

The "amusing range of passionate opinions" are the caustic public debates between some scientists that Hazen chronicles in his book *Genesis: The Scientific Quest for Life's Origin*; that is, debates between scientists who have passionate commitments to different paradigms.

Different paradigms often dictate different research methods. These vary so widely that it would seem foolish to think that a single, logical, five-step method—"*the* scientific method"—could represent all Eurocentric sciences. According to Rudolph (2005) this

phrase was misappropriated by science educators from Dewey's 1910 book *How We Think*. The ubiquitous existence of "the scientific method" today in schools, universities, and the media suggests that this anti-Kuhnian notion continues to pervade people's thinking about Eurocentric sciences. Many scientists and scholars, including Dewey himself, have denounced the idea, and it is in their denunciations that we find greater clarity to the diversity among Eurocentric sciences.

In Holton's (1978) *The Scientific Imagination*, for instance, he included several case studies to show how intuitive imagination propels Eurocentric sciences forward, and how different values held by various scientists can alter the course of Eurocentric sciences.

Perhaps the most direct refutation came in Bauer's (1992) *Scientific Literacy and the Myth of the Scientific Method*. He identified variations in different sorts of Eurocentric sciences, for instance: young/mature, data-driven/theory-driven, data-rich/data-poor, experimental/observational, and quantitative/qualitative; and different sorts of scientists, for instance: good/poor, competent/incompetent, outstanding/mediocre, creative/uninspired, and interesting/ignorable. Any one of these variations can influence the scientific method used by a team of practitioners.

But how do Eurocentric sciences really work? In his critique of the scientific method, Bauer (1992) pointed to four salient features of Eurocentric sciences:

> modern science began when cooperation among scientists became widespread and systematic; modern science is a quite particular sort of cooperative venture, working most successfully when autonomous; what really constitutes pseudoscience is isolation from the scientific community; and science cannot be successful and also produce what ideologues want. (pp. 43–44)

Along with Kuhn, Bauer describes legitimate Eurocentric sciences in terms of working within a community of scientists (i.e., professionalized science). Membership, more than methodology and content, characterizes an operational legitimacy of Eurocentric sciences (i.e., what counts as Eurocentric science is what scientists decide what counts). In short, Eurocentric sciences are communal. Consensus making within a community of practitioners determines scientific truth, a process that maximizes, but does not achieve, objectivity. Rather than achieving objectivity, consensus making reduces the subjectivities of individual scientists and of tradition within that community.

In addition to this operational-legitimacy approach to finding commonality among Eurocentric sciences, scholars have examined the underlying, and often subconscious, presuppositions that unite most, but not all, Eurocentric scientists. We include Kuhn's (1970) and Bauer's (1992) work in this literature. Descriptions of Eurocentric sciences emerge from: philosophical analysis (e.g., Margenau 1950), historical analysis (e.g., Mendelsohn 1976; Mendelsohn and Elkana 1981), ideological analysis (e.g., Smolicz and Nunan 1975), sociocultural analysis (e.g., Ziman 1984), cultural worldview analysis (e.g., Cobern 1991), and cross-cultural analysis (e.g., Battiste and Henderson 2000, Ch. 7; Irzik 1998; Little Bear 2000; Snively and Williams in press). Our purpose is not to review this expansive literature and the intellectual disagreements therein, but instead, we draw upon it eclectically to identify several fundamental presuppositions claimed to be inherent in most Eurocentric sciences. We present these presuppositions in categories for the sake of efficient communication; however, the categories are interrelated in a number of ways. These presuppositions further enrich our characterization of Eurocentric science and offer evidence for its European cultural foundation. Given the ideological nature of these presuppositions, it is not surprising that some continue to be contentiously debated among scientists and other scholars.

Nature is knowable

A fundamental presupposition in Eurocentric sciences posits that nature is knowable. This knowledge usually comprises generalized descriptions and mechanistic explanations. Mechanistic explanations are models or a series of cause-effect events that operate like a well-ordered clock. (A historical source for this metaphor is suggested below, in the subsection "Rectilinear Time.")

Mystery in nature creates the need to know nature, which leads to investigations aimed at eradicating that mystery by generating scientific descriptions and explanations. Eradication of mystery is a key intellectual goal in Eurocentric sciences.

Social goals of scientists

The need to know nature motivates scientific curiosity. The acquisition of knowledge of nature to satisfy scientific curiosity is a reasonable psychological goal for individual scientists. From a sociological perspective, the goal becomes the acquisition of knowledge for the sole purpose of acquiring knowledge. As described above, this ideal was written into the social contract of natural philosophers when the Royal Society was institutionalized in the 17th century. The social goal or value, knowledge for knowledge's sake, circumvented political clashes over issues of authority with the church and royalty at the time (Mendelsohn and Elkana 1981). The value has lost its relevance for contemporary society, yet it survives as an ideal in academic and school science today (Mendelsohn 1976).

Sociocultural analyses of professionalized Eurocentric sciences have uncovered diverse social goals. Individually, scientists are generally motivated by several reasons, including: to satisfy their curiosity, to acquire or maintain credibility among their peers, to receive financial remuneration, to win in the competition for research grants, and in a few cases, to gain fame and fortune. Social goals also vary according to the institution employing scientists, and according to the nature of the R&D project undertaken. Collectively, research is conducted for businesses, industry, the military, government agencies, private foundations, etc. Therefore, these contexts add more social goals to the list above, including: prestige, social and economic progress, medical advances, corporate profits, national security, enactment of foreign policy, third-world colonization through globalization, etc. Because R&D is always done within social contexts, social goals are inherent presuppositions in Eurocentric sciences (Glasson et al. 2006). There is one stark feature, however, common to all of these social goals: competition. Eurocentric sciences are highly competitive.

Predictive validity

A major feature of an experiment is to test the predictability of a hypothesis. Hypotheses stand or fall on their predictability. When the predictability of a law or theory is challenged by anomalous evidence, a paradigm's acceptability is threatened. In addition to experimental studies, however, descriptive research studies contribute systematic knowledge to Eurocentric sciences, in some paradigms more than others. These descriptions are valued for their predictable consistency and for their success at initiating novel experimental research, which is all about identifying successful predictors. Predictive validity is a foundational presupposition for Eurocentric sciences.

Predictive validity can be contrasted with content validity, represented by the epistemology of Aristotle's "intelligible essences." "The essence is the form of matter that lends

each being its distinctive identity. The supporters of the doctrine of intelligible essences [which includes spiritual forces] held that the standards of right and wrong must also have 'essences' that thought can comprehend. Plato's ethics and St. Thomas Aquinas's theory of natural law exemplify this line of argument" (Battiste and Henderson 2000, p. 121). By denying the validity of intelligible essences (i.e., denying the fidelity to a true world), Eurocentric scientists delimit the validity of their own scientific knowledge to its ability to predict, which is inextricably tied to an ability to control phenomena and events (described below). In short, predictive validity concerns itself with *how* the universe works, while content validity addresses the issue of *what* the universe is.

Uniformitarianism

The uniformitarianism presupposition states that all Eurocentric scientific constructs must be applied consistently through time and space (Margenau 1950). Sir Isaac Newton expressed this generalizability value as his third rule of reasoning in natural philosophy, in his 1687 *Principia* (Cajori 1962). This universality presupposition is an idealized formulation of, or a value aspiration for, Eurocentric scientific knowledge (Kawada 2001). This type of knowledge can be contrasted with Eurocentric science-in-action (i.e., practical knowledge), for which idealized constructs have been deconstructed and then reconstructed according to the idiosyncratic demands of a particular context, thereby qualitatively altering the original construct (Jenkins 1992; Roth and Lee 2004; Ryder 2001). For example, a context for science-in-action could be a science-related medical event on a hospital surgical ward (Aikenhead 2005). Eurocentric science-in-use is context-based; however, its generalizability across similar contexts is highly valued.

Rectilinear time

The presupposition of rectilinear time is a culture-based conception. Bolter (1984) analyzed the concept of time held by ancient Greeks, Europeans in the Middle Ages and Renaissance, and modern computer engineers. He argued that a particular technology endemic to each culture defined different concepts of time: the clay pot (ancient Greece), the mechanical clock (a 14th century invention), and the computer (an invention attributed to Alan Turning, about 1936). Of interest to us here is Bolter's contention that the concept of linear time was constructed as a result of the invention of a mechanical clock.

> What kind of a universe did the clock suggest? A precise and ordered cosmos, for the clockwork divided time into arbitrary, mathematical units. It encouraged men [sic] to abstract and quantify their experience of time, and it was this process of abstraction that led to the creation of modern astronomy and physics in later centuries. ... The clock made explicit a view of the universe that orthodox Christianity had been tacitly encouraging for centuries. (p. 27)

Prior to mechanical clocks, time was, more or less, a subjective personal concept.

Bolter speculated that today we may be living with a radically new defining technology—the low-temperature CPU computer, for which the concept of time surpasses 20th century human experience with time. For now, Eurocentric sciences embrace rectilinear time as an absolute feature of reality.

Cartesian dualism

This foundational presupposition bifurcates existence into two substances: matter and mind. They are distinct, independent, and non-interacting. The heavens and earth comprise the matter category. Thus, knowledge of matter is necessarily devoid of any kind of human intuition, spiritual forces, or divinities because these belong to the category of mind. Cartesian duality inspired the metaphor that Cartesian matter is a huge machine that runs according to mechanistic laws of nature.

People who do not subscribe to Cartesian dualism perceive it as destroying their unity of existence (Irzik 1998). Their alternative is a monist ontological presupposition in which Descartes' matter and mind intermingle. One group of monist scientists is found in a paradigm of particle physics ("the marriage between quantum physics and cosmology;" Loo 2005, p. 7). This paradigm enjoys a history of public attention, for instance, *The Idea of Nature* (Collingwood 1945) and *The Dancing Wu Li Masters* (Zukav 1979). The paradigm's "Eastern monist" perspective replaces a Cartesian "Occidental dualist" perspective (Loo 2005).

Reductionism

This foundational presupposition holds that Eurocentric scientists can understand "the structure and function of the whole in terms of the structure and function of its parts" (Irzik 1998, p. 168). Many scientists analytically break down (reduce) a complex phenomenon into simple parts, factors, or variables amenable to measurement, conceptualization, and experimentation. The "whole" can then be understood through the integration of these partial, fragmented, bits of knowledge.

A very small number of fields within Eurocentric sciences (e.g., certain areas of ecology and geology, emergent complex systems, and elementary particle physics) profess a non-reductionist approach to knowing nature. Many of these non-reductionist Eurocentric fields embrace Cartesian dualism, but a few do not (Capra 1996; Hazen 2005; Zukav 1979). This latter group consists of monist thinkers.

Anthropocentrism

An anthropocentric presupposition views nature as a servant to humankind. Anthropocentrism is sanctioned by some religious and philosophical doctrines in general, and by the Judeo-Christian tradition in particular (Cajete 2000b; Kawada 2001; Smolicz and Nunan 1975). This anthropocentric tradition places humans just below the heavenly angels but above animals, plants, and the rest of nature. It was embraced by 17th century natural philosophers and enthusiastically taken up by 19th century scientists. Practitioners were free to investigate, rule and exploit nature with the divine sanction of Christianity (Mendelsohn 1976). Anthropocentrism suggests the dichotomy, humankind versus nature, which resonates with the presuppositions of predictive validity and Cartesian dualism. The anthropocentric presupposition is often couched in the value "power and dominion over nature." As a result, Eurocentric scientists are characterized as manipulators of nature, even though not all manipulate nature (e.g., astronomers). Kawada (2001) argues that European anthropocentrism is characterized by a strong universalist posture found in both uniformitarianism (above) and positivism (below).

Quantification

The quantification presupposition applies to Cartesian matter alone. It holds that materialistic reality is comprised of objective mathematical relationships. As a consequence, the quantification of natural phenomena is either a requirement or at least an ideal in Eurocentric sciences. Although some Eurocentric sciences are not known for their quantification, their status as a discipline within the larger scientific community varies accordingly. By representing entities and events by numbers, scientists tend to objectify an entity or event by stripping it of qualitative, human, or spiritual attributes (i.e., stripping it of intelligible essences). "Objectivity concerns itself with quantity and not quality" (Little Bear 2000, p. 83). Subjective constructs (e.g., complexity of life), if not measurable, are not scientific (Hazen 2005). Quantified objectivity tends to depersonalize scientists and what they study.

Realism

In addition to depersonalizing people, objects, and events, quantification tends to reify scientists' observations, constructs, descriptions, and mechanistic explanations. In short, if we can measure it, it must exist. According to this doctrine, when scientific logic is applied to one's senses the result is a direct connection with nature. This implies that scientists describe reality independent of their act of perceiving. The resultant knowledge of nature is therefore a true reflection of things as they really are. The assumption of reification is often called *realism* or *naïve realism* (Milne and Taylor 1998; Nadeau and Désautels 1984). For example, many people continue to believe that Newton's construct of gravity is reality, rather than a quantitative, evidence-based, paradigm-anchored, general description with extremely high predictive validity. However, when its predictability seriously failed (e.g., by not accounting for Mercury's orbit), a shift from a Newtonian paradigm to an Einsteinian paradigm ensued for some scientists. Alternatives to realism have preoccupied science educators for several decades, and these alternatives include various concepts of constructivism (Jenkins 2000; Tobin 1993) and the cultural concept of image (Ogawa 1998a).

The doctrine of realism claims fidelity of a true world. This may sound similar to the doctrine of intelligible essences. The two doctrines are different, however, in that realism pertains to Cartesian matter while intelligible essences pertain to both matter and mind in accordance with a monist ontology.

Positivism

With its modern roots in the Vienna Circle in the early 20th century (Holton 1978) and sustained by 20th century technical rationality (Habermas 1972), the ideology of positivism has exerted a strong influence on the nature of Eurocentric sciences up until about the 1960s (Ziman 1984). Ironically, this ideology's project was to construct a science *free from* any worldview or ideology. It passionately emphasizes inductive and deductive logic applied impartially to theory-neutral observations and to strict empirical and experimental methodologies, all of which yield objective, value-free, universal, secure knowledge of nature. Its focus on logical procedures lends credence to "the scientific method."

Positivists consider their scientific thinking to be the ultimate measure of rationality (Holton 1978), and therefore, positivists' knowledge singularly represents the fidelity of a true world. Positivism embodies a universalist worldview in which there can only be one

ideal, one norm, and one standard—the positivists' ideal, norm, and standard. From this pinnacle of fidelity, it is simply common sense to hold inferior all other knowledge systems and ways of knowing nature. Nadeau and Désautels (1984) succinctly encapsulated positivism as blissful empiricism, credulous experimentalism, and excessive rationalism.

For the last several decades, scientists and scholars have lived in a post-positivist world, but strong vestiges of a positivist ideology remain, nevertheless. For example, positivism continues to grip school science today.

School science

The culture of Eurocentric sciences and the contexts of their R&D are a far cry from the culture of schools and the contexts of science classrooms. A false security of positivism and the naïve bliss of realism, for example, may have pragmatic force for professional teachers diligently trying to serve conflicting interests and needs of diverse students, but at the same time, trying to get through the week burdened with increasing social and professional responsibilities. The conventional culture of school science is not conducive to teachers' rising above *the* scientific method, realism, and positivism (Gaskell 1992; Smolicz and Nunan 1975). As a result, school science generally fails to enlighten students about the authentic Eurocentric sciences that permeate their everyday lives (Aikenhead 2006; Lederman 2007), and science teaching continues to convey what many scholars see as mythical images of realism and positivism (Abd-El-Khalick and Lederman 2000).

This failure was painfully evident in some curriculum materials developed in two First Nations communities in Canada. The Ahkwesahsne Mohawk Board of Education (1994) produced *Lines & Circles*, a curriculum integrating several school subjects and combining "Western science" with "Ahkwesahsne ways of knowing—Native science." In the opening unit, Western science is described in terms of: following the scientific method, finding the truth, and producing technology. In some of the unit's activities, students critically analyze these features in terms of the advantages and disadvantages of the two ways of knowing, but nevertheless, Eurocentric sciences are portrayed in highly positivist ways. Another project, *Forests for the Future* (Menzies 2003), included a table in Unit 1 that compared "Western science" with "Traditional Ecological Knowledge" of the Tsimshian nation (p. 9). Among the descriptors of Western science one reads "purely rational" and "value-free." Other descriptors, however, do authentically address Eurocentric sciences as being reductionist and mechanistic. Both curriculum materials (*Lines & Circles* and *Forests for the Future*) were explicitly developed to encourage greater participation in school science by First Nations students, but the materials conveyed some serious myths or half-truths about Eurocentric sciences, although not to the extent one sees in most conventional school science materials.

Decades of research has shown that few students and adults critically understand the many human dimensions to Eurocentric sciences, for example: their paradigmatic dynamics; their multiple methodologies; their culture-laden presuppositions; and their social, economic and political orientations. Whether or not students and adults should be conversant with such knowledge is an issue beyond the scope of this article. We simply wish to underscore the fact that school science is not synonymous with Eurocentric science, and in some ways it is the antithesis of Eurocentric science.

Conclusion

In one sense, Eurocentric sciences defy a universalist characterization because of their dramatically diverse paradigms, and because some of the presuppositions listed above do not have consensus among scientists (e.g., realism and positivism). Every individual scientist holds a unique hybridized stance on those presuppositions. However, our characterization has identified a major feature: *Eurocentric science is cultural* (Kawada 2001; Pickering 1992). We conclude with the following summary of other characteristics.

Kuhnian disciplinary matrices and paradigms point to human characteristics of, and the variability within, Eurocentric sciences. There are many types of Eurocentric sciences, for instance: young/mature, data-driven/theory-driven, data-rich/data-poor, experimental/observational, and quantitative/qualitative; and there are different sorts of scientists, for instance: good/poor, competent/incompetent, outstanding/mediocre, creative/uninspired, and interesting/ignorable. Eurocentric sciences are fundamentally communal, but highly competitively communal. Scientists embrace many values, a plethora of methodologies, and various degrees of imaginative intuition. Eurocentric sciences assume nature is knowable through the eradication of mystery. This knowledge of nature is characterized by: its predictive validity; a validation process that includes argumentation and consensus making by a group of practitioners (a process that reduces inherent subjectivity); uniformitarianism; an assumption of rectilinear time; anthropocentrism; Cartesian dualism (in almost all cases); reductionism (in most cases); and quantification (in most cases). Some scholars continue to debate: the influence of social goals on the content of Eurocentric scientific knowledge, the credibility of realism, and the appropriateness of positivism.

Our project is not to formulate conclusions about such influence, credibility, and appropriateness for school science. Instead, this summary establishes a base from which to build decolonizing bridges between Eurocentric sciences and diverse Indigenous and neo-indigenous ways of knowing nature.

Indigenous knowledge systems

> Indigenous scholars discovered that Indigenous knowledge is far more than *the binary opposite* of western knowledge. As a concept, Indigenous knowledge benchmarks the limitations of Eurocentric theory – its methodology, evidence, and conclusions – reconceptualizes the resilience and self-reliance of Indigenous peoples, and underscores the importance of their own philosophies, heritages, and educational processes. *Indigenous knowledge fills the ethical and knowledge gaps in Eurocentric education, research, and scholarship*. (Battiste 2002, p. 5, emphasis added)

The fallacy of binary opposites, that is, treating Indigenous knowledge systems and Eurocentric sciences as parallel equivalent systems, requires that we be sensitive to legitimate incommensurability. Sensitivity is heightened by seeing Indigenous knowledge systems with fresh eyes, unfiltered by the polarized lenses of Eurocentric worldviews, metaphysics, epistemologies, values, and ideologies described in the previous section. Although this creates a challenge, it is one way for individual science educators to transform science education's colonial discourse.

We begin our exploration of Indigenous knowledge systems and ways of knowing nature by clarifying two pivotal terms, *knowledge* and *Indigenous*. In doing so, we lay out a conceptual map for establishing some decolonizing bridges. The science education research literature often identifies Indigenous knowledge by such phrases as: traditional knowledge (ICSU 2002), traditional wisdom (George 1999b), traditional ecological knowledge (Snively and Corsiglia 2001), Native science (Cajete 2000b), Aboriginal science (Aikenhead 2006), Mäori science (McKinley 1996), and Yupiaq science (Kawagley 1995), to name just a few. But here we take a much different approach by adopting a less Eurocentric (more Indigenous) perspective on *knowledge* and *Indigenous*. We are not Indigenous people ourselves, and we apologize ahead of time for any misrepresentation that might occur. Any general statement should be read as indicative, not definitive.

Clarification of *knowledge* and *coming to know*

The noun *knowledge* does not translate easily into most verb-based Indigenous languages. When translated back into English, the corresponding Indigenous expression often comes out something like *ways of living* (and sometimes *ways of being*). Therefore, the English expression *Indigenous knowledge* obviously conveys, like a Trojan horse, a Eurocentric noun-oriented epistemology. In this Eurocentric worldview, knowledge (as a noun) is something that can be given, accumulated, banked, and assessed by paper and pencil examinations. In short, knowledge within a Eurocentric worldview is an entity separate from the knower.

Such an epistemic concept is totally foreign to most Indigenous worldviews, and consequently, there is no equivalent word for *knowledge* in their Indigenous languages. Knowledge and the knower are intimately interconnected. This is the case for the Nehiyawak (Plains Cree nation), one of the many First Nations in Canada, for whom the phrase *coming to know* means that a Nehiyaw (Cree person) is on a quest to become wiser in living properly in their community and in nature. To live properly includes the goal of living in harmony with nature for the sake of the community's survival (Michell 2005). In short, while Eurocentric scientists pursue knowledge, keepers of Nehiyawak ways of living in nature pursue wisdom (or wisdom-in-action). Knowledge and wisdom are two very different goals for ways of knowing nature. Wisdom is intimately and subjectively related to human action. "Nature provides a blue print of how to live well and all that is necessary to sustain life" (Michell 2005, p. 39).

The process of generating or learning Indigenous ways of living in nature is *coming to know* (Cajete 2000b), or *coming to knowing* (Peat 1994), phrases that connote a journey. Coming to know differs from the Eurocentric science process *to know* (i.e., to discover) that connotes a destination, such as a patent or a published record of a discovery. An Indigenous coming to know is a journey toward wisdom or a journey in wisdom-in-action, not a destination of discovering knowledge.

We extend our decolonizing project to the expressions *Indigenous knowledge* and *Indigenous knowledge systems* by substituting the more authentic (less Eurocentric) descriptive phrase *Indigenous ways of living in nature*, a phrase that encompasses *Indigenous ways of knowing*, as well. Thus, the phrase *scientific knowledge* fits the context of Eurocentric thinking, while the phrase *ways of living in nature* fits an Indigenous context.

In this article we are not able to describe in specific detail an Indigenous way of living in nature because, unlike Eurocentric knowledge, coming to know a specific detail in an Indigenous way of living in nature is a journey that requires experiential processes,

described below. Reading an article is not an adequate experience in coming to know how to live in nature. Ways of living in nature is action-oriented (verb-based); it cannot be given, accumulated, banked, and assessed by paper and pencil examinations. It must be experienced in the context of living in a particular place in nature, in the pursuit of wisdom, and in the context of multiple relationships (described below in the section "Indigenous Ways of Living in Nature"). "Woodlands Cree [Nēhîthâwâk] epistemology is participatory, experiential, process-oriented, and ultimately spiritual" (Michell 2005, p. 36). Barnhardt and Kawagley (2005) described ways of living in nature in terms of competencies:

> In Western terms, competency is often assessed based on predetermined ideas of what a person should know, which is then measured indirectly through various forms of "objective" tests. Such an approach does not address whether that person is actually capable of putting that knowledge into practice. In the traditional Native sense, competency has an unequivocal relationship to survival or extinction – if one fails as a caribou hunter, the entire family is in jeopardy. One either has or does not have requisite knowledge [ways of living in nature], and it is tested in a real-world context. (p. 11)

Conventionally, Indigenous ways of living in nature are communicated and learned in the oral tradition through modeling the practices of others, listening to stories, singing songs, reciting prayers, dancing at celebrations, and participating in spiritual ceremonies; all of which are passed on from generation to generation. Kawagley et al. (1998), scholars of the Yupiaq nation in Alaska, point out that a Yupiaq way of knowing nature "is manifested most clearly in their technology" (p. 136). (In contrast, school science is communicated and learned in the written tradition that conventionally eschews technology, for reasons described above in the section "Science.") Indigenous ways of living in nature are also embedded in local entertainment such as drama, proverbs, and jokes (George 1999b). Proverbs are particularly powerful in the Indigenous culture of Hawai'i (Chinn 2006).

No wonder a journal article is unable to specify concrete instances of Indigenous ways of living in nature.

Clarification of *Indigenous*

Indigenous peoples, according to a UN perspective, are the descendents of the first people to inhabit a locality, who self-identify as members of a collective, who are recognized by other groups or by state authorities, and who wish to perpetuate their cultural distinctiveness in spite of colonial subjugation and pressures to assimilate (Battiste and Henderson 2000, pp. 61–64). They generally share a collective politic of resistance arising from commonly shared experiences of oppression, that is, "marginalization, economic servitude, and sociocultural genocide" (Niezen 2003, p. 246).

Within the UN paradigm of Indigeneity, McKinley (2007), a Māori scholar and science educator, acknowledged different types of Indigenous peoples, including: (1) those whose colonial settlers/invaders have become numerically dominant (e.g., Māori of Aotearoa New Zealand, First Nations of Canada, the Quechua nation of Peru, and the Amei nation of Taiwan); (2) those in Third World contexts whose colonial settlers/invaders never reached a majority but left a legacy of colonization (e.g., Africa and India); and (3) those who have been displaced from the locality from which they once drew their cultural self-identity (e.g., immigrant Hmong communities in the USA and China, originally from Thailand). In addition, McKinley warned, "Indigeneity is a heterogeneous, complex concept that is

contextually bound" (2007, p. 202). The qualification "contextually bound" means there is no universal definition of Indigenous. Indigenous peoples worldwide tend to reject a universal definition for fear it might create an outsider-imposed Indigenous identity, thereby colonizing them all over again (Niezen 2003).

McKinley (2007) pointed out that Third World contexts were extraordinarily complex and beyond the scope of her review of the literature on Indigenous students and science education. This complexity is demonstrated in Semali and Kincheloe's (1999) discussion about the Indigeneity of local knowledge of (way of living in) a particular ecosystem; knowledge held by Kincheloe himself. He had acquired this knowledge as a poor white Appalachian boy in rural Tennessee. His local Appalachian knowledge of nature appears to be Indigenous in its characteristics and specific details. However, Semali and Kincheloe, assuming a political stance, concluded that such knowledge could not be considered Indigenous because Kincheloe's Appalachian knowledge of nature was held by a member of a privileged group (i.e., a white American). Their political criterion concerning privilege (or oppression) of the knowledge holder reflects the UN's perspective on the meaning of Indigenous.

The complexity of identifying Indigeneity becomes much deeper when we turn our semantic spotlight onto non-Eurocentric knowledge systems of nature (ways of living in nature) held by socially and economically privileged nations, usually found in Asia. These non-Eurocentric knowledge systems are characterized by a long standing, intimate, ecological, knowledge of nature. We wish to add one further dimension to the discussion of Indigeneity, without compromising the sovereignty of Indigenous peoples who continue to suffer the legacy of colonialism.

We affirm that mainstream cultures in many relatively privileged countries evolved over hundreds of years and are today recognized as the established cultures of those countries. One example is the island nation of Japan. In the following discussions, the abbreviations CE and BCE stand for "common era" and "before the common era" respectively. These are date designations slightly more culturally neutral than AD and BC ("anno Domini" and "before Christ" respectively), although the numerals remain the same. As described in more detail below, Japanese culture originated in the south-western part of Japan, about 12,000 BCE, with hunter-gatherer Indigenous people. They lived during the Jomon era (ca. 12,000–ca. 300 BCE). About 300 BCE immigrants with rice technologies from the continent began to arrive. During the Yayoi era (ca. 300 BCE to ca. 300 CE), the immigrants' culture dramatically influenced the culture of the direct descendents of the people of the Jomon era. As a result of this confluence of cultures, a hybrid culture was established across Japan where rice could be cultivated (not in the northern Japan, however). Today's Japanese culture developed principally from the people living during the ensuing eras. It is not surprising, therefore, to read that a contemporary traditional Japanese way of knowing nature "fits well with the [Canadian] First Nations sense of connection with nature" (Suzuki 2006), as will be evident later in this article.

The established culture of any country such as Japan is indigenous to its particular geographical area, and that indigenous culture will have its own knowledge of nature that can differ from Eurocentric sciences as much as Indigenous ways of living in nature differ from Eurocentric sciences.

In this article we continue the political sense of Indigeneity associated with an agenda of decolonization, but we distinguish between two senses of *indigenous*: First, there are the descendents of the first people to inhabit a locality or place, as described just above. We refer to this group as *Indigenous*—capital "I"—as many scholars do. A second meaning denotes a long standing, non-Eurocentric, mainstream culture, which we call *neo-indigenous*. For instance, Japan's neo-indigenous mainstream culture is not necessarily related to

the culture of some of the very first people who continue to inhabit northern Japan today (where rice does not grow), for example, the Ainu nation, an Indigenous people.

Our distinction between *Indigenous* and *neo-indigenous* is not a stipulative definition; rather it simply serves as a way to distinguish between two highly heterogeneous groups whose ways of knowing nature are both non-Eurocentric and often place-based, but whose political standing in terms of privilege and colonization are quite different. In this article, each group's collective worldview, metaphysics, epistemology, and ways of living in nature are explored in two major sections (below), "Indigenous Ways of Living in Nature" and "A Neo-Indigenous Way of Knowing Nature." In the latter section we discuss the neo-indigenous concepts of knowledge and to know, which parallels our discussion of knowledge and coming to know for Indigenous peoples (above).

Given McKinley's (2007) "contextually bound" qualification to any definition of Indigeneity, the context of white, poor, rural, Appalachian Tennessee people holding non-Eurocentric knowledge of nature might be viewed as neo-indigenous knowledge, depending on one's perspective.

From a different perspective, Viergever (1999) entered the quagmire of defining Indigeneity when he gave preference to the *process of generating* knowledge, rather than to specific details of the knowledge itself.

> [W]e should not focus on bits of specific knowledge, but rather on the *generation* of knowledge. What matters in the long term is the continuation of a system that has shown to be able to generate knowledge...; a system that has developed alternative solutions for several local problems. Perhaps these solutions are not as "sophisticated" as the solutions developed by the scientific system, but often they are equally effective and environmentally more sustainable. (pp. 334–335, emphasis in original)

In a Nehiyawak (Cree) worldview, *generating* Indigenous ways of living in nature is equivalent to *learning* Indigenous ways of living in nature, because learning is a personal, participatory, constructive process toward gaining wisdom or wisdom-in-action (Michell 2005).

Indigenous ways of living in nature (IWLN)

In addition to describing political and process-oriented perspectives on Indigeneity, Indigenous scholars have written about the underlying, and often subconscious, presuppositions (i.e., worldviews, metaphysics, epistemologies, and values) that unite most, but not all, Indigenous communities and nations worldwide. In this article, we focus on the work of scholars belonging to Indigenous nations of Turtle Island (North America). As was our approach in describing Eurocentric sciences, we do not review this diverse literature, but instead we eclectically draw from it to identity fundamental features that help clarify similarities and differences between IWLN and Eurocentric sciences. We draw quite heavily upon quotations from Indigenous scholars to bring greater authenticity to our descriptions.

Monist

Based on Collingwood's (1945) historical analysis of concepts of nature, Loo (2005) concluded that an alternative to a Cartesian dualist worldview is a monist worldview.

Monism mingles Descartes' matter and mind, and as a result, everything in the universe is alive: animals, plants, humans, rocks, celestial bodies, natural forces, etc. (Battiste and Henderson 2000; Cajete 2000b; Chinn 2006; Kawagley et al. 1998). Such a worldview is sustained by Indigenous languages.

> Aboriginal languages are, for the most part, verb-rich languages that are process- or action-oriented. They are generally aimed at describing "happenings" rather than objects. The languages of Aboriginal peoples allow for the transcendence of boundaries. For example, the categorizing process in many Aboriginal languages does not make use of dichotomies.... There is no animate/inanimate dichotomy. Everything is more or less animate. Consequently, Aboriginal languages allow for talking to trees and rocks, an allowance not accorded in English. If everything is animate, then everything has spirit and knowledge. (Little Bear 2000, p. 78)

Animate objects are imbued with a life spirit.

> In Western science, the closest to Yupiaq science can be seen in the study of ecology, which incorporates biological, chemical, and physical systems (earth, air, fire, and water). However, even many ecologists have ignored the fifth element, spirit. Lack of attention to the fifth element has resulted in a science that ignores the interaction and needs of societies and cultures within ecosystems. (Kawagley et al. 1998, p. 139)

Nature is both physical and spiritual simultaneously and interactively. Spirituality (not to be confused with religion) was removed from the discourse of natural philosophy in the 16th and 17th centuries to achieve a type of empiricist authority independent of other social authorities at that time in Europe (e.g., religious and royal authorities).

This metaphysical spirituality is described by Nehiyaw scholar Ermine (1995) in terms of an inner space (the spiritual world) and an outer space, (the physical world); both of which interact holistically.

> Those who seek to understand the reality of existence and harmony with the environment by turning inward have a different, incorporeal knowledge paradigm that might be termed Aboriginal epistemology. Aboriginal people have the responsibility and the birthright to take and develop an epistemology congruent with holism. (p. 103)
> ...
> Only by understanding the physical world can we understand the intricacies of the inner space. Conversely, it is only through journeys into the metaphysical that we can fully understand the natural world. (p. 107)

Existence only makes sense when physical and spiritual experiences are unified, a presupposition that melds well with a holistic presupposition.

Holistic

Holism can be contrasted with Eurocentric reductionism:

> No separation of science, art, religion, philosophy, or aesthetics exists in Indigenous thought; such categories do not exist. Thus, Eurocentric researchers may know the name of a herbal cure and understand how it is used, but without the ceremony and ritual songs, chants, prayers, and relationships, they cannot achieve the same effect. (Battiste and Henderson 2000, p. 43)

Battiste and Henderson also point out that holism leads to "harmony as a dynamic and multidimensional balancing of interrelationships in [Indigenous peoples'] ecologies. Disturbing these interrelationships creates disharmony" (p. 43). By splitting up and segregating a description of a natural phenomenon into biology, chemistry, and physics, we disturb the fundamental presupposition of holism.

A monist ontology and a holistic epistemology not only challenge the forms and content of Eurocentric sciences, they reproduce "new forms of knowledge through [their] emphasis on breaking down disciplines and taking up objects of study that were unrepresentable in the dominant discourses of the western canon" (Giroux 1992, p. 56).

Relational

Blackfoot scholar Little Bear (2000), who explains holism as "everything is animate" (quoted above), extends his explanation: "If everything is animate, everything has spirit and knowledge. If everything has spirit and knowledge; then all are like me. If all are like me, then all are my relations" (p. 78). As a constant reminder of this powerful presupposition, some Indigenous peoples end an Elder's prayer with the invocation, "All my relations." The expression proclaims a profound ontology: as we make our way through life, we travel in a relational existence.

> [A Navajo way of living in nature] may be viewed as the practice of an epistemology in which the mind embodies itself in a particular relationship with all other aspects of the world. For me as a Navajo, these other aspects are my relations. I have a duty toward them as they have a duty as a relative toward me. (Yazzie 1996; as quoted in Cajete 2000b, p. 64).

IWLN "tend to focus on relationships between knowledge, people, and all of creation (the natural world as well as the spiritual). [IWLN requires] participating fully and responsibly in such relationships" (McGregor 2002, p. 2).

In Eurocentric thought, hierarchies are often associated with relationships, as is the case for the anthropocentric Judeo-Christian hierarchy that places heavenly angels above humans, humans above animals, animals above plants, etc. (i.e., humans have power and dominion over nature). Significantly, Indigenous worldviews do not subscribe to this hierarchy (Cajete 1999). Hence, either everything in nature enjoys equal status, or humans are placed at a lower level of importance to all the other parts of creation (Chinn 2006; Cajete 2000b). To understand nature is to live in harmony with nature, not to dominate any part of nature. Domination disturbs the balance among relationships. In short, to acquire IWLN is to search for a balance among a web of relationships in a holistic monist world. This is wisdom (wisdom-in-action).

> Balance at the inner level [Ermine's inner space] is about maintaining a multidimensional equilibrium of physical, emotional, spiritual and intellectual development. ... Balance at the outer level is about maintaining respectful interconnected, reciprocal and sustainable relationships beginning at the individual level embracing family, community, nation, and extending out toward the environment, plants, animals, and cosmos. (Michell 2005, p. 40)

In his article, Michell goes on to describe how Nēhîthâwâk (Woodlands Cree) demonstrate their relationships with plants and with animals through protocols and ceremonies.

When everything is related and relationships require responsibilities, the whole of existence is comprised of a web of interrelationships sustained by concomitant

responsibilities. The act of observing, for example, includes the relationship between the observer and the observed, the antithesis to a Eurocentric scientist's sense of an objective observation. Barnhardt and Kawagley (2005) describe it this way:

> As an elder completed the story of how he and his brother were taught the accrued knowledge associated with hunting caribou, he explained that in those days the relationship between the hunter and the hunted was much more intimate than it is now. With the intervention of modern technology, the knowledge associated with that symbiotic relationship is slowly being eroded. (p. 9)

Knowledge (ways of living) gained through relationships established by repeated observations over time carries a concomitant responsibility by the knowledge keeper to both nature and to the person's community. Therefore, a knowledge keeper can only pass that knowledge (ways of living) along to others who have formed an appropriate relationship with the knowledge keeper. When we request knowledge of a Nehiyaw Elder, for instance, we must first establish a relationship with the Elder, signified by his/her accepting a gift, often tobacco. Gifts are not a payment (a noun). Instead, accepting a gift (a verb) is a way of acknowledging that a relationship has been formed. Everything is relational—all my relations!

Mysterious

IWLN include celebrating mystery and living in harmony with mystery, in the inner and outer spaces of existence (Ermine 1995). This presupposition contrasts with the Eurocentric scientific presupposition of eradicating mystery in nature.

One aspect of mystery in an Indigenous worldview is the constant motion or flux in nature. The world is constantly changing. Some stories that convey IWLN teachings introduce a transformer or trickster, sometimes associated with coyote on Turtle Island. In the constancy of natural cycles there is also spontaneous unpredictable flux.

> A perfect reflection of this cycle and transformation is the mythical figure Wisâkēchâk in our traditional [Woodlands] Cree stories. Wisâkēchâk reflects the notion of flux, change, continuity and interconnectedness as it transforms itself into various forms and crosses spiritual and physical boundaries, in order to teach people life lessons. (Michell 2005, p. 37)

One way to achieve harmony with the web of interrelationships for the purpose of survival is to coexist with the mysteries of nature. Harmony with nature is certainly not a romanticized notion.

Place-based

Unlike the imagined universal type of knowledge claimed by Eurocentric sciences, IWLN is place-based (Brandt 2004). This is both a power and a limitation. Profound implications of a place-based ontology are described by Cajete (2000b).

> All human development is predicated on our interaction with the soil, the air, the climate, the plants, and the animals of the places in which we live. The inner archetypes in a place formed the spiritually based ecological mind-set required to

> establish and maintain a correct and sustainable relationship with place. ... But people make a place as much as a place makes them. Native people interacted with the places in which they lived for such a long time that their landscapes became reflections of their very souls. (p. 187)

The history of the Nēhîthâwâk, for example, and the history of their land do not simply coexist; they are one and the same:

> We personify the Land – as our Mother Earth. It has memory. ... To displace and disconnect Woodlands Cree people from the land is to sever the umbilical cord and life-blood that nurtures an ancient way of life. Our Cree way of life requires that we maintain a balanced and interconnected relationship with the natural world. (Michell 2005, p. 38).

Cajete (1999, p. 47) also points out, "Native science evolved in relationship to places and is therefore instilled with a 'sense of place'." Because Indigenous peoples' self-identities are imbued with a sense of place, place becomes part of their inner space (Ermine 1995). Indigenous peoples' notion of land-as-identity differs dramatically from the Eurocentric notion of land-as-a-commodity to be bought, depleted, and sold.

> Native peoples' places are sacred and bounded, and their science is used to understand, explain, and honor the life they are tied to in the greater circle of physical life. Sacred sites are mapped in the space of tribal memory to acknowledge forces that keep things in order and moving. The people learn to respect the life in the places they live, and thereby to preserve and perpetuate the ecology. (Cajete 2000b, p. 77)

Dynamic

Similar to Eurocentric scientific knowledge that changes as a result of new or anomalous evidence and creative insights, IWLN change as well.

> It is important to realize that there is more to traditional knowledge than the repetition, from generation to generation, of a relatively fixed body of data – or the gradual, unsystematic accumulation of new data over generations. In each generation, individuals make observations, compare their experiences with what they have been told by their teachers, conduct experiments to test the reliability of their knowledge, and exchange their findings with others. Everything that pertains to tradition, including cosmology and oral literature, is continually being revised at the individual and community levels. Indeed, we suggest that the knowledge systems of Indigenous peoples are more self-consciously empirical than those of Western scientific thought – especially at the individual level. Everyone must be a scientist to subsist by direct personal efforts as a hunter, fisher, forager, or farmer with minimal mechanical technology. (Battiste and Henderson 2000, p. 45)

Interestingly, the word *scientist* in this quotation suggests that every culture has a science. Battiste and Henderson appear to subscribe to the pluralist, superordinate, decolonizing definition of science found in this article.

Survival of Indigenous individuals and communities over millennia depends on their dynamic knowledge base.

> Indigenous people have traditionally acquired their knowledge through direct experience in the natural world. For them, the particulars come to be understood in relation to the whole, and the "laws" are continually tested in the context of everyday survival. (Barnhardt and Kawagley 2005, p. 11)

For instance, the survival of First Nations in Canada today is challenged by their loss of traditional land to industrial and resource development (e.g., hydro dams and mining), and by the contamination of their water and traditional food resources. In this Canadian context, Castellano (2000) predicts:

> The knowledge that will support their survival in the future will not be an artifact from the past. It will be a living fire, rekindled from surviving embers and fuelled with the materials of the twenty-first century. (p. 34)

Indigenous inner space guides people's reaction to spontaneous unanticipated flux in their outer space; described in the words of a Lakota ceremonialist's view of science and technology:

> This is not a scientific or technologic world. The world is first a world of spirituality. We must all come back to that spirituality. Then, after we have understood the role of spirituality in the world, maybe we can see what science and technology have to say. (quoted in Simonelli 1994, p. 11)

IWLN is not static, but evolves dynamically with new observations, new technologies, new insights, and new spiritual messages (Kawagley 1995).

Systematically empirical

Systematic empiricism ensures a dynamic quality to IWLN, but it serves Indigenous peoples in much richer ways. Rather than exercising dominion and power over nature as Eurocentric scientists and engineers do, Indigenous peoples live more in harmony with nature by systematically collecting data over many generations as flux *naturally* occurs in their land (instead of *causing* flux to occur superficially as in experiments).

> Yupiaq scientific knowledge is based on thorough longitudinal studies and observations of the natural surroundings. Traditionally, knowledge was passed down from the elders to the youth through storytelling. Until recently, the Yupiaq language was not written down. Thus, all important knowledge was preserved by oral traditions which were crucial to survival. The preservation of the next generation depended on an efficient method of learning that which previous generations had already discovered (such as knowledge of seasonal and long-range weather patterns, salmon migration patterns, and knowledge about river ice and sea ice formation and movement). (Kawagley et al. 1998, p. 137)

In a sense, these longitudinal observations of nature parallel a Eurocentric engineer's experimental methodology that maximizes and minimizes variables (rather than controls them as scientists attempt to do). "Behind these variables, however, there are patterns, such as prevailing winds or predictable cycles of weather phenomena, that can be discerned through long observation (though climate change has rendered some of these patterns less predictable)" (Barnhardt and Kawagley 2005, pp. 11–12).

The meaning derived from Indigenous peoples' observations is connected into a holistic and monist web of relationships. Unlike Eurocentric engineering, *Indigenous systematic empiricism enjoys holistic power*. "Through long observation [Indigenous peoples] have become specialists in understanding the interconnectedness and holism of our place in the universe" (Barnhardt and Kawagley 2005, p. 12). Moreover, Indigenous observations are monist, and hence they relate to a metaphysical inner space in systematic ways known to certain Elders within each community. *Indigenous empiricism enjoys spiritual power*.

This holistic spiritual power expands the sources of data for IWLN to include, for instance, dreams, visions, and intuitions (Brody 1982; Castellano 2000; Dyck 1998; Michell 2005). Some of these data (observations and images) are collected systematically in, for example, vision quests, fasting, smudging, prayer, sweat lodges, and various ceremonies. All data are usually vetted collaboratively with wise knowledge keepers (often Elders), and all are tested out in the everyday world of personal experience. The source of these data may be revelational, but their meaning making is usually not.

When people live in a monist holistic (non-Cartesian and non-reductionist) world situated in a specific place over long periods of time, their powers of observation are expanded. They are attuned to look at multiple relationships that are not part of the consciousness of Eurocentric scientists. The expressions *listen to nature* and *taught by nature*, for instance, are illustrated by Saulteaux Elder Musqua (personal communication, 1997) when he recounted events from his youth. Because of his small size, his grandmother would send him into a beaver lodge to pick out some of the "medicine" the beavers had meticulously collected from the land and stored systematically (and hence, predictably) in one of the lodge's small cavities, for use when they became ill. She had been taught which substances help different human ailments. The original source of this pharmaceutical knowledge thousands of years ago, perhaps came from systematic empirical studies of beavers and related animals (a group often called "keepers of the beaver"), over long periods of time. It is in this sense that Indigenous people listen to nature.

> When observed very carefully, animals reveal many secrets of living in balance and harmony. It is believed that animals have certain powers that can be used for personal, family and community health and survival. (Michell 2005, p. 40)

Data collected by Indigenous peoples are mostly qualitative, but the peoples' ingenuity with quantitative concepts is broadening the empiricism of IWLN. These Eurocentric quantitative concepts must be reconfigured, however, so they align with an Indigenous worldview.

> Over time, Native people have observed that the weather's dynamics are not unlike the mathematical characteristics of fractals, where patterns are reproduced within themselves and the parts of a part are part of another part that is a part of still another part, and so on. For indigenous people there is a recognition that many unseen forces are at play in the elementsof the universe and that very little is naturally linear, or occurs in a two-dimensional grid or a three-dimensional cubic form. (Barnhardt and Kawagley 2005, p. 12)

The acquisition of data for IWLN is not restricted by a Euclidean world, as it is for most Eurocentric sciences. Consequently, Indigenous systematic empiricism picks up on data that are figuratively and literally off the Eurocentric radar screen.

Circular time

One alternative to Eurocentric science's rectilinear time is circular time (Peat 1994), a concept of time that harmonizes with the myriad of cycles observed in nature.

> The idea of all things being in constant motion or flux leads to a holistic and cyclical view of the world. If everything is constantly moving and changing, then one has to look at the whole to begin to see patterns. For instance, the cosmic cycles are in constant motion, but they have regular patterns that result in recurrences such as the seasons of the year, the migration of the animals, renewal ceremonies, songs, and stories. Constant motion, as manifested in cyclical or repetitive patterns, emphasizes process as opposed to product. It results in a concept of time that is dynamic but without motion. Time is part of the constant flux but goes nowhere. Time just is. (Little Bear 2000, p. 78)

Repetitive cycles in Indigenous outer space interact with cycles in inner space (Ermine 1995). Therefore, spiritual ceremonies that connect with past generations (i.e., in inner space), for instance, must occur in harmony with specific events in a cycle of outer space. A Eurocentric worldview might perceive such a happening as time travel into the past, but that perception comes through the lens of linear time. Through the lens of circular time, it is not time travel, but a natural relationship in the web of relationships of existence.

Valid

Michell (2005) speaks for Indigenous peoples worldwide when he concludes, "Woodlands Cree [Nēhîthâwâk] cultural knowledge needs no validation from Euro-Western knowledge systems" (p. 37).

As mentioned above, the validity of Eurocentric sciences' restricts itself to predictive validity. Although the power to predict is essential for Indigenous peoples to secure subsistence from nature and survive, and although they have survived over tens of thousands of years thanks to their IWLN, the immediate predictive power of IWLN does not compare favorably with the predictive power of most Eurocentric sciences. The validity of IWLN lies elsewhere.

> Indigenous peoples throughout the world have sustained their unique worldviews and associated knowledge systems for millennia, even while undergoing major social upheavals as a result of transformative forces beyond their control. Many of the core values, beliefs, and practices associated with those worldviews have survived and are beginning to be recognized as being just as *valid* for today's generations as they were for generations past. The depth of Indigenous knowledge rooted in the long inhabitation of a particular place offers lessons that can benefit everyone, from educator to scientist, as we search for a more satisfying and sustainable way to live on this planet. (Barnhardt and Kawagley 2005, p. 9, emphasis added)

The "depth of Indigenous knowledge systems" mentioned by Barnhardt and Kawagley hints at content validity. Any knowledge system that has succeeded for such a long time must have content validity. The evidence is time plus survival.

Barnhardt and Kawagley (2005) also make two implicit suggestions: (1) that 450 years (the time since the institutionalization of natural philosophy) is a relatively short period of time compared with tens of thousands of years; and (2) that Eurocentric science's resulting impact on planet Earth stands as evidence against its content validity, a sentiment found throughout the literature (Cajete 2000a; ICSU 2002; Knudtson and Suzuki 1992; Snively and Corsiglia 2001).

However, content validity is established on Aristotle's notion of intelligible essences, described above in the "Science" subsection "Predictive Validity." Battiste and Henderson (2000) argued that this content validity, though rejected by Eurocentric sciences, fits well with IWLN. It addresses what the universe is, not how it works.

Battiste and Henderson (2000) also argued that anyone "engaged in a lifelong personal search for ecological understanding, the standard of truth in Indigenous knowledge systems is personal experience" (p. 45). Success in the everyday world of personal experience is a much different criterion than the criteria utilized by Eurocentric scientists during their consensus-making processes to determine truth. Many Indigenous Elders teach us that

> we are not so much meant to discover the one true picture of reality, but rather we are meant to construct the fullest and clearest picture of the situation we can, by integrating our best collective knowledge. The more viewpoints and ideas included, the more complete and meaningful the picture will be. Knowledge embedded in context and interpreted from a network of perspectives has the opportunity to be rich in metaphors. It is not only the perspective of the people engaged in the dialogue whose views must be taken into consideration, but ideas are always examined against views of the ancestors embedded in people's memory and in the stories, songs, and dances. Equally, the viewpoints include future generations and how current decisions will affect them and their world. (Snively and Williams in press, manuscript p. 16)

This pluralist richness of truth is a particular challenge to positivism.

Rational

As a rational way of knowing, mathematics is built upon a set of axioms. Axioms are neither true nor false; they are simply assumed. If we change one axiom in Euclidian geometry, we create a very different geometry system (e.g., Riemann geometry, depending on the change). In the section "Science" (above), we identified some key axiom-like ideas of Eurocentric ways of knowing nature. A consistent use of logical reasoning that flows from these axiom-like ideas, including the input of empirical data where applicable, constitutes a rational system of reasoning. Similarly, IWLN are built upon axiom-like ideas, several of which we have described here. Indigenous knowledge keepers demonstrate a consistent use of logical reasoning that flows from their axiom-like ideas, along with empirical data where applicable. Thus, IWLN is a rational system of reasoning; and like Eurocentric rationality, its rationality is culture-based.

Understandably, practitioners in each way of knowing have faith in their own group's rationality. This faith, however, causes some scientists to think that IWLN is based on superstition; this faith also causes some Indigenous people to think that the Eurocentric sciences are based on superstition. Lakota Elder Deloria (1992) stated:

> The present posture of most Western scientists is to deny any sense of purpose and direction to the world around us, believing that to do so would be to introduce mysticism and superstition. Yet *what could be more superstitious* than to believe that the world in which we live and where we have our most intimate personal experiences is not really trustworthy, and that another mathematical world exists that represents a true reality? (p. 40, emphasis added)

The concept of knowledge revisited

Since our initial description of Indigenous knowledge systems as a journey toward wisdom (or wisdom-in-action), many details about IWLN have accumulated. We end our exploration of IWLN by revisiting the concept of knowledge in IWLN through the writings of four First Nations scholars from the Mi'kmaq, Chickasaw, Cree, and Tewa nations, respectively.

In the context of clarifying Indigenous knowledge, Battiste and Henderson (2000) summarize the following points about IWLN:

> Indigenous peoples regard all products of the human mind and heart as interrelated within Indigenous knowledge. They assert that all knowledge flows from the same source: the relationships between a global flux that needs to be renewed, the people's kinship with other living creatures that share the land, and the people's kinship with the spirit world. (p. 41)
>
> ...
>
> Indigenous ways of knowing share the following structure: (1) knowledge of and belief in unseen powers in the ecosystem; (2) knowledge that all things in the ecosystem are dependent on each other; (3) knowledge that reality is structured according to most of the linguistic concepts by which Indigenous people describe it; (4) knowledge that personal relationships reinforce the bond between persons, communities, and ecosystems; (5) knowledge that sacred traditions and persons who know these traditions are responsible for teaching "morals" and "ethics" to practitioners who are then given responsibility for this specialized knowledge and its dissemination; and (6) knowledge that an extended kinship passes on teachings and social practices from generation to generation. (p. 42)

Similarly, Michell (2005) talks about different types of knowledge.

> From an Indigenous worldview, all living things are endowed with a conscious spirit. From this understanding Woodlands Cree knowledge is manifested in different forms, some of which is practical and learned through day-to-day activities that revolve around survival. Our people also possess empirical knowledge that is learned from careful observations of the natural world over extended periods of time. There are other types of knowledge that link with ceremonial ways that need to be handled with extreme sensitivity. The "revelatory" knowledge is often assessed through elders' guidance, consultation, and preparation; using proper protocols, including dreaming and visioning. Certain knowledge is given to people when they are ready to receive it. (p. 38)

Cajete (1999) points out some features of IWLN that subtly parallel the Eurocentric sciences and some features that do not.

> Indigenous science is internally consistent and self-validating. Its definition is based on its own merits, conceptual framework, practice and orientation. It is a disciplined process of coming to understanding and knowing. It has its own supporting metaphysics about the nature of reality. It deals with systems of relationship. It is concerned with the energies and processes within the universe. It provides its own basic schema and basis for action. It is fully integrated into the whole of life and being, which means that it can not be separated into discrete disciplinary departments. (p. 84)

In summary, the Eurocentric concept of knowledge is by and large incommensurate with IWLN, but Indigenous people need to communicate effectively with Eurocentric people, nevertheless. Indigenous people accomplish a rudimentary communication by using the word *knowledge* rather than the expressions *ways of living in nature* or *ways of being*. The more one learns about IWLN, however, the more one appreciates the ideas that get lost in translation from one way of knowing to another. We have attempted to identify some of those lost ideas. By incorporating lost ideas into our discourse of science education, we move toward a postcolonial discourse.

Conclusion

Understanding IWLN is as much a political act as it is an intellectual achievement, because understanding IWLN is a step toward renegotiating the meaning of science education in many educational jurisdictions. "It is about the politics of identity as well as the politics of local understanding" (Aikenhead et al. 2006, p. 407). This political negotiation applies equally to an understanding of neo-indigenous ways of knowing nature.

A neo-indigenous way of knowing nature

Predominant in Asia, neo-indigenous cultures are mainstream non-Eurocentric cultures with a long standing history often tied to a geographic region. This history does not include being colonized by Western nations to the degree so many Indigenous peoples were; and thus, in this sense, neo-indigenous peoples are privileged. (Cases of Western colonization certainly did occur in small regions of some countries, but such incursions did not appreciably influence the privileged status of the people in the whole country.)

Indigenous cultures worldwide are heterogeneous, yet neo-indigenous cultures are far more heterogeneous. For instance, Islamic, Bhutanese, and Japanese ways of knowing nature differ so widely that no one culture can be reasonably indicative of the others, in spite of their being non-Eurocentric.

The science education literature offers a modicum of information on neo-indigenous ways of knowing nature, and most of these sources only address the cultures of Islam and Japan. For instance, Irzik (1998), Krugly-Smolska (1992), Loo (2005), and Sadar (1997) describe what they call "Islamic science." Kawasaki (1990, 2002) and Ogawa (1989, 1995, 1998a, b, 2002, 2004) have been the principal contributors to the science education literature on Japan. In this article, we explore a Japanese neo-indigenous way of knowing nature. We invite others to do the same for their neo-indigenous cultures.

The literature concerning Japan talks about "indigenous science," and does so from an insider's (an indigenous person's) rather than an outsider's (Eurocentric) point of view. In the context of a multi-science perspective (discussed above in the section "Science"), Ogawa (1995) defined indigenous science as "a culture-dependent collective rational perceiving of reality" (p. 588). He elaborated:

> Indigenous science is held by a specific cultural group, not by a specific individual. Indigenous science may be of a nature such that even individuals living in that culture may neither recognize its existence nor be aware of being governed by it

> tacitly. Also, indigenous science might be tacitly transferred from generation to generation through daily social and cultural events.... I claim that "metaphorically, indigenous science is superordinate to individual minds." An individual cannot express indigenous science as a kind of specific theoretical system. Rather, indigenous science is, so to speak, only collectively lived in and collectively experienced by the people of that culture. (pp. 585–586)

"Indigenous science" in this quotation and the phrase *ways of knowing nature* seem quite similar. If there is a significant distinction between the two, it will arise from their respective postures toward the key terms *knowledge* and *to know*.

Clarification of *knowledge* and *to know*

In the section describing IWLN, we concluded that the phrase *ways of living in nature* fits a verb-oriented Indigenous context while the word *knowledge* fits the noun-oriented context of Eurocentric thinking. Verb-oriented ways of knowing are manifest in many neo-indigenous cultures as well, including the Japanese culture in which *to know* (shiru) has much more significance than *knowledge* (chishiki).

From a Japanese person's view of reality, knowing nature arises from praxis and metaphysics, whereas knowledge is something extracted and abstracted from reality by a Eurocentric point of view. This was particularly the case prior to 1868. Political events of 1868 initiated the Meiji era in Japan, in which acculturation of the Western academy occurred.

Originally, the word *chishiki* had meant: (1) the function of considering; (2) the function of self-consciousness toward recognizing the outer world; (3) a clear consciousness and judgment toward a certain matter, and the persons who hold that consciousness and judgment; and (4) friends or acquaintances (Morohashi 1958, Vol. 8, p. 8419; Nihon Kokugo Dai Jiten 1975, Vol. 13, pp. 353–354). These meanings convey a subtle sense of action related to like-minded people. During the Meiji era, the English meaning of knowledge was added to the list of meanings for *chishiki*. At first, the English meaning was somewhat foreign to Japanese people, but over time it became dominant with use. Today the traditional meanings of *chishiki* are rarely used among Japanese people. Accordingly, English-Japanese dictionaries translate *knowledge* into *chishiki*, and vice versa. The old meanings of *chishiki* may have been lost, but they continue to reside subtly within Japanese culture, for example, in the verb *to know* (shiru).

The word *shiru* does not express "what is known" in a way the English verb *to know* does (as in "to know that sake is made from rice"). Instead, the goal of shiru, together with the content of what is known, produce michi (righteousness) that means, in general, "ways to behave" (Watsuji 1935); a meaning closer (but not at all equivalent) to the English *to know how*. There is no Japanese translation for "the content of what is known" that would capture a Japanese perspective. In other words, *shiru* and *chishiki* are not directly related in Japanese, but *to know* and *knowledge* are directly related in English. Conceptually for Japanese people, the knower and what is known are so inextricably intertwined that Japanese people are apt to focus almost entirely on the knower when they use or hear the term *shiru*. In summary, *shiru* is action-oriented with a focus on the actors (the people involved in the action).

How is it possible for Japanese people to adopt a foreign meaning for the word *chishiki* (knowledge) but not be assimilated by the Western academy's meaning of the word? In the

seminal monograph, *Ways of Thinking of Eastern Peoples: India-China-Tibet-Japan*, philosopher Nakamura (1964) writes:

> The Japanese, owing to the tolerant and more open side of their nature, [acculturated] some aspects of foreign culture without much repercussion. They try to recognize the value of different cultural elements, at the same time endeavoring to preserve the values inherited from their own past. (p. 400)

Japanese culture through its long history has been able to adopt various components of foreign cultures without losing its own identity (Ogawa 1998a). This can be explained by Japan's verb-oriented language that insulates itself from assimilation by noun-based languages such as European languages. The case of *shiru* illustrates the point. Japan's resiliency in adopting foreign ideas can also be explained in part by its complex writing system, comprised of three different systems (kanji, hirakana, and katakana). It allows for the adoption of a foreign meaning but writes it in a way that marks it as foreign to a Japanese way of thinking. In contrast, most Indigenous cultures have an oral tradition, not a written system (other than the one imposed by colonizers). As a consequence, it is more difficult for Indigenous people to be as flexible with foreign words and ideas as Japanese people are.

The triad of Eurocentric, Indigenous, and neo-indigenous Japanese, all have different positions regarding the English terms *knowledge* and *to know*. The Indigenous and neo-indigenous Japanese groups are quite similar in their emphasis on the action *to know* and on a people-centered connotation of *to know*. Both find the noun *knowledge* to be foreign. Yet they differ in two important ways. The Japanese language has much more flexibility to adopt a Eurocentric meaning for a Japanese word (e.g., *chishiki*), while Indigenous languages give much more prominence to a relational ontology (e.g., "all my relations"). We acknowledge these differences among the three groups by referring to the neo-indigenous Japanese group uniquely as "a Japanese way of knowing nature" (JWKN). This phrase replaces the expression *Japanese indigenous science*.

The meaning of JWKN is explored in this article by considering: Japanese historical ways of knowing nature, Japanese ideas about nature (shizen), and a developmental model for knowing nature. We conclude by discussing the Japanese concept of seigyo (roughly translated: subsistence) that synthesizes a JWKN perspective.

Historical ways of knowing nature

A contemporary JWKN is a composite sketch of ideas that arose in, and endured, many eras of Japan's history. Based on Ogawa (1998a), several eras are summarized here for the purpose of elucidating some fundamental ideas underlying JWKN. This history is drawn upon in subsequent discussions of JWKN.

Jomon era (ca. 12,000 BCE–ca. 300 BCE)

The earliest Japanese people lived during the Jomon era, at first in the southwest region of present-day Japan. Research evidence suggests that climate warming around 9,000 BCE allowed deciduous forests to dominate many areas across Japan (i.e., southern, western, central and eastern regions). People of the Jomon era enjoyed a stable rich life in the flatlands near forests and seashores. In the spring they collected shellfish; in the summer

they fished; and in the autumn they gathered acorns, nuts, and various kinds of wild root crops from the forests and flatlands. Because these people had suitable techniques for food preservation, they were able to store food for winter consumption. Although there is evidence of small-scale primitive cultivation and incipient agriculture, these hunter-gatherers were traditionally Indigenous people.

After 6,000 BCE, further warming and resultant changes in forestation caused a new lifestyle based on slash-and-burn cultivation to emerge in southwestern Japan. Although this agricultural method supplied most food needs for the people, its productivity was still not stable enough to rely on. Consequently, earlier forms of hunting and gathering continued.

Life in the Jomon era depended heavily on climate and the natural environment. At its best, the natural environment could be "merciful mother." It could also be the "stern father" visiting the people of the Jomon era with floods, typhoons, snow, droughts, earthquakes, tsunamis, and volcanic eruptions. These Indigenous people embraced a metaphysics in which everything had its own spirit (e.g., animals, insects, birds, plants, nonliving things, and natural phenomena such as thunder and weather). The spiritual and the natural environment were intertwined, in a way similar to the metaphysical spirituality of IWLN.

Yayoi era (ca. 300 BCE–ca. 300 CE)

During the Yayoi era, climate cooling brought increased cold spells and concomitant lifestyle changes in the southwestern regions of Japan. Life became harsh. The flatlands' vegetation suffered from the colder climate, thereby destabilizing food sources.

Immigrants from the continent began to arrive in the flatlands of western Japan. They introduced the new technology of rice agriculture. (This foreign rice agriculture did not at first spread to central and eastern regions of Japan where deciduous forests protected against the cold, and where the people continued to live off the land as hunters and gathers.) The descendents of the people of the Jomon era living in the western flatlands readily accepted the new rice technology. Cultivation of rice flourished, and as a result, the hunting-gathering and simple agriculture of the Jomon era was gradually replaced by the more sophisticated and systematic cultivation of rice imported by the continental immigrants. The two cultures evolved into a hybrid agricultural culture based mainly on rice cultivation. This new culture then spread across Japan where rice could be cultivated.

Post-Yayoi eras (ca. 300 CE–ca. 1185 CE)

Because rice agriculture enriched the food supply and stabilized its productivity, people could afford to have more children and the population grew. Communities were established and required a managerial class to administer and rule. Surplus rice served as currency for an increasingly complex society. As villages prospered, some members of the ruling class had leisure time to contemplate nature and to cultivate a sense of respect and a special feeling for natural things. In turn, they taught others this respect in the form of a concept of "one-body-ness"—all human beings and every natural thing are one body in total. This monist ontology engenders a totality orientation that manifests as a feeling of love for nature, as if natural things within nature were people themselves.

As the sophistication of agriculture and governance developed (during the Kofun era, ca. 250 – 600 CE), a number of small nations competed for supremacy through endless battles. The dominant Yamato nation initiated trade (ca. 350 CE) with nations that produced iron on the Korean peninsula, a commodity important to agriculture and other technologies. During the 5th century, the Yamato nation began to invite China's craft people and scholars to visit Japan. This contact made significant contributions to Yamato cultural development, including the introduction of Chinese characters into Japan's oral tradition. At the time, there was no written language in Japan. Chinese characters were eventually used to write expressions found in the oral Yamato (Japanese) language, a written language known as kanji. Hirakana script was invented at a later date by Japanese people.

During the Asuka era (ca. 600–ca. 710 CE), Buddhism from China was fully developed in Japan along with Buddhist sculptures. Craft, art, and architecture flourished. Such developments likely had far more impact on the elite classes than the lay public. The Asuka era was followed by the Nara era (710–794), named as such when the capitol of Japan relocated to the city of Nara. A political governance system was completed by modeling the Chinese system. Subsequently, the capital moved to Kyoto (the Heian era, 794–1185).

The earlier metaphysics of a living nature endured through these eras. Artistic images representing nature would show: the sea, flatlands, rice fields, villages, vegetable gardens, bushes, streams, forests, and mountains; all familiar to the people living in post-Yayoi eras, but even more, all instilled in their collective minds through subtle cultural influences from the Jomon era people and the Yayoi era immigrants from the continent. The image of a spiritual unity, based on concrete absolute experiences with nature (i.e., experiences untainted by personal or cultural interpretations; Nishida 1990), was indelibly imprinted in the collective worldview of nature inherited by the people living in the post-Yayoi eras in most of Japan.

The cold environment of the northern island of Hokkaido, however, did not sustain rice cultivation, and as a consequence, descendents of the Indigenous peoples originally living there (during the Jomon era or earlier) were unaffected by the cultural evolution that took place during the Yayoi and post-Yayoi eras in other regions of Japan. Today the Ainu nation, for example, continues to live by its own Indigenous worldview of nature and by its evolved IWLN, including its oral language.

Encounters with European technology and natural philosophy (ca. 1500–1868 CE)

The first piece of European technology, the gun, arrived in Japan by 1543. More technology followed with the arrival of Jesuit missionaries. In response to proselytizing Christians and their threat to Japan's traditional religions in the 17th century, Japan's Tokugawa regime severely restricted European contact with Japan. The regime only allowed trade with the Dutch and Chinese (who had no religious ambitions) through the harbor at Nagasaki. European technology and natural philosophy (known as "science" after 1861 when the BAAS was established) continued to enter through Nagasaki, but only through the medium of Dutch books and Chinese translations of European publications. Soon, Japanese translations of these works, plus translations of other books on Western technology and natural philosophy, became available. Because Japan was a literate society at the time, these works were easily and widely disseminated.

Details about Japan during this period of history are important as they explain why Japanese people came to know European technology and natural philosophy, not through

close and continuous contact with Europeans and their technology as other nations did, but through translating, reading, and comprehending Eurocentric ideas from a Japanese perspective. This process ensured that Japanese people would reconceptualize the imported ideas so they aligned with Japan's, and not with Europe's, cultural purposes and ways of knowing nature. The process also established a Japanized version of a Eurocentric science and technology framework with which to acculturate further ideas when close and continuous contact with Western people occurred during the Meiji restoration era (post 1868).

Contemporary Japan (ca. 1970–present)

In spite of the industrial development in Japan since 1868, agrarian scenes and ways of knowing nature similar to post-Yayoi eras could be found throughout Japan up until about 1970, at which time an enormously large-scale industrial and manufacturing growth occurred. This rapidly caused the destruction of long-standing natural scenery, a component to Japan's national identity. Rural and urban Japanese people's daily observation of nature had largely been ruined.

In the early 1990s, a techno-informational way of life (based on information technology) developed in Japan, and today it permeates Japanese culture. Japanese people are keen to recover their natural environment and are currently developing community-based initiatives to achieve a recovery. In their minds, an ideal image of the environment seems to be the harmonization between the natural scenery prior to the 1970s and the latest techno-informational scenery.

Japanese ideas about nature (shizen)

Central to a Japanese way of knowing nature (JWKN) is the Japanese concept of nature. Although a Japanese-English dictionary translates *shizen* to *nature*, a great deal is lost in translation.

Originally there was no Japanese concept that corresponded to the English meaning of *nature* (i.e., natural things and natural phenomena in general, unencumbered by the influence of human beings). But even more: the word *nature* is a noun while the traditional Japanese word *shizen* was an adverb (described below). *Shizen*'s traditional (adverb) meaning endures in the contemporary popular use of *shizen*, alongside its new (noun) meaning. What is this new meaning?

The contemporary meaning of *shizen* (as a noun) continues to be an issue debated among Japanese scholars of diverse disciplines. Rather than visit this debate, however, we draw upon our discussion "Historical Ways of Knowing Nature" (just above) to report on a generally accepted meaning.

In 713 CE (during the Nara era) the word *shizen* first appeared in written Japanese. It was taken from the Chinese *tzujan* (Ito 2002; Kawasaki 1990) or *zǐrán* (Loo 2005)—two different ways to communicate the same Chinese characters in English. Kawasaki (1990) wrote that the original Chinese *tzujan* meant a state of spontaneity which stands for the highest virtue. Loo (2005) added:

> The Chinese concept of nature is expressed in the word *zǐrán*... . It is the first part of the binary monist script, *zǐ*..., that carries meaning; the suffix *rán* is largely for phonetic purposes although it suggests a connection to temporal material reality. The term *zǐrán* encapsulates the curiously contradictory idea of a creation without a

> creator – in other words, a spontaneously, self-generated, temporal reality that was perhaps once unified within the ancient Taoist concept *tiāndi*... which literally means a merger between heaven and earth. (p. 9, Chinese characters omitted)

According to Ito (2002), the meaning attributed to *shizen* by Japanese people of the Nara era was "spontaneously," that is, a state of spontaneity, or a state unaffected by human activities and skills. (This sense of spontaneity independent of human intervention is reminiscent of the Turtle Island's Indigenous notion of flux; above.) *Shizen* was an adverb, not a noun. It is most difficult to translate or even transpose a noun into an adverb.

The word *nature* (a noun) can stand for the whole of natural things in general, sometimes spelled with a capitol "N"—Nature. The Japanese language has idiomatic expressions comprised of a set of concrete natural things, for example, "San sen sou moku" (literally: mountain, river, grass, tree), but such expressions are never used to represent natural things in general. No such phrase exists in Japanese. This discrepancy between English and Japanese constitutes another translation pitfall.

Understandably, a linguistic problem surfaced for Japanese people in the 1890s during the Meiji era when Western vocabulary, such as the English word *nature*, streamed into the Japanese consciousness. A famous Japanese novelist (Ogai Mori) was the first to introduce *shizen* (as a noun) for the translation of *nature* (Yanabu 1982), and in doing so he rejected other Japanese words that vied for acceptance at the time (e.g., ten, tennen, tenchi, banyuu). Because late 19th century Japanese people could not understand the foreign English concept of nature, they needed to create their own meaning for *shizen* (as a noun); a customary way of accepting a foreign culture. The traditional meaning of *shizen* (as an adverb) needed to be reflected in the newly invented *shizen* (as a noun) (Ogawa 1998b). The linguistic problem was solved by unconsciously integrating two conflicting ideas (Yanabu 1982): (1) an opposition to, and incompatibility with, artificiality brought about by human activity; and (2) a holistic complementarity between natural and human action. This was the solution a 100 years ago.

Often today, *shizen* (as a noun) holistically connotes an interrelationship between human activity and the natural environment in which that activity occurs (Shimada 1993). This reflects a Japanese ontological presupposition: for Japanese people, both their perception of natural environments and the activities therein are not separable from the natural environments. They are all one in the same (Ogawa 1998a). This relates to the epistemology of people having concrete absolute experiences with reality (i.e., experiences untainted by personal or cultural cognition; Nishida 1990). The sense of interrelationship described here can be attributed to the ancient people of the Jomon era, for whom the spiritual and the natural were intertwined as a unity, a view that was renewed in the post-Yayoi era as a concept of "one-body-ness"—all human beings and all natural things are one body in total.

What does "one-body-ness" look like? A visual image representing the complementarity of all human beings and all natural things is drawn most often today as a scene that depicts (from near to far): the sea, flatlands, horses, rice fields, villages, hens and roosters, vegetable gardens, bushes, birds, small shrines, coppices, streams, rabbits, forests, wild boar, fox, deer, and mountains; all in one restful ideal tapestry (Ogawa 2002). No component of contemporary technology is found. Minamoto (1985) argues that *shizen* (as a noun) is not only a beautiful landscape, it is simultaneously the root of life characteristic of religions.

More importantly, *shizen* (as a noun) does not mean what *nature* means (i.e., the whole system of the existence and arrangement of forces and events of all physical life that are

not controlled by humans; Collins English Dictionary 1994). Instead, *shizen* (as a noun) represents a metaphysics constructed by each Japanese person in accordance with a common feature among Japanese people, nurtured by their historical ways of knowing nature (Minamoto 1985).

Another way to compare *shizen* (as a noun) and *nature* is in the context of education. An education in shizen implies loving natural things in a totality with human experiences (verb oriented), while an education in nature (i.e., in Eurocentric sciences) implies the acquisition of knowledge of nature conventionally isolated from human experiences (noun oriented).

Almost insurmountable barriers lie along the path of translating *shizen* (as a noun) to *nature* and vice versa. Strictly speaking, instead of "a Japanese way of knowing nature," one might write "a Japanese way of knowing shizen (as a noun)." Throughout this article, "shizen (as a noun)" is implied in this context. The two systems of thought, Japanese and Eurocentric sciences, seem challengingly incommensurate. (The nature that Eurocentric sciences investigate is comprised of Cartesian matter alone, and is knowable by dualist, primarily reductionist, and often quantitative methodologies.)

A helpful perspective on the problem of incommensurability is proposed below in our discussion of seigyo. But first, a contemporary model of how to know nature (or shizen) in almost any culture is explained.

A developmental model for knowing shizen

According to a view popular among Western people, civilizations or cultures develop rather linearly from hunter-gatherer to agricultural, to manufacture-industrial, and finally to techno-informational. An alternative view holds that cultures develop by adding a new cultural component to the accumulation of components from the past (Nakano 1988). Thus, a contemporary culture is seen as being *stratified* by components of precedent cultures.

Ogawa (2002) advanced a variation of this developmental stratified model, because he recognized that the cultural components that accumulate over time do not necessarily exist independently of each other; they could interact. Newer components can affect and modify components from earlier times. Thus, in the everyday world, it may be difficult to distinguish newer components from older components; they are all cultural components of one's life. For this reason, Ogawa described such cultural components as *an amalgam* (a metallurgy metaphor), and he proposed a "stratified amalgam model" that helps one understand JWKN. The model is applicable to almost any culture. Two Japanese examples will illustrate the model.

Jomon way of life (hunter-gatherer)

In Japan today, we can find activities whose origins are traceable to a Jomon way of life (Ogawa 2002). Adults and children enjoy fishing and fish-hand-catching, and they enjoy eating their catch. Although some modern technologies are often used in these pursuits, the spirit and sympathy of fishing and fish-hand-catching (i.e., personally participating in shizen) seem to be similar to those of people living in the Jomon era. Japanese people today also enjoy collecting wild grass in the spring time, and nuts, fruit, and mushrooms in autumn. Since most of these activities are supported by both modern tools and Jomon-era metaphysics, the activities are an amalgam of past and contemporary components.

Similarly, fishermen on Biwako Lake, the largest lake in Japan, work on ships equipped with engines, radios, GPS systems, and fish detectors. The fishermen generally know how their equipment works, and they can repair their engines when breakdowns occur. They also possess ways of knowing shizen useful during Jomon times, for example, how to react to wind direction, to weather changes, and to wave activity; and how to use their intuition to improve fish detection. These ways of knowing Biwako Lake are critical to the fishermen's safety and productivity on the lake. Fishermen do not care about the origins of these ways of knowing shizen; they utilize all components holistically including their ways of knowing modern technology. In other words, their understanding is an amalgam.

Yayoi way of life (agricultural)

In contemporary Japan, rice fields are found almost everywhere, but especially in rural areas. Animal breeding (e.g., dogs, cats, rabbits, chickens, and wild boars) is another activity that originated in Japan during Yayoi times. In urban areas, vegetable and flower gardens are a type of hobby today, but they had survival value for Yayoi-era people. Many Japanese people today share an ancient sympathy for planting and animal breeding, because they are guided by cultural ontologies and epistemologies developed during the past. Technologies such as genetic modification, fertilizers, and pharmaceuticals have transformed gardening and breeding to a large extent, but ancient intuitive ways of knowing those activities are found today in contemporary cultural components. Together they form an amalgam of components. Similarly, rice cultivation is heavily controlled by technology, but it still requires wisdom of rice field management (e.g., When to plant? When to harvest?) originally developed in Yayoi times, but vitally important to rice farmers in various regions throughout Japan today.

Conclusion

A contemporary Japanese way of knowing shizen (nature) can be viewed from the perspective of a holistic amalgam model, stratified by various components from precedent and contemporary Japanese cultures. Some of these components emerged perhaps hundreds or thousands of years ago and have evolved ever since along with more recent components. Thus, JWKN is not a single systematic knowledge system, nor does it embrace a single metaphysics; but rather, it is a dynamic amalgam of stratified cultural components. Importantly, JWKN is "of the present." It is not "in the past." The idea of cultural components is further articulated by the Japanese concept of seigyo.

Seigyo

Our project to explore a Japanese way of knowing shizen (or living in shizen) is almost complete. We have examined a neo-indigenous point of view with respect to several issues, for example: the perspective "to know" (an action) rather than the perspective "knowledge" (a noun); the perspective of shizen rather than nature; and a dynamic amalgam of stratified cultural components from precedent and contemporary Japanese cultures, rather than a knowledge system reminiscent of a Eurocentric science knowledge system. We complete our exploration of JWKN by drawing on the scholarly field of Japanese folklore

studies to help gain greater insight into Japanese neo-indigenous reality through the lens of *seigyo*. The concept of seigyo also has potential to animate ways of knowing nature in other neo-indigenous cultures, as well.

In the context of traditional ways of living, the word *seigyo* is usually translated as *subsistence* in English. The *Dictionary of Japanese Folklore Studies* (Nihon Minzoku Daijiten 1999, p. 925) defines *seigyo* as "works performed for making and maintaining a living," and it goes on to explain that the meaning of *seigyo* is broader than what the English word *occupation* signifies. *Seigyo* includes activities necessary to sustain a way of living, whether or not those activities are directly linked to income (as in an occupation). Take, for example, a man catching salmon in a small river for his family to eat. The man could be a fisherman, farmer, merchant, CEO, or craftsman; yet his catching salmon can be called seigyo if he perceives the activity as part of his way of living. He could be motivated to catch salmon for any number of reasons (e.g., to be seen as a good family provider, to enjoy regular relaxation, to celebrate a particular village festival, or to participate in shizen).

In order to catch salmon, the man must possess an integrated set of refined skills. Psychomotor and intellectual skills are acquired for seigyo. One example is the intellectual skill of detecting the position of a fish by observing tiny waves on the river's surface. The man must know how to "read nature" in terms of this species of salmon in this river (i.e., a place-based understanding). This action-oriented experiential knowledge, or know-how, is gained through continuous participation in salmon catching with someone who possesses the set of refined skills, usually from an older generation. "Coming to know" or "coming to knowing" were Indigenous ways of expressing the acquisition of this type knowledge in IWLN. Experiential knowledge (e.g., to know river salmon fishing) is certainly not attained through reading textbooks. Abstract bits of knowledge alone do not ensure successful action.

Consider the following list of components to salmon fishing, given the context mentioned above: the man's various actions, the salmon's behavior, the man's worldview related to shizen (nature), the tools used, the skills relied upon, the river, the catch, the cleaning, the cooking, and the eating. None of these by itself makes sense as seigyo. Seigyo comprises a *place-based holistic* activity; in this case, catching a species of salmon in a particular river for the purpose of eating. Neo-indigenous people live in a world of multiple activities, many of which consist of various kinds of seigyo. That is their reality.

Seigyo and shizen

A connotative aspect of seigyo is that it does not distinguish between nature (shizen) and culture (bunka). The activity of catching salmon intrinsically harbors both natural and cultural features concerning the man's way of living. A natural feature, for instance, is the life cycle of the salmon in that region, while a cultural feature could be revealed by his motivation to catch salmon. Participation in a seigyo-type of activity necessarily engages a person in shizen, and perhaps, teaches that person about shizen. This suggests a fundamental relationship between seigyo and shizen.

Japanese people think of seigyo and shizen as two sides of the same coin, with each side contributing a different emphasis to reality. Seigyo tends to emphasize *people* energetically working or vividly engaged in their local world. Shizen, on the other hand, tends to emphasize *the local world* in which people are energetically working or vividly engaged. Seigyo and shizen create a yin and yang of reality, if you like. Together, seigyo and shizen

(i.e., seigyo-shizen) harmonize with the world of praxis, not with the world of knowledge claims.

Seigyo subsistence theory

Japanese ecological anthropologist Matsui (1998) reported on research into ancient people's self-identities in terms of their seigyo. He investigated such questions as: Why are different kinds of seigyo (e.g., hunting-gathering, nomadic, and agricultural) sometime found simultaneously in a single community? His research led him to propose a seigyo subsistence theory that sorts out meaning and significance of various activities within a culture (Ogawa 2004). He distinguishes, at first, between two types of seigyo: (1) *major subsistence*, seigyo that contributes moderately or extensively to people's living (e.g., fishing by a fisherman), and (2) *minor subsistence*, seigyo that contributes little or nothing to people's living (e.g., fishing by a CEO). Secondly, Matsui makes a similar distinction between two types of major subsistence activities (see Fig. 1): (1.a) *main subsistence*, seigyo with an extensive impact on a person's livelihood; and (1.b) *subordinate subsistence*, seigyo with a moderate impact on a person's livelihood. These categories are clarified in our analysis of the following case story.

About 300 years ago in rural Japan, a rice farmer, in the off season for rice cultivation, goes into a nearby forest to hunt small animals, collect wild grass, or fish in a small river. The farmer is also extremely interested in collecting wasp hives in his neighborhood. Wasp hive collection occurs only once or twice a year and requires a set of secret skills guardedly passed on from generation to generation.

In this case story, rice cultivation is a major-main subsistence (category 1.a), the hunting-gathering activities belong to major-subordinate subsistence (category 1.b), and wasp hive collecting is a minor subsistence (category 2). However, these categorizations change when we apply the theory to contemporary Japan, where most livelihoods derive from urban employment in business, industry, and government. However, some people are "weekend rice farmers." This would make rice cultivation for them a major-subordinate subsistence (category 1.b) perhaps. Hunting-gathering types of seigyo in contemporary Japan are like hobbies and would be minor subsistence activities (category 2), assuming that the spirit of seigyo-shizen is vividly alive for the people participating in the activities. Obviously, the status of seigyo within Matsui's (1998) subsistence theory changes according to circumstances.

Seigyo subsistence theory has direct implications for JWKN when conjoined with the developmental model of a dynamic amalgam of stratified cultural components. As concluded above, JWKN by its nature is contemporary, even though we find many examples of minor subsistence activities (category 2) that in the Jomon era, for instance, were major-main subsistence activities (category 1.a). Modern versions of ancient seigyo are much more refined today due to technological advances. Nevertheless, their fundamental metaphysical nature and structures seem to be intact.

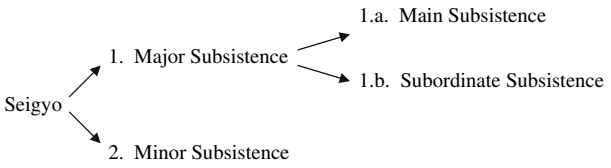


Fig. 1 Matsui's (1998) seigyo subsistence theory

We conclude that JWKN can be described, in part, by a stratified amalgam of various seigyo, along with concomitant metaphysical notions of shizen from precedent cultures. Thus, contemporary Japanese people's views of shizen relate either to Jomon metaphysics with its prominent hunting-gathering seigyo, or to Yayoi metaphysics with its prominent rice cultivation seigyo.

This conclusion is illustrated by another case story. An elementary school teacher returned to his rural town after earning his teaching certificate from university. His weekdays are crowded with teaching responsibilities (e.g., working on the Internet to prepare lessons). But on weekends, he usually has time to help his parents with their rice fields. He knows how to work the planting machines, the harvesting machines, and various chemical fertilizers and herbicides. However, he can also help decide the exact time to plant rice in his parent's unique fields, because he developed the appropriate wisdom during his youth. On autumn weekends, he often collects mushrooms in a nearby forest as a hobby. He is proud of his expertise and he is generous in sharing the season's gift of mushrooms with his family, friends, and neighbors.

This story illustrates four different ways of life that make up an amalgam of stratified seigyo for JWKN (Ogawa 2004). Some of the teacher's weekday activities indicate a techno-informational way of living (information technology type of seigyo). His weekend assistance given to his parents draws on two ways of living: manufacturing-industrial (modern type of seigyo) and agricultural (Yayoi type of seigyo). His collecting mushrooms goes back to a hunter-gatherer way of living (Jomon type of seigyo). He experiences all of these seigyo in the present, most likely unconscious of their origins in the past, moving seamlessly from seigyo to seigyo. He lives in a stratified amalgam of culture components from present and precedent Japanese cultures.

Seigyo and self-identity

Matsui (1998) discussed minor subsistence activities with respect to their connection to people maintaining identities. (We remind readers that in Japanese, the singular and plural forms of a noun are spelled the same, as are a few English nouns such as *deer*.)

> Some seigyo only have trivial economic significance, yet they persist through a long historical time. Even though minor subsistence activities are in the shadow of main subsistence activities, people continue to engage in them even when their disappearance would not have had any significant economic effect on the people (p. 248, translation by authors)

Some seigyo may be important to people's self-identity. Cultural self-identity is a major issue in culture studies in science education because learning is now being understood in terms of students forming new self-identities (Aikenhead 2006; McKinley 2007). Therefore, JWKN has a major significance for contemporary Japanese self-identity, particularly in light of the post-1970, destructive, industrial developments and the recent, ecology-minded, aesthetic reactions to it (above).

Conclusion

A JWKN, formerly known as indigenous science, is a monist, place-based, holistic, communal, dynamic, stratified, amalgamated complex of seigyo-shizen comprised of components of contemporary and precedent cultures. Now that our description of JWKN

has attained this degree of authenticity, it seems proper to change its label to match this authenticity. Accordingly, we refer to the Japanese neo-indigenous way of knowing nature as a *Japanese way of knowing seigyo-shizen* (JWKSS).

Each seigyo in a seigyo-shizen complex is a relevant experience, action, or enterprise in people's worlds of work, crafts, skills, and cultural practices; in short, *praxis*. Important features of seigyo are: being, doing, and living in. A seigyo-shizen complex is not a collection of various fragments of knowledge; such fragments are trivial features of seigyo-shizen in JWKSS. Seigyo-shizen is holistic, not reductionist.

Given the seigyo-shizen grasp of a neo-indigenous reality, Ogawa's (1995) multi-science definition of JWKSS is poignant and worth repeating here: "a culture-dependent collective rational perceiving of reality" (p. 588); where the word *perceiving* encompasses both a process and a product: the process of constructing what is perceived to be reality through the participation of a group of people, and their resultant mental constructions of reality.

Conclusion: caveats, comparisons, and critiques

We have explored three culture-based ways to know nature: Eurocentric sciences (ES, plural), IWLN, and neo-indigenous ways of knowing nature. Each is highly heterogeneous; but for neo-indigenous peoples, the heterogeneity is so great we described only one, a JWKSS. Comparisons among the three groups (ES, IWLN, and JWKSS) are difficult for several reasons. Five are considered here as caveats.

Caveats

Our first caveat recognizes that each group is vulnerable to stereotyping, especially when their similarities and differences are noted. Stereotyping is reduced, however, when we are particularly conscious of the groups' heterogeneities and when we treat general statements as indicative of a group rather than prescriptive. The heterogeneities of ES, IWLN, and JWKSS are represented by the myriad of details in this article. Our comparisons are offered in the context of those details.

Second, we know that translations between languages can obfuscate clarity if made simplistically, but translations can enhance understanding if made patiently. Language is also a currency of power. Given the pluralist framework of this article, we would be remiss in concluding, for example: "All three groups deal with nature," a statement that privileges a Eurocentric position by using the English word *nature*. More accurately we might say, "All three groups deal with Mother Earth, seigyo-shizen, and nature (IWLN, JWKSS, and ES, respectively)." But even the phrase *Mother Earth* is perceived by some First Nations people as a phrase unduly influenced by European colonizers because the phrase appears in Indigenous speech only after contact with the settlers/invaders and particularly since the 1960s (CBC 2003). Linguistically, *Mother Earth* can be traced back to Gaia, the Greek Earth Mother goddess, after whom the discipline of geology was named. The expression is not found in major First Nations languages in Canada, and so we shall continue to use *nature*. Language is a quagmire and must be treated with an optimum of sensitivity. We have attempted to reach this optimum.

Third, an important aspect of communicating sensitively is the consideration of one's audience. The phrase *Indigenous knowledge*, for instance, is often necessary to use when

addressing a Eurocentric audience who needs a thoughtful introduction to the expression *Indigenous ways of living in nature* (IWLN). In some circumstances *Native science* is appropriate, as are other expressions. We do not suggest that science educators adopt our terminology. Instead, our terminology allows us to express certain ideas in ways sensitive to worldviews different from our own, and in ways that may help readers understand science, ES, IWLN, and JWKSS, in order to enhance an anti-hegemonic discourse.

Fourth, sensitivity toward worldviews different from our own is easy to achieve as an attitude or an intention, but it is difficult to achieve in concrete prose. Language can undo the best of intentions (e.g., Carter 2004; McKinley and Aikenhead 2005; Snively and Corsiglia 2005). Our fourth caveat recognizes that our comparisons among ES, IWLN, and JWKSS unavoidably become tainted with the brush of Eurocentric thought as a result of our writing in English. Although we hold the view that ES, IWLN, and JWKSS are all culture based, and that not one is superior, our point of reference for making comparisons inescapably rests on a framework tacitly lodged within the English language. We acknowledge this problem.

A partial solution would involve a new research program in science education culture studies that applies Kawada's (2001) "triangulation of cultures" method; a method based on an analogy borrowed from geodesic methods. Three steps are needed: ES would be examined by taking IWLN and JWKSS as points of reference; then IWLN would be examined with ES and JWKSS as points of reference; and lastly, JWKSS would be examined with ES and IWLN as points of reference. The rationale behind Kawada's triangulation of cultures clarifies our fourth caveat:

> As regards to civilizations or cultures, the subject and the object of the study being of the same dimension, in both a cognitive and moral sense, we must deny the false belief in the objectivity of any particular standpoint, even if it is equipped with some scientific apparatus. That is, all our standpoints are subjective, with inevitable cultural bias. ... Starting from this awareness of our subjectivity, we must not take any standpoint as absolute or universal. Instead, we must try to relativise and objectify our subjectivity, from other cultural viewpoints. This attempt leads us to the method of "triangulation of cultures." (p. 2)

This method allows investigators to pose the same key question to all three culture-based entities. A synthesis of answers would provide a clearer and less superficial comparison among ES, IWLN and JWKSS than what we are equipped to write.

A fifth caveat arises from the school science delimitation of this article. Which version of ES will be presented in any comparison that involves ES?—The positivist version typically found in schools? or A version based on scholarly research into the enterprise of ES? We have opted for the latter: because the former supports a school science that is most often a screening device for status, privilege, and elitism; because a positivist ideology militates against a pluralist position endemic to postcolonialism; and because positivism rejects the notion that ES are culture based.

These difficulties can undermine any comparisons among the three ways of knowing. However, a fact remains: the different ways of knowing do co-exist on our planet, and a postcolonial agenda calls for strong bridges to be built among them (Kawagley 1990). Therefore, comparisons do have a legitimate role to play in culture studies in science education, despite the risk of some superficiality. Superficiality is reduced by perspicacious readers who have already formed their own ideas from having read the descriptions of ES, IWLN, and JWKSS; ideas that bridge cultural divides and transform hegemonic discourse.

Comparisons

Our comparisons of ES, IWLN, and JWKSS are offered with the deepest respect for each group, and with the intention to augment a criticality toward science education materials that claim to compare any of the three ways of knowing (our own work included). We demonstrate this criticality in the subsection that follows these comparisons.

IWLN and JWKSS

These two groups share many key features to their collective worldviews, metaphysics, and epistemologies. Both are monist, holistic, place-based, dynamic, systematically empirical, communal, and rational. The basis for their validity is content validity because both groups attend to Aristotelian intelligible essences as a consequence to their monism. Both groups do not distinguish between, on the one hand, what is known, and on the other hand, the person who knows it. Both groups' languages are primarily verb-based, although linguists will point out how these languages otherwise differ greatly.

Similarities between the two groups are diminished, however, by the fact their histories differ so widely. On the one hand, Japan as a whole nation has never been colonized. Instead, Japanese people were heavily influenced by continental Asian cultures, especially China's. These influences occurred through acculturation, not assimilation. For instance, the Japanese appropriation of Chinese characters was accomplished by a system that ensured a Japanese meaning to the characters rather than a Chinese meaning (Ogawa 1998a). Japanese people successfully insulated themselves from Western metaphysics when they autonomously acculturated selected components from Western cultures (e.g., Eurocentric sciences, technology, and industrialization) in ways that "Japanized" those components.

On the other hand, Indigenous peoples historically faced total assimilation by colonizers, which they resisted by maintaining strong ties with their Indigenous cultural roots, while at the same time acculturating certain components of Western cultures (e.g., some aspects of ES and many sorts of technologies). Cultural survival sustained a very strong emphasis on place-based understanding by Indigenous people. Japanese people, however, never faced such a threat of colonization, and so they give less emphasis to place-based understanding today. Consequently, placed-based understanding of nature forms the core of Indigenous self-identity, while placed-based understanding of seigyo-shizen is not associated with Japanese people's self-identities.

Some notable differences are evident between IWLN and JWKSS. But when compared to ES, the two appear quite similar overall. For this reason, we turn our attention to comparing IWLN and ES, assuming that similar comparisons are likely applicable to JWKSS and ES if modified by culturally sensitive and appropriate qualifications.

IWLN and ES

Both groups originate in the human impulse to make sense of their world so they can take care of themselves (George 1999b). Both groups conform to a pluralist definition of *science* (described above): a rational empirically based way of knowing nature that yields, in part, descriptions and explanations of nature; in short, a rational perceiving of reality. Because both groups are empirically based, they share intellectual processes such as observing, looking for patterns, inferring, predicting, verifying, etc. (Corsiglia and Snively 1995). Elders and scientists (practitioners in each cultural group) exercise rational thought,

and when doing so, they demonstrate communal characteristics of IWLN and ES. Communally shared values found in both groups include: honesty, inquisitiveness, perseverance, and open-mindedness (Cajete 2000b; Stephens 2000). Both groups employ empirical data and rational ways of knowing in creative and intuitive ways. To accomplish this, tools are required. Indigenous tools include those appropriated from ES, plus "the preparation of the mind and heart" (Cajete 1999, p. 85). Both groups generate an outcome, wisdom-in-action and knowledge, respectively, for which models have a function. For IWLN wisdom-in-action, "Models include symbols, numbers, geometric shapes, special objects, art forms, songs, stories, proverbs, metaphors, structures and the *always present circle*" (Cajete 1999, p. 85, emphasis added). The circle-of-life model sometimes takes the form of the medicine wheel (Cajete 1999; Dyck 1998). The outcomes from both groups are continually being revised in light of new observations and new ideas. Thus, both IWLN and ES are dynamic and historic, that is, change is based on past understandings. The outcomes from both groups are most accurately communicated in the language of each culture: an Indigenous language for IWLN and a technically sophisticated language of an expert for ES. In summary, IWLN and ES both exhibit rational thinking, empirical approaches, intellectual processes, and a dynamic evolution of their wisdom-in-action or knowledge (respectively). The most foundational characteristic they share, however, is the fact that both are based in culture.

Culture-based observations occur in IWLN with the assumption (faith) that the observer is related and responsible in some way to what is being observed (*wâpiwin* in Plains Cree); and those observations are mainly qualitative. Culture-based observations in ES stand on the assumption (faith) that the observer and the observed are not at all related (i.e., the objective observer), and on the assumption (faith) that what is being observed is more or less mathematical, thus quantitative observations are most often expected. Culture-based predictions in IWLN lead to harmonizing with nature for the purpose of survival by maintaining a balance within a web of relationships, not harmonizing with nature in any romanticized sense. In ES, culture-based predictions are about exercising power and dominion over nature. Culture-based empirical methodologies in IWLN emphasize holistic and spiritual power, whereas culture-based empirical methodologies in ES emphasize the power of reductionism and Cartesian dualism. These three examples (observation, prediction, methodologies) illustrate how IWLN and ES are predicated on very different worldviews, metaphysics, epistemologies, and values. (This is not a claim that all members of each group hold the same views. Quite the contrary.)

Any accurate comparison of IWLN and ES requires a structure that identifies their fundamental similarities and then takes into account two types of contexts: a cultural context in which these similarities exist, and a historical-political context in which these similarities are enacted. The historical-political context for IWLN is one of colonized repression, which differs significantly from the historical-political context of ES: privilege, power, and progress. Instances of collaboration between IWLN and ES invariably occur in the political arenas of resource management, economic progress, and Indigenous sovereignty. Systemically these arenas have caused collaborative ventures to conform to the colonizer's agenda (Battiste and Henderson 2000; Glasson et al. 2006; McGregor 2000; Nadasdy 1999). As a result, wisdom for living in nature does not match the social and political power of quantized, "objective," dualist, knowledge claims. Notions of power belong in any comparisons of IWLN and ES but are usually absent in science education materials.

In a colonial discourse, IWLN and ES have often been described in terms of polar opposites (i.e., two parallel but incommensurate sets; Battiste 2002) or in terms of false dichotomies (i.e., X versus Y, with one being correct; Macedo 1999). In a postcolonial

discourse, both IWLN and ES would be recognized as ways of thinking that are co-existent, incommensurate, and culturally valid, along with the recognition of each group's heterogeneity. As mentioned above, stereotype descriptors of IWLN and ES are difficult to avoid. With these caveats in mind, we find that most scholars agree that IWLN and ES each possess culture-laden rationalities that differ from each other to varying degrees and in several ways:

- *social goals*: wisdom-in-action for survival, *compared with* individual scientific credibility, corporate profits, medical advances, national security, economic progress, knowledge for its own sake, among many others.
- *attribute of nature*: mysterious compared with knowable.
- *intellectual goals*: co-existence with the mystery of nature by celebrating mystery through the maintenance of a host of relationships, *compared with* eradication of mystery by describing and explaining nature in ways familiar to a community of Eurocentric scientists.
- *fundamental value*: harmony with nature as a dynamic and multidimensional balancing of interrelationships for survival, *compared with* power and dominion over nature.
- *association with human action*: intimately, subjectively, morally, and ethically related to human action with respect to seven generations to come; *compared with* formally and objectively decontextualized from normative prescriptions of human action.
- *concept of ways of living/knowledge*: monist, holistic, relational, place-based; *compared with* a collection of concepts, principles, and techniques that are mainly dualist, reductionistic, anthropocentric, and that aspire to a universality goal.
- *notion of time*: circular *compared with* rectilinear.
- *validity*: content validity as defined by Aristotle's notion of intelligible essences and supported by tens of thousands of years of survival based on that content, *compared with* predictive validity, the cornerstone of the epistemology of natural philosophy and Eurocentric sciences since the 16th century.
- *general perspective*: holistic, empirical, intuitive, spiritual, place-based descriptions and explanations of nature; *compared with* reductionistic, empirical, intuitive, materialistic, generalized descriptions and mechanistic explanations of nature.

These categories are interrelated and overlap to some extent, but they summarize much of the literature. Often one finds a two-column table comparing IWLN and ES (e.g., Ahkwesahsne Mohawk Board of Education 1994; Colucci-Gray et al. 2006; Menzies 2003; NTDE 1999).

A more reasonable three-column comparison produced by Stephens (2000) has appeared in several publications (e.g., Barnhardt and Kawagley 2005). The three columns are generated by two overlapping ellipses called "Traditional Native Knowledge" (TNK) and "Western Science" (WS), with the overlap area called "Common Ground." Stephens's scheme is represented in Table 1, which has been modified from his original elliptical format into a table format, and modified by adding a separate column on the left to explicate his themes. Clusters of statements in the TNK and WS columns indicate differences between traditional Native knowledge and Western science (to use the language of Stephens's publication). Their similarities are described by statements in the middle area (Common Ground), which is an innovative way to emphasize similarities. In all three areas, statements are clustered around four themes: organizing principles, habits of mind, skills and procedures, and knowledge. This vocabulary fits well with the genre of

Table 1 Stephens's (2000) similarities and differences between traditional native knowledge and western science

(Themes)	Traditional native knowledge	Common ground	Western science
Organizing principles	• holistic • includes physical & metaphysical world linked to moral code • emphasis on practical application of skills and knowledge	• universe is unified • body of knowledge stable but subject to modification	• part to whole • limited to evidence and explanation within physical world • emphasis on understanding how
Habits of mind	• trust for inherited wisdom • respect for all things	• honesty • inquisitiveness • perseverance • open-mindedness	• skepticism
Skills and procedures	• practical experimentation • qualitative oral record • local verification • communication of metaphor and story connected to life, values, and proper behavior	• empirical observations in natural settings • pattern recognition • verification through repetition • inference and prediction	• tools expand scale of direct and indirect observation and measurement • hypothesis falsification • quantitative written record • global verification • communication of procedures, evidence and theory
Knowledge	• integrated and applied to daily living and traditional subsistence practices	• plant and animal behavior, cycles, habitat needs, interdependence • properties of objects and materials • position and motion of objects • cycles and changes in earth and sky	• discipline-based • micro and macro theory (e.g., cell biology and physiology, atomic theory, plate tectonics, etc.) • mathematical models

science standards in the USA. The popularity of Stephens's scheme among scholars attests to its reasonableness.

Critiques

Our purpose here is to demonstrate a criticality that can be brought to science education materials, based on the discussions in this article. Unlike the IWLN literature, publications concerning JWKSS, written in English, have not yet found their way into science education materials for teachers and students. By default then, our demonstration is limited to schemes comparing IWLN and ES.

Similar to most literature comparing IWLN and ES (including Aikenhead 1997), it is time to update Stephens's (2000) scheme. Our critique (not criticism) of his scheme is a way to make suggestions for improving it or for creatively producing an alternative.

The intended audience for Stephens's scheme is clearly indicated by the publication's title (*Handbook for Culturally Responsive Science Curriculum*) and by how the scheme was introduced in the text:

> For many Native educators, culturally responsive science curriculum...has to do with presenting science within the whole of cultural knowledge in a way that embodies that culture. ... For those educators not so linked to the local culture, culturally responsive science curriculum has more to do with connecting what is known about Western science education to what local people know and value. (p. 10)

Perhaps the scheme is appropriate for the intended audience. A Eurocentric and lay-oriented language could certainly be a necessary compromise for effective communication with policy makers and school personnel currently ensconced in a worldview endemic to ES.

However, if we were to revise it, what might a more advanced scheme look like? Several points are worth considering. First, historical-political and cultural contexts are either missing or misrepresented in Stephens's scheme. For instance, a historical-political context of (in this case) Alaska would address issues of power in colonial and postcolonial times. The scheme's pedagogical context, a culturally responsive school science, hints at a historical-political context, but hinting tends to silence issues of power and power imbalance.

The cultural context for the scheme has been skewed; only Native knowledge is deemed cultural. By default, this makes Western science non-cultural, a stance embraced by positivism. This misrepresentation privileges Western science, thereby continuing a history of colonization of Alaskan Native peoples, a history silenced in this case by an inadequate historical-political context. Both Native knowledge and Western science are based on cultures. A postcolonial discourse in science education expresses their cultural foundations. A better label for the WS column of the scheme (Table 1) would be "The Culture of Western Science," for example. However, more than pertinent labels are required for an appropriate cultural context.

Second, an authentic cultural context for an improved scheme would explicitly deal with problems of language. A decolonizing agenda asks: Whose language is being heard? Table 1 exclusively privileges the colonizer's conventional language, for instance, by using the English word *knowledge* (a familiar problem by now). The word *knowledge* belongs to the WS column of the scheme, not the TNK column. In the TNK column, phrases are missing such as: *ways of knowing nature*, *ways of living in nature*, *ways of being*, *wisdom*, or *wisdom-in-action*. Combinations of appropriate words from both groups belong in the middle (Common Ground). Otherwise Table 1 conveys a Eurocentric image of what can be learned from nature.

Third, statements (e.g., "applied" to real life) in the TKN column of the scheme treat Elders' wisdom as a commodity decontextualized from life and its web of relationships. Wisdom *is* real life in an Indigenous monist, holistic, relational worldview; it does not get *applied* to real life. The issue raised here is not one of semantics; it is one of how to build strong bridges across the fallacy of binary opposites (Battiste 2002).

Fourth, an authentic cultural context recognizes the dynamic and contemporary nature of IWLN, which today appropriates Western tools and techniques by realigning them with Indigenous metaphysics. In Table 1, information about tools appears only in the WS column of the scheme, which suggests a static Native way of knowing nature, although statements such as "local verification" (in the TNK column) suggest a dynamic way of knowing nature. This ambiguity or misrepresentation is exacerbated by the term *traditional*, as in "traditional Native knowledge." What is traditional? Does it refer to times long ago before contact with the settlers/invaders? If so, does this meaning adequately represent the dynamic local culture of Alaskan Native communities in which students

currently live? These questions are really about power. Who has the power to *prescribe* authenticity to a community's culture?—the author or the community? A postcolonial dialogue would listen to and follow the wishes of the Alaskan Native peoples. (Perhaps this did happen; but if so, it was not reported.) The descriptor *traditional* is best avoided in comparisons between IWLN and ES in a science education context (Ninnes 2000).

Fifth, a false dichotomy seems evident in Table 1 within the theme "habits of mind" (values). In the TNK column one reads, "trust for inherited wisdom" and "respect of all things;" while the WS column states "skepticism." Many issues arise from this section of the scheme, but we discuss only a few. Skepticism also abounds in IWLN, giving force to the "local verification" (a statement in the TNK column) implemented by many Indigenous people to test ideas in their personal everyday experiences (Battiste and Henderson 2000). On the other hand, scientists must trust most of what they learn from reading research reports, a trust stemming from their colleagues' assumed honesty. Otherwise ES simply do not progress. The phrase "healthy skepticism" would seem appropriate for the Common Ground column of Table 1, replacing "trust for inherited wisdom" in the TNK column, and "skepticism" in the WS column.

Sixth, the statement "trust for inherited wisdom" relates to content validity in IWLN and to the survival of Indigenous nations over millennia. Content validity (defined in terms of Aristotle's notion of intelligible essences) concerns *what* the universe is. In the WS column of Table 1, the statement "emphasis on understanding how the universe works" correctly relates to predictive validity but in an obtuse way. Here are two fundamental presuppositions about validity in IWLN and ES obscured by statements appearing in different themes, and by statements whose cultural significance seems lost.

Seventh, the WS column in Table 1 gives no hint of the great heterogeneity found in the Eurocentric sciences. Instead, it offers a universalist characterization that inherently supports a hegemonic discourse, because IWLN tend to be marginalized or discounted when compared to a universalist position. A pluralist heterogeneous perspective on ES enhances a postcolonial discourse.

Eighth, a more advanced scheme will better clarify foundational presuppositions of IWLN and ES. A positive instance of clarity in Table 1 is found in the first two statements in the TNK and WS columns ("holistic" and "includes physical and metaphysical world linked to moral code" in the TNK column, and "part to whole" and "limited to evidence and explanation within physical world" in the WS column). These phrases clearly speak to holism compared with reductionism and monism compared with dualism. However, many other presuppositions are implicit and scattered throughout the scheme, making them inaccessible to many readers. Examples include: systematic empiricism ("practical experimentation, qualitative oral record"), place-based knowing ("local verification"), and universality ("global verification"). In addition, a few key presuppositions are missing, for example, concepts of time (circular compared with rectilinear), treatment of mystery (harmony compared with eradication), and relationships (subjectively responsible, compared with "objectively" non-existent). And finally, a crucial Common Ground item is missing in Table 1: both ways of understanding the universe are *rational*.

Ninth and lastly, a more advanced scheme would also convey *the degree to which* IWLN and ES are incommensurate with the collective worldview held by the other group. George (1999a, p. 85) proposed four categories to describe this range of discrepancy: (1) "The indigenous practice can be explained in conventional science terms;" (2) "A conventional science explanation for the indigenous knowledge seems likely, but is not yet available;" (3) "A conventional science link can be established with the indigenous knowledge, but the underlying principles are different;" and (4) "The indigenous

knowledge cannot be explained in conventional science terms." A mirror image of the fourth category would be: The conventional science cannot be explained in indigenous knowledge terms. George's system is yet another way to add complex authenticity to comparisons between IWLN and ES.

Similar critiques of other materials intended for curriculum developers, teachers, or students will advance a postcolonial agenda for school science (e.g., Ninnes 2000). A self-critique of one's own writing will transform one's own discourse, as well.

Final thoughts

We have revisited the colloquial domains of Indigenous knowledge and science by exploring culture-based ES, IWLN, and a JWKSS, in a manner that celebrated their heterogeneities. We also noted some challenges to understanding unfamiliar ways of knowing. These challenges are reviewed here.

A concept in one culture may not exist in another culture (e.g., the Eurocentric concept of knowledge). Thus, we do not treat the three ways of knowing as if they were knowledge systems, nor do we treat them as if they were similar to three parallel mathematical sets, that is, matching concept A in one culture with concepts A^1 and A^{11} in the other cultures. In other words, we avoid the fallacy of polar opposites often found in hegemonic discourse (Battiste 2002).

Sometimes a concept in one culture can be approximated in a second culture by using words that reflect certain characteristics of their subtle differences. That was the case for nature and seigyo-shizen in ES and JWKSS, respectively. By not viewing one concept as the correct one, we avoid a false dichotomy associated with colonial discourse (Macedo 1999). (Indigenous languages generally do not have an equivalent word for *nature*, other than, for example, *wilderness* and the somewhat controversial *Mother Earth*.)

A further challenge is the choice of reference point with which to describe the three ways of knowing. Descriptors such as monist, holistic, dualist, and reductionist are not culture neutral; they can subtly radiate a Eurocentric worldview that is extremely difficult to detect unless one is well versed in each culture, including its language. One way to proceed is to apply Ogawa's (2002) holistic, stratified, amalgam model to a contemporary Indigenous or Eurocentric culture. One could compare IWLN and JWKSS, IWLN and ES, or JWKSS and ES, in much greater detail. Today most IWLN include agricultural, manufacture-industrial, and techno-informational components, due to assimilation and acculturation.

Ideally, someone literate in Japanese, Cree, and English, for instance, could completely rewrite (not just translate) this article entirely from a Japanese worldview perspective and then again entirely from a Cree worldview perspective. Next, two of the three versions would be translated into the language of the third (e.g., the Japanese and Cree versions translated into English for English readers). The same would be done for Japanese and Cree readers. A reader would benefit from contemplating three different approaches to ways of understanding nature. The method approximates Kawada's (2001) more systematic triangulation of cultures. These methods minimize stereotyping and superficiality, but the authors must still choose a genre for their intended audience.

Less complex research could valuably explore other neo-indigenous ways of knowing nature (e.g., Islam) and focus on other IWLN (e.g., African and Polynesian nations) not addressed in this article. Attention given to the challenges mentioned here could guide

science educators in building anti-hegemonic bridges over cultural divides that arise from different ways of attending to the world.

References

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International Journal of Science Education, 22*, 665–701.

Ahkwesahsne Mohawk Board of Education. (1994). *Lines & circles*. Cornwall, Ontario, Canada: Ahkwesahsne Mohawk Board of Education.

Aikenhead, G. S. (1997). Toward a First Nations cross-cultural science and technology curriculum. *Science Education*, *81*, 217–238.

Aikenhead, G. S. (2005). Science-based occupations and the science curriculum: Concepts of evidence. *Science Education*, *89*, 242–275.

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

Aikenhead, G. S., Calabrese Barton, A., & Chinn, P. W. U. (2006). Forum: Toward a politics of place-based science education. *Cultural Studies of Science Education*, *1*, 403–416,

Barnhardt, R., & Kawagley, A. O. (2005). Indigenous knowledge systems and Alaska Native ways of knowing. *Anthropology and Education Quarterly*, *36*, 8–23.

Battiste, M. (Ed.). (2000). *Reclaiming Indigenous voice and vision*. Vancouver, Canada: University of British Columbia Press.

Battiste, M. (2002). *Indigenous knowledge and pedagogy in First Nations education: A literature review with recommendations*. Ottawa: Indian and Northern Affairs Canada.

Battiste, M., & Henderson, J. Y. (2000). *Protecting Indigenous knowledge and heritage*. Saskatoon, Saskatchewan: Purich Publishing.

Bauer, H. H. (1992). *Scientific literacy and the myth of the scientific method*. Chicago: University of Illinois Press.

Bolter, J. D. (1984). *Turing's man: Western culture in the computer age*. New York: Viking Penguin Inc.

Brandt, C. B. (2004). A thirst for justice in the arid Southwest. The role of epistemology and place in higher education. *Educational Studies*, *36*(1), 93–107.

Brody, H. (1982). *Maps and dreams*. New York: Pantheon Books.

CBC (Canadian Broadcasting Corporation). (2003). *Mother Earth* (Ideas Series transcript (2668). Toronto: Canadian Broadcasting Corporation.

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

Cajete, G. (2000a). Indigenous knowledge: The Pueblo metaphor of Indigenous education. In M. Battiste (Ed.), *Reclaiming Indigenous voice and vision* (pp. 181–191). Vancouver, BC: University of British Columbia Press.

Cajete, G. A. (2000b). *Native science: Natural laws of interdependence*. Santa Fe, NM: Clear Light.

Cajori, F. (Translator) (1962). *Sir Isaac Newton's mathematical principles of natural philosophy and his system of the world (Principia)*. Berkeley: University of California Press.

Capra, F. (1996). *The web of life: A new scientific understanding of living systems*. New York: Doubleday.

Carter, L. (2004). Thinking differently about cultural diversity: Using a postcolonial theory to (re)read science education. *Science Education*, *88*, 819–836.

Castellano, M. B. (2000). Updating Aboriginal traditions of knowledge. In G. J. S. Dei, B. L. Hall, & D. G. Rosenberg (Eds.), *Indigenous knowledges in global contexts: Multiple readings of our world* (pp. 1–36). Toronto, Canada: University of Toronto Press.

Chinn, P. W. U. (2006). Preparing science teachers for culturally diverse students developing cultural literacy through cultural immersion, cultural translators and communities of practice. *Cultural Studies of Science Education, 1*, 367–402.

Cobern, W. W. (1991). *World view theory and science education research* (Monograph Series, Vol. 3). Cincinnati, OH: National Association for Research in Science Teaching.

Collingridge, D. (1989). Incremental decision making in technological innovations: What role for science? *Science, Technology, & Human Values, 14*, 141–162.

Collingwood, R. G. (1945). *The idea of nature*. Oxford: Oxford University Press.

Collins English Dictionary (managing Ed., M. Makins). (1994). *Collins English Dictionary*. Glasgow, UK: HarperCollins Publishers.

Colucci-Gray, L., Camino, E., Barbiero, G., & Gray, D. (2006). From scientific literacy to sustainability literacy: An ecological framework for education. *Science Education*, *90*, 227–252.

Corsiglia, J., & Snively, G. (1995). Global lessons from the traditional science of long-resident peoples. In G. Snively & A. MacKinnon (Eds.), *Thinking globally about mathematics and science education* (pp. 25–50). Vancouver, Canada: University of British Columbia, Centre for the Study of Curriculum and Instruction.

Deloria, V. (1992). Relativity, relatedness and reality. *Winds of Change*, *7*(Autumn), 35–40.

Dyck, L. (1998). An analysis of Western, feminist and Aboriginal science using the medicine wheel of the Plains Indians. In L. A. Stiffarm (Ed.), *As we see...: Aboriginal pedagogy* (pp. 87–101). Saskatoon, Canada: University Extension Press, University of Saskatchewan.

Elkana, Y. (1971). The problem of knowledge. *Studium Generale, 24*, 1426–1439.

Ermine, W. J. (1995). Aboriginal epistemology. In M. Battiste & J. Barman (Eds.), *First Nations education in Canada: The circle unfolds* (pp. 101–112). Vancouver, Canada: University of British Columbia Press.

Gaskell, P. J. (1992). Authentic science and school science. *International Journal of Science Education, 14*, 265–272.

George, J. M. (1999a). Indigenous knowledge as a component of the school curriculum. In L. M. Semali & J. L. Kincheloe (Eds.), *What is indigenous knowledge? Voices from the academy* (pp. 79–94). New York: Falmer Press.

George, J. M. (1999b). World view analysis of knowledge in a rural village: Implications for science education. *Science Education, 83*, 77–95.

Giroux, H. (1992). *Border crossings: Cultural workers and the politics of education*. New York: Routledge.

Glasson, G. E., Frykholm, J. A., Mhango, B. A., & Phiri, A. D. (2006). Understanding the earth systems of Malawi: Ecological sustainability, culture, and place-based education. *Science Education, 90*, 660–680.

Habermas, J. (1972). *Knowledge and human interests*. London: Heinemman.

Hammond, L., & Brandt, C. (2004). Science and cultural process: Defining an anthropological approach to science education. *Studies in Science Education, 40*, 1–47.

Hazen, R. M. (2005). *Genesis: The scientific quest for life's origin*. Washington, DC: Joseph Henry Press.

Holton, G. (1978). *The scientific imagination: Case studies*. Cambridge: Cambridge University Press.

ICSU (International Council for Science). (2002). *Science and traditional knowledge: Report from the ICSU study group on science and traditional knowledge*. Paris, France: Author.

Irzik, G. (1998). Philosophy of science and radical intellectual Islam in Turkey. In W. W. Cobern (Ed.), *Socio-cultural perspectives on science education* (pp. 163–179). Boston: Kluwer Academic.

Ito, S. (2002). *Bunmei to shizen* (Civilization and nature). Tokyo: Tosui Shobo. (In Japanese).

Jenkins, E. (1992). School science education: Towards a reconstruction. *Journal of Curriculum Studies, 24*, 229–246.

Jenkins, E. (2000). 'Science for all': Time for a paradigm shift? In R. Millar, J. Leach, & J. Osborne (Eds.), *Improving science education: The contribution of research* (pp. 207–226). Buckingham, UK: Open University Press.

Kawada, J. (2001, August). *Beyond cultural relativism and globalism: A proposal to deepen cultural awareness through "trialogues."* A paper presented to the UN University International Conference on the Dialogue of Civilizations, Kyoto, Japan.

Kawagley, A. O. (1990). Yup'ik ways of knowing. *Canadian Journal of Native Education, 17*(2), 5–17.

Kawagley, A. O. (1995). *A Yupiaq worldview*. Prospect Heights, IL: Waveland Press.

Kawagley, A. O., Norris-Tull, D., & Norris-Tull, R. A. (1998). The indigenous worldview of Yupiaq culture: Its scientific nature and relevance to the practice and teaching of science. *Journal of Research in Science Teaching, 35*, 133–144.

Kawasaki, K. (1990). A hidden conflict between Western and traditional concepts of Nature in science education in Japan. *Bulletin of School of Education, Okayama University, 83*, 203–214.

Kawasaki, K. (2002). A cross-cultural comparison of English and Japanese linguistic assumptions influencing pupils' learning of science. *Canadian and International Education, 31*, 19–51.

Knudtson, P., & Suzuki, D. (1992). *Wisdom of the elders*. Toronto, Canada: Stoddart.

Krugly-Smolska, E. (1992). A cross-cultural comparison of conceptions of science. In G. L. C. Hills (Ed.), *History and philosophy of science in science education* (Vol. I, pp. 583–593). Kingston, Ontario, Canada: Faculty of Education, Queen's University.

Krugly-Smolska, E. (2004). Let's stop talking about western science. *Canadian Journal of Science, Mathematics and Technology Education, 4*, 419–422.

Kuhn, T. (1970). *The structure of scientific revolutions* (2nd ed.). Chicago: University of Chicago Press.

Lederman, N. G. (2007). Nature of science: Past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 831–879). Mahwah, NJ: Lawrence Erlbaum.

Little Bear, L. (2000). Jagged worldviews colliding. In M. Battiste (Ed.), *Reclaiming Indigenous voice and vision* (pp. 77–85). Vancouver, Canada: University of British Columbia Press.

Loo, S. P. (2005). The two cultures of science: On language-culture incommensurability concerning 'nature' and 'observation.' In W. P. Loo & C. Q. Sarmiento (Eds.), *Proceedings of the Japan Foundation Intellectual Exchange Project Workshop: Southeast Asian and Japanese Cultural Influences on the Understanding of Scientific Concepts* (pp. 1–14). Penang, Malaysia: RECSAM-SEAMEO.

Macedo, D. (1999). Preface: Decolonizing indigenous knowledge. In L. M. Semali & J. L. Kincheloe (Eds.), *What is indigenous knowledge? Voices from the academy* (pp. xi–xvi). New York: Falmer Press.

MacLeod, R., & Collins, P. (Eds.) (1981). *The parliament of science*. Northwood, Midx., UK: Science Reviews.

Margenau, H. (1950). *The nature of physical reality*. New York: McGraw-Hill.

Matsui, K. (1998). Minor subsjstence no sekai: Minzoku sekai ni okeru rodo, shizen, shintai (World of minor subsistence: Work, shizen, and body in folklore a world). In T. Shinohara (Ed.), *Minzoku no gijutsu (Techniques in folklore)* (pp. 247–268). Tokyo: Asakura Shoten. (In Japanese.)

McGregor, D. (2000). The state of traditional ecological knowledge research in Canada: A critique of current theory and practice. In R. F. Laliberte, P. Settee, J. B. Waldram, R. Innes, B. Macdougall, L. McBain, & F. L. Barron (Eds.), *Expressions in Canadian native studies* (pp. 436–458). Saskatoon, Canada: University of Saskatchewan Extension Press.

McGregor, D. (2002). Traditional ecological knowledge and the two-row wampum. *Biodiversity, 3*(3), 2–3.

McKinley, E. (1996). Towards an indigenous science curriculum. *Research in Science Education, 26*, 155–167.

McKinley, E. (2005). Locating the global: Culture, language and science education for indigenous students. *International Journal of Science Education, 27*, 227–241.

McKinley, E. (2007). Postcolonialism, indigenous students, and science education. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 199–226). Mahwah, NJ: Lawrence Erlbaum.

McKinley, E., & Aikenhead, G. (2005). Comments on "Thinking differently about cultural diversity: Using a postcolonial theory to (re)read science education." *Science Education, 89*, 901–906.

Mendelsohn, E. (1976). Values and science: A critical reassessment. *The Science Teacher, 43*(1), 20–23.

Mendelsohn, E., & Elkana, Y. (Eds.). (1981). *Sciences and cultures: Anthropological and historical studies of the sciences*. Sociology of the Sciences Yearbook, Vol. 5. Boston: Reidel.

Menzies, C. R. (Project Leader) (2003). *Forests for the future*. Vancouver, Canada: Department of Anthropology, University of British Columbia.

Michell, H. (2005). Nēhîthâwâk of Reindeer Lake, Canada: Worldview, epistemology and relationships with the natural world. *Australian Journal of Indigenous Education, 34*, 33–43.

Milne, C. E., & Taylor, P. C. (1998). Between myth and a hard place. In W. W. Cobern (Ed.), *Socio-cultural perspectives on science education* (pp. 25–48). Boston: Kluwer Academic.

Minamoto, R. (1985). Nihonjin no shizen-kan (Japanese people's view of shizen [nature]). In S. Omori, et al. (Eds.), *Shizen to kosumosu (Shizen and cosmos)*: *Iwanami New Philosophy Series* (Vol. 5, pp. 348–374). Tokyo: Iwanami Shoter (In Japanese).

Morohashi, T. (1958). *Dai Kanwa Jiten (Chinese-Japanese Dictionary)*. Tokyo: Taishukan Shoten.

Nadasdy, P. (1999). The politics of TEK: Power and the "integration" of knowledge. *Arctic Anthropology,* 36(1–2), 1–18.

Nadeau, R., & Désautels, J. (1984). *Epistemology and the teaching of science*. Ottawa: Science Council of Canada.

Nakamura, H. (1964). *Ways of thinking of Eastern peoples: India-China-Tibet-Japan*. Hunolulu, Hawai'i: East-West Center Press.

Niezen, R. (2003). *The origins of indigenism: Human rights and the politics of identity*. Los Angeles: University of California Press.

Nihon Kokugo Dai Jiten (managing Ed., Kanko-kai). (1975). *Nihon kokugo dai jiten (Japanese language dictionary)*. Tokyo: Shogakkan.

Nihon Minzoku Daijiten (1999). *Nihon Minzoku Daijiten* (*Dictionary of Japanese Folklore Studies*). Tokyo: Yoshikawa Kobunkan. (In Japanese.)

Ninnes, P. (2000). Representations of indigenous knowledges in secondary school science textbooks in Australia and Canada. *International Journal of Science Education, 22*, 603–617.

Nishida, K. (1990). *An inquiry into the good* (translated by M. Abe & C. Ives). New Haven, USA: Yale University Press.

NTDE (Northern Territory Department of Education). (1999). *Intercultural understandings in teaching science: A handbook for teachers*. Darwin, Australia: Northern Territory Department of Education.

Ogawa, M. (1989). Beyond the tacit framework of 'science' and 'science education' among science educators. *International Journal of Science Education, 11*, 247–250.

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

Ogawa, M. (1998a). A cultural history of science education in Japan: An epic description. In W. W. Cobern (Ed.), *Socio-cultural perspective on science education* (pp. 139–161). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Ogawa, M. (1998b). *Rika no Sai-Hakken: Ibunka to shiteno Seiyo Kagaku (Re-discovery of Rika: Western science as a foreign culture)*. Tokyo: Nosangyoson Bunka Kyokai. (In Japanese.)

Ogawa, M. (2002, July). *Nature of indigenous science: A stratified and amalgamated model of knowledge and cosmology*. Paper presented to the 33rd Annual Meeting of the Australasian Science Education Research Association, Townsville, Australia.

Ogawa, M. (2004, April). *Origin, structure and nature of indigenous science and "seigyo" (subsistence)*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Vancouver, Canada.

Orange, A. D. (1981). The beginnings of the British Association, 1831–1851. In R. MacLeod & P. Collins (Eds.), *The parliament of science* (pp. 43–64). Northwood, Midx., UK: Science Reviews.

Peat, F. D. (1994). *Lighting the seventh fire*. New York: Birch Lane Press.

Pickering, A. (Ed.). (1992). *Science as practice and culture*. Chicago: University of Chicago Press.

Roth, W.-M., & Lee, S. (2004). Science education as/for participation in the community. *Science Education, 88*, 263–291.

Rudolph, J. L. (2005). Epistemology of the masses: The origins of "the scientific method" in American schools. *History of Education Quarterly, 45*, 341–377.

Ryder, J. (2001). Identifying science understanding for functional scientific literacy. *Studies in Science Education, 36*, 1–42.

Sadar, Z. (1997). Islamic science: The contemporary debate. In H. Selin (Ed.), *Encyclopaedia of the history of science, technology, and medicine in non-western cultures*. Boston: Kluwer Academic.

Semali, L. M., & Kincheloe, J. L. (1999). Introduction: What is indigenous knowledge and why should we study it? In L. M. Semali & J. L. Kincheloe (Eds.), *What is indigenous knowledge? Voices from the academy* (pp. 1–57). New York: Falmer Press.

Shimada, Y. (1993). *Ijigenkokan no seiji-jinruigaku: Jinruigakuteki shiko towa nanika* (Political anthropology of hetero-dimensional exchange: What is anthropological thinking?). Tokyo: Keiso Shobo. (In Japanese.)

Simonelli, R. (1994). Sustainable science: A look at science through historic eyes and through the eyes of indigenous peoples. *Bulletin of Science, Technology & Society, 14*, 1–12.

Smolicz, J. J., & Nunan, E. E. (1975). The philosophical and sociological foundations of science education: The demythologizing of school science. *Studies in Science Education, 2*, 101–143.

Snively, G., & Corsiglia, J. (2001). Discovering indigenous science: Implications for science education. *Science Education, 85*, 6–34.

Snively, G., & Corsiglia, J. (2005). Response to Carter's postmodern, postcolonial analysis of Snively and Corsiglia's (2001) article "Discovering Science." *Science Education, 89*, 907–912.

Snively, G. J., & Williams, L. B. (in press). "Coming to know": Weaving Aboriginal and Western science knowledge, language, and literacy into the science classroom. In P. Chinn, B. Hand, & L. Yore (Eds.), *Language, culture, ontological assumptions, epistemological beliefs and knowledge about nature and naturally occurring events*. Dordrecht, the Netherlands: Springer.

Stephens, S. (2000). *Handbook for culturally responsive science curriculum*. Fairbanks, Alaska: Alaska Native Knowledge Network.

Suzuki, D. (2006). *David Suzuki: The autobiography*. Greystone Books.

Tobin, K. (Ed.) (1993). *The practice of constructivism in science education*. Washington, DC: American Association for the Advancement of Science.

Traweek, S. (1992). Border crossings: Narrative strategies in science studies and among physicists in Tsukuba science city, Japan. In A. Pickering (Ed.), *Science as practice and culture* (pp. 429–465). Chicago: University Chicago Press.

Viergever, M. (1999). Indigenous knowledge: An interpretation of views from indigenous peoples. In L. M. Semali & J. L. Kincheloe (Eds.), *What is indigenous knowledge? Voices from the academy* (pp. 333–359). New York: Falmer Press.

Watsuji, T. (1935). *Issues on the relation between Japanese language and philosophy*. Tokyo: Iwanami Shoten.

Yanabu, A. (1982). *Homyakugo seiritsu jijo* (How are the translations of words established?). Tokyo: Iwanami Shoten. (In Japanese.)

Yazzie, R. (1996, July). *Law as a form of cultural restoration and healing*. A paper presented to the International SSHRCC Summer Institute on Cultural Restoration of Oppressed Indigenous Peoples, University of Saskatchewan, Saskatoon, Canada.

Ziman, J. (1984). *An introduction to science studies: The philosophical and social aspects of science and technology*. Cambridge: Cambridge University Press.

Zukav, G. (1979). *The dancing Wu Li masters: An overview of the new physics*. New York: Bantam Books.

Glen Aikenhead is professor emeritus, Aboriginal Education Research Centre, University of Saskatchewan, Canada. His research and development projects over the years have emphasized relevance of school science for students' everyday lives. During the past 15 years his work has focused on a cross-cultural perspective, particularly with Indigenous communities worldwide. Currently he is involved in the integration of policy, research, practice, and politics of science education for the recognition of Indigenous ways of knowing in Saskatchewan.

Masakata Ogawa is professor of science and technology education at the Graduate School of Human Development and Environment, Kobe University, Japan. His recent research interests lie in cultural contexts of science and science education (especially in Japan), as well as in science education policy studies. His major publications include "Science Education in a Multiscience Perspective" (1995) and "Reform Japanese Style: Voyage into an Unknown and Chaotic Future" (2001). He was a contributing editor of *Science Education*, and is a member of several editorial boards: *Cultural Studies of Science Education*, *Studies in Science Education*, and *Canadian Journal of Science, Technology and Mathematics Education*. He currently serves as the president of the Japan Society for Science Education.

Ayaawx: in the path of our ancestors[1]

Patricia Vickers

Perhaps the greatest challenge for us as Indigenous scholars is twofold, (a) learning our ancestral principles handed down through the generations and (b) writing from the center of that world. As scholars, we have been conditioned to believe that the language of logic is the highest state of being. However, when we are faced with human relationships in births, coming of age, deaths and grief, the world of logic is insufficient. Indigenous leaders, Marie Battiste, Vine Deloria Jr., Buffy St. Marie, George Manuel, James Gosnell and Frank Calder are a few who have been scouting the terrain to create camping spots where we can dialogue within our communities and with the other, or those outside of our Indigenous communities.

While the paper "Indigenous Knowledge and Science Revisited" (Aikenhead and Ogawa 2007) discusses the differences between academic society and Indigenous knowledge, the paper also discusses how we remain sitting in two different camps that perpetuate conflict between two human ways of being. The question is not about whether or not we as Indigenous peoples have a scientific way of relating to the world, for Nobel Peace laurite and physicist, Richard P. Feynman (1998) defines science as simply, "a special method of finding things out ... the body of knowledge arising from the things found out...and the new things you can do when you have found something out, or the actual doing of new things" (p. 5). Anthropologists and archeologists have uncovered ways in which we as Indigenous peoples on the northwest coast of British Columbia have hunted, fished, and gathered to provide for our families and communities for thousands of years. The hunting, fishing, and gathering methods came from observing animals and their relationship with the land (finding things out), and from that observation, came knowledge of appropriate hunting, fishing and medicine gathering methods (the body of knowledge arising from the things found out) which was passed on within the family and clan, with adaptations to new technology which were made to facilitate more efficient ways of hunting, fishing, and plant gathering (the new things you can do when you have found something out). Our method of relating to the land and 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.

Our quest as Indigenous scholars, students, politicians, businessmen, health practitioners or as practitioners in any other profession is to recover from oppressive violence inflicted through colonization and to restore the principles our ancestors left behind to guide us in our relationships with each other, with animals, the land, the supernatural, and other nations. Denial that colonization of North America was inhumane and unjust is no longer an option. There are many accounts gathered in the Royal Commission on Aboriginal Peoples (1996), and many stories have gone with the survivors who died without releasing their agony; instead, this agony was transmitted to successive generations to be found in the suffering in our families today. The issue at hand is how to recover from such an onslaught. Our ancestors have given us, as Ts'msyens, clear direction through the principles of the ayaawx (ancestral law) (Gisday Wa and Delgam Uukw 1992). All Indigenous people have guiding principles that are passed down through the generations to assist humans in their relationships with each other, with animals, the land/water and the supernatural world. These principles will not only assist us as the Indigenous to restore individual and collective balance, they will also assist the schooling system, presently an oppressive system (Freire 1995), to deliver knowledge in a respectful way.

[1] This article should be cited as: Vickers, P. (2007). Ayaawx: in the path of our ancestors. *Cultural Studies of Science Education, 2*, DOI 10.1007/s11422-007-9067-8.

This article is written from the need to dialogue and the need to present our world view as the Indigenous with methods that will transform oppression and add ancestral practice in the quest for knowledge.

The task at hand: restoring ancestral teachings

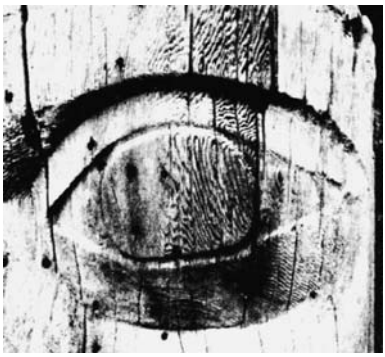
The heart of the ayaawx is respect. All relationships, humans with humans, humans with animals, humans with the land, and humans with the supernatural world, all revolve around the act of respect. An example of the teachings of respect in human/animal/supernatural relationships can be found in "Adawga gant wilaaytga gyetga suwildook: Rituals of respect and the sea otter hunt" (The Tsmishian Chiefs 1992).

The shortcoming: disrespect

The story gives us the account of a head canoe man, a sea otter hunter who did not respect the rules for purification before hunting. Although the sea otter were within direct spearing distance, he was not successful in hitting them with his spear; instead, his spear would consistently miss the sea otter resulting in the hunters in the other canoes ridiculing him for his disrespect of the purification process. The head canoe man's shame for his wrongdoing and then his determination to succeed in the hunt did not go unnoticed by the supernatural beings.

Retribution and Mouse Woman to the rescue

Eventually the head canoe man along with his crew were pulled down into the supernatural world where, under the direction of Mouse Woman, the sea hunters were kept from death and gained favor with the great chief of the sea otters. Mouse Woman appears to human beings at their greatest time of need as a powerful being in the supernatural world, she guides humans into restored favor with the leadership in whatever village the journeying figure or offender has fallen captive in the village of the supernatural.



Reconciliation & favor

After they gained favor with the supernatural sea otters by the offering of fat from the kidneys of mountain goat the hunters were recognized as nephews of the great chief at a feast. The sea hunters then witnessed the supernatural beings that included the grizzly of the sea, blackfish, sea lion and whale. Having provided the mountain goat fat that was prized by all sea beings, to the great chief and his guests the sea hunters gained the favor of the great sea otter chief.

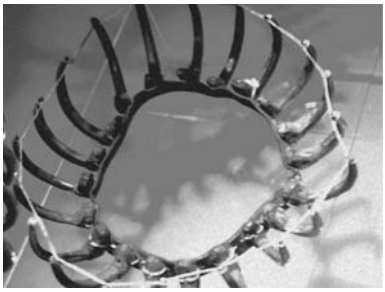
Gifted by the supernatural

The sea otter chief gifted the head canoe man with a supernatural spear for hunting sea otter and providing guidance and instruction on issues of purification. The supernatural spear had specific instructions for care and the need for seclusion with only the head canoe man using it and keeping it from the vision of a woman. Fasting, and bathing in devil's club water before using the spear was also necessary; all of the supernatural sea creatures and his fellow canoe men were witnesses to the gift from the sea otter chief.

Transformation & integration

The sea hunters were then sent back to their village, returning with the teachings given to them by the supernatural beings of the village and Mouse Woman. The story concludes

with the head canoe man, changed by his encounter with the supernatural world, and understanding the consequences of his disrespectful behavior.



Taking it to heart: the inner life

The central principle from the ayaawx concerning the importance of respect in relationships is demonstrated in this adaawx. The lack of respect impacts those who are closest to us, our family, our tribe, and our community. The supernatural world responds to disrespect and pulled the hunters down into their world where death was inevitable, until Mouse Woman maneuvered them through the attempts of the supernatural to kill the hunters and with them the disrespectful act itself. Change was inevitable for the hunters, especially for the head canoe man. Witnessing justice in the supernatural world, Mouse Woman demonstrated that respect through the giving of Mountain Goat fat could restore balance. The sea hunters encounter with the supernatural world transformed their understanding of the power of respect, hence the importance of the adaawx in contributing to our ancestral principles today. Respect impacts the individual and collective simultaneously.

Our first task in claiming ancestral law has been set out in the Gisda'wa-Delgamuukw court case in the opening address by Delgamuukw (Gisda'wa and Delgam Uukw 1992), and the address includes the following points:

- Ownership of territory is a marriage between the Chief and the land
- The Chief's ancestors encountered and acknowledged the life of the land
- Encounters with the land give power
- The land, plants, animals and people all have spirit and must be shown respect
- The Chief's responsibility is to ensure all people in his House respect the spirit in the land and in all living things
- Original power can be recreated when the Chief directs his House to obey the law
- The source of the Chief's authority is in fulfilling the law

Our relationship with the land gives us the power to discover, maintain and restore spiritual balance. Indigenous people around the world have ceremonial rituals that are practiced to strengthen the will and provide focus for intentioned action. In North America these ceremonies have been shared by the plains nations by way of the sweat lodge, vision quest fasts, the sacred pipe and the Sundance ceremonies. Amongst the Ts'msyen (this includes the Nisga'a and Gitxsan), receiving power from the land involves dialogue through ceremonial fasting, bathing, prayer and the use of plant medicines. Ceremonial practice is the doorway to focused, and intentional action.

Taking it to heart: the outer life

Our feasts (potlatches) are legal transactions between the host and the witnesses; feasts have and continue to be the pulse of the Ayaawx (Halpin and Seguin 1990). Being a matriarchal society, all names and territories are passed down through the woman at a settlement feast. Every child is born into a clan having their mother and father belonging to two different clans. Marriage into the same clan is forbidden. For example, my father was a Gispudwada (Killer Whale) and my mother, an English woman, was adopted into the Lax Sgeek (Eagle). When my father died, it was his tribe that hosted the memorial feast and his father's side (Ravens) that purchased the coffin and clothes that he wore in his coffin; as well, the father's side contributed food for the feast and finances toward the funeral arrangements.

The hosts of a feast are responsible for the following: knowing the names of the Sm'ooygits (Chiefs) and seating them in the appropriate places, knowing the order of transactions and the events that must be recorded, assigning the appropriate individuals to complete the transactions, serving the guests, receiving cash donations, distributing goods to the appropriate recipients, paying expenses, acknowledging individuals who supported the necessary tasks of the clan, and knowing any other tasks that need to be completed to complete the transaction. Each individual host must be focused and complete their tasks without mistakes. Any mistakes must be acknowledged and rectified. By paying for a mistake as a host, the individual is both respecting the need to be present and focused to fulfill clan duties, and is acknowledging the importance of cleansing and purification ceremonies that are practiced to strengthen the ability to respect the Ayaawx in a focused manner.

Colonialism and change

Edward W. Said (1994) concerning colonialism writes,

> Neither imperialism nor colonialism is a simple act of accumulation and acquisition. Both are supported and perhaps even impelled by impressive ideological formations that include notions that certain territories and people require and beseech domination, as well as forms of knowledge affiliated with domination: the vocabulary of classic nineteenth-century imperial culture is plentiful with words and concepts like "inferior" or "subject races," "subordinate peoples," "dependency," expansion," and "authority." (p. 9)

Canadians have been conditioned through colonial jargon, legislation and segregation, to believe that Indigenous peoples are inferior to those of European descent. Brazilian educator Paulo Freire (1995) identifies oppression as a human condition of dehumanization of both the oppressor and the oppressed. Freire (1995) writes,

> Once a situation of violence and oppression has been established, it engenders an entire way of life and behavior for those caught up in it—oppressors and oppressed alike. Both are submerged in this situation, and both bear the marks of oppression. Analysis of existential situations of oppression reveals that their inception lay in an act of violence—initiated by those with power. This violence, as a process, is perpetuated from generation to generation of oppressors, who become its heirs and are shaped in its climate. (p. 40)

The violence recorded in the Report of the Royal Commission on Aboriginal Peoples (RCAP) (1996), identifies the bleak climate of oppression in our communities today. The violence our grandparents and parents were subjected to in residential schools (Law Commission of Canada 2000) is being perpetuated by subsequent generations. We have internalized the delusion of inferiority and are practicing it within our families and communities. The oppression continues internally and externally.

Externally we are faced with trauma perpetuated from one generation to the next without intervention. Mental Health through the Federal Government—11 years after the publication of RCAP—continues to ignore the importance of addressing trauma and violence through traditional healing methods; post-secondary institutes continue to neglect the study of the history of abuse in federal day schools by ignoring the need for appropriate support mechanisms for Indigenous students who eventually drop out unable to reconcile their past schooling experiences with the present; Social Services continue to apprehend Indigenous children neglecting ancestral law and the ability of the community to provide family support (RCAP 1996).

Transforming cultural oppression according to Freire (1995), requires the oppressed to embrace the dynamics and the impact on individuals and the collective to change their belief that they are inferior thus freeing the oppressor and the oppressed as well. As a human condition, both the oppressor and the oppressed are caught in this depressing reality. As a human condition, there is an invitation for both parties to own the problem working together through dialogue to change relationships in schooling, health, business, bureaucracy, and to rectify, in this way, the injustices of the past.

Conclusion

The global history of colonization stems from the human act of greed. Colonization is the act of one people from one land exerting their force over another people to claim land and

resources. As described in the writings of Thomas Berger (1999) and Edward Said (1994), colonization has a world history of violence and oppression based on the delusional belief that the Indigenous are inferior and subhuman needing to be subdued, civilized and controlled. The Report of the Royal Commission on Aboriginal Peoples (1996) contains four volumes of information confirming through research the ongoing oppression of Indigenous peoples in Canada. Transformation of oppression according to our ayaawx requires the spiritual act of respect, and respect is born and matured through our sacred ceremonies in dialogue with the land.

The unfortunate result of colonization is the diminishment or loss of Indigenous ceremonies and rituals that are intimately connected to the land. We are witnesses to the result of the changed connection to the land in our communities today, the violence we are doing to ourselves in our families is a direct result of lost connection to the power of the land. The land is more than a commodity to be bought and sold, according to our ayaawx, it carries the power to bring about positive change in the individual and collective.

Intimate connection with the power of the land compels the individual to act from the heart, fulfilling compassionate acts of power and goodwill, working toward the betterment of humankind.

References

Aikenhead, G. S., & Ogawa, M. (2007). Indigenous knowledge and science revisited. *Cultural Studies of Science Education, 2*(4).

Berger, T. R. (1991). *A long and terrible shadow: White values, Native rights in the Americas 1492–1992*. Vancouver: Douglas & McIntyre.

Feynman, R. P. (1998). *The meaning of it all: Thoughts of a citizen-scientist*. Reading, MA: Perseus.

Freire, P. (1995). *Pedagogy of the oppressed*. New York: Continuum.

Gisday'Wa, & Delgum Uukw. (1989). *The spirit in the land: The opening statement of the Gitksan and Wet'suwet'en Hereditary Chiefs in the Supreme Court of British Columbia May 11, 1987*. Gabriola, BC: Reflections.

Halpin, M., & Seguin Anderson, M. (1990). *Tsimshian Peoples: Southern Tsimshian, Coast Tsimshian, Nishga, and Gitksan. Handbook of North American Indians Northwest Coast: Vol. 7*. Washington: Smithsonian Institution.

Royal Commission on Aboriginal Peoples. (1996). *Report of the Royal Commission on Aboriginal peoples*. (Canada Communication Group Publishing). Ottawa: Minister of Supply and Services Canada.

Said, E. W. (1994). *Culture and imperialism*. New York: Vintage.

The Tsimshian Chiefs. (1992). *Adawga gant wilaaytga gyetga suwildook: rituals of respect and the sea otter hunt*. Prince Rupert, BC: School District (52.

Patricia June Vickers is an ethno-consultant with more than 20 years of professional experience in the arenas of education, mental health, conflict resolution and capacity building. Her current emphasis is on the integration of Ancestral Law into her consulting practice to facilitate positive change within Indigenous communities and the jurisdictions that interact with them. Born in Prince Rupert, British Columbia with Tsm'syen, Heiltsuk, Haida and British ancestry she is currently completing a Ph.D. at the University of Victoria. Patricia's dissertation topic is "Ayaawx (Ancestral Law): Transformational power." She holds a Bachelor of Education degree and a Master's Degree in Education Psychology.

Epistemology and temporal/spatial orders in science education: a response to Aikenhead & Ogawa's: Indigenous Knowledge and Science Revisited[2]

Carol B. Brandt

Virginia Polytechnic Institute and State University, Blacksburg, VA, USA
e-mail: cbbrandt@vt.edu

This spring, in moments between my academic writing deadlines, I have been in my garden preparing a new bed for planting. Spading the soil provided an important context for meditation as I composed my thoughts around Aikenhead and Ogawa's ambitious undertaking of describing and comparing diverse ways of coming to know and live within nature. As I turned over each shovel and broke up the soil into a finer tilth, I thought about my first mentor in gardening, Minnie Roeschley, a devote Mennonite who, together with her husband, was part of a family-owned dairy farm, just down the road from us. Minnie always planted by the cycles of the moon, just as she also offered prayers for an abundant harvest and integrated new ideas from the county agriculture extension agent. Her understanding of gardening was born out of a lifetime of trial and error, knowledge gleaned from others in her rural community, and seeds passed down in her family.

In a sense, Minnie's understanding of gardening was much like the "amalgam" of knowledge that Aikenhead and Ogawa describe for the Japanese fishermen on Biwako Lake, who utilized the components of their knowledge holistically, from modern sonar to ancient understandings of surf, weather, and fish behavior. If Minnie were alive today, I doubt she would call her understanding a "science," or even attribute it to a scientific field. To her, she was simply carrying out her role as a dutiful wife, providing fresh food for her family's table, and offering the surplus to her neighbors. Her practice of gardening was tucked in between the schedule for milking, the planting cycles of the corn and soybeans, and her volunteer work for the Mennonite church in her small Midwestern community. Gardening was tied to not only the seasons but also to the scales of domestic time and space, regional economies, and the invocation of long-held ethnic traditions.

Since her passing, the agricultural context of the rural Midwest has been transformed where dairy production is now a computerized industry and corn yields are implicated in ethanol's new role in the global competition for oil. Appadurai (1996) speaks of the compression of time and space that has come with globalization and new transcontinental flows of people and information. Farming is at the same time both localized and transnational in dynamic and shifting frames of reference. Intersections of time/space relationships in these new times undoubtedly have an impact on how people are organized, the meaning people make of natural phenomena, as well as their relationship with the natural world.

In their article "Indigenous Knowledge and Science Revisited," Aikenhead and Ogawa explore the diversity of knowledge systems and hint at the folding of time/space that happens in the practice of knowing nature. The authors' careful analysis opens the door to look at learning, knowledge, and educational practice in new ways, especially for students from non-mainstream backgrounds. In my response to their complex and multi-layered presentation of Indigenous, Japanese, and Eurocentric means of "knowing" or "ways of

[2] This article should be cited as: Brandt, C.B. (2007). Epistemology and temporal/spatial orders in science education: a response to Aikenhead & Ogawa's: Indigenous knowledge and science revisited. *Cultural Studies of Science Education, 2*, DOI 10.1007/s11422-007-9067-8.

living in nature," I would like to expand this point, that science education would benefit from theorizing the scales of time/space in the learning process. Below I provide some examples from my own research that have motivated me to look for ways to examine the complexity of time/space relationships in what Aikenhead and Ogawa cite as diverse ways of coming to know nature.

Time and the pace of production in the molecular biology laboratory

My research focuses on how undergraduate students from linguistically and culturally diverse backgrounds appropriate scientific discourse, the particular way that scientists communicate and the style of speaking and writing that is accorded prestige and value in higher education. I am a White, middle-class woman raised in a homogenous, Midwestern rural community. In terms of ethnicity and class, I was similar to other staff advisors at the university when I first began my research with Indigenous women. My first case study (Brandt 2007) described the experiences of Deborah, a middle-aged American Indian woman who was struggling to make sense of Eurocentric science in the context of her Navajo Indigenous knowledge. Deborah worked in a molecular biology laboratory and we talked about her experiences with scientific discourse in this new context. Prominent in her narrative was a self-reflective stance, a reluctance to fully identify with the promises of molecular research. I felt that Deborah's participation in biology presented risks to her sense of self, with little space for her to openly critique the norms of Eurocentric science. In our interviews together, Deborah emphasized this new concept of time imposed by the laboratory, and keeping up with the harried pace of homework, exams, and research, often clashed with her family's sense of time. She often felt as if the demands of time came at the expense of participating in ceremonies at home, or spending time with her children. These issues that Deborah raised could be seen as "symbolic violence" (Bourdieu and Passeron 1990) as subtle, but coercive forces within the academic system that emphasized her lack of fit into the molecular research lab. She internalized a sense of being "less than" and felt guilty about being torn between home, her parents on the reservation, and her work at the university. Deborah says about the pressures of school and research:

> At home, I've become more methodical. I try to structure everything and ...because my home life is really mellow. My husband is, like "what comes next, comes next. If we're late, we'll get there when we get there." And time doesn't matter to him. There's no structure to time for him. And I used to be like that ... if we don't finish the laundry Sunday night, then my week is shot. I feel everything else is unorganized. He says, "When the dishes get done they get done." But for me, if they don't get done tonight, they'll never get done. We HAVE to do it. That's not your normal, healthy Navajo life-style.

Nespor (2004) notes how temporal-spatial scaling of life and work are dominated and calibrated by education. Similarly, the university laboratory orders time and space to create new frames of reference—ones that are not static, but shifting, "a spatial extensiveness and temporal synchronicities of networks within which identities are attached to people in fateful ways" (p. 310). In this sense, molecular biology does indeed have consequences for Deborah, and she openly questioned what it meant for her as an American Indian woman to become involved in laboratory research.

Deborah too, has her own way of resisting; that is, she hesitates, and does not immediately embrace new technology and knowledge produced by Eurocentric science. In our

interviews together, Deborah spoke about how as a Navajo woman she feels a need to sometimes "stand apart" and critique what is presented in her science classes; she does not readily consent to all that molecular biology seems to offer. When we were talking about molecular biology she said:

> If I'm writing a paper, sometimes I just want to start quickly. But then I have to think about it. Wait a minute, how do I as being a Navajo, how really, seriously – what do I think about it? Do I give your normal response that everyone else is going to give? Sit back and think. Does my belief and upbringing – does that really influence how a certain topic is? Because I'm Indian, I have to seriously think about it. Being a Navajo, what does genetics mean? Can I still say "YEAH(" or simply "good?" I can't just jump in with enthusiasm. I have to think about it and say "wait a minute!"

In an academic discipline like molecular biology where efficiency, speed, precision, and the pace of production are so highly valued, Deborah's hesitation and her reflective stance could be viewed as a liability. In fact, as I began my interviews with Deborah, I soon learned that the faculty director of the laboratory had moved Deborah from gene sequencing to a bibliographic review of community health literature. As an undergraduate advisor and coordinator of summer research programs for undergraduates, I witnessed how students were re-assigned outside the lab when faculty wanted to remove "unproductive" undergraduates from their research labs. Deborah's transfer to a new work assignment signaled to me that she was being marginalized even further from scientific practice.

Two worlds, bridges, and third space

The case study of Deborah set into motion a more detailed ethnographic study (Brandt 2006) where I looked for those discursive spaces where American Indian women had the opportunity to use and practice scientific language. As I listened to their narratives, I questioned where I would find a "border" that distinguished Indigenous ways of knowing from Eurocentric science. Often, I was confused by how their understanding of Eurocentric science and Indigenous knowledge were seamlessly presented by the participants. I wondered if a model like border crossing (Aikenhead 2001) between Eurocentric science and traditional Navajo beliefs adequately represented their experience.

In their paper, Aikenhead and Ogawa emphasize that diverse paradigms exist within Eurocentric sciences and Indigenous ways of living with nature. The authors cite their goal of building a "bridge:"

> Our project is not to formulate conclusions about such influence, credibility, and appropriateness for school science. Instead, this summary establishes a base from which to *build decolonizing bridges* between Eurocentric sciences and diverse Indigenous and neo-indigenous ways of knowing nature.

And yet, the use of a bridge as a metaphor, sets up Eurocentric sciences and Indigenous knowledge as opposed to one another, a binary in which "two worlds" exist—as does the model of border crossing, where students are making epistemic movements from their Indigenous worldview to participate in Eurocentric science.

Deyhle (1998) argues that a model of two worlds assumes students' movement is linear and hierarchical, with Native students moving "*from* their culture *to* the dominant Anglo culture" (p. 9). She contends that the two-world model implies that: "There are clear-cut choices – one either stays Indian (traditional), becomes Anglo (assimilates), or chooses the

best of the both worlds (bicultural/bilingual). ... It is more accurate to describe them as living in one complex and conflictual world" (p. 10).

To go beyond the simplistic veneer of a two-world metaphor, we need to look at the politics of difference and how binaries are constructed. Feminist research is deeply concerned with the dualistic nature of Western language, and the underlying power relationships that support these classifications. According to feminist theory, binaries reinforce and reify privileged categories in normative thought. For example, when considering the binary of Indigenous knowledge and Eurocentric science, academics have privileged Eurocentric science as more powerful and desirable, resulting in the exclusion of Indigenous knowledge from the university as a legitimate approach to understand the physical and natural world. Binaries in our language reinforce the "hierarchical ordering of knowledge" (Hughes 2002, p. 412) and maintain ascendant categories that in turn, support discriminatory practices. As Hughes says, the two positions of a binary are more than uncomplimentary ("incommensurate" as noted by Aikenhead and Ogawa); they are utterly irreconcilable, and require one to take a position at one end of the binary or the other. Hughes contends that we often find ourselves in the uncomfortable place of attempting to hold on to two competing ends of a binary, or in the awkward situation of disagreeing with both options. Hughes argues for "an analytical framework that can be described as *both/and* rather than *either/or*" (p. 412) when examining a binary. By embracing the position of *both/and* as a framework, one can take on multiple, competing, and conflicting points of view, and challenge the fixed nature of the binary to reveal positions that were previously erased and ignored simply because they did not fit into normative categories.

Other researchers in education and sociology have likened this process of embracing dichotomous positions to what they describe as a "thirdspace," or a location of hybridity (Turnbull 1997). However, hybridity or a blending of worldviews, as if one was looking at the overlapping section of two circles, did not adequately describe the experiences of the participants in my research. Rather the women in this study held firm to their traditional views and selectively added new ideas or concepts about medicine or ecology, much like the epistemic "amalgam" that Aikenhead and Ogawa described. One student in particular, Ramona, held multiple epistemologies where she referenced her Indigenous Navajo worldview, beliefs through the Native American Church, teachings from her education in the Catholic school, oral traditions within her family, and Eurocentric science.

Despite their embrace of multiple epistemologies, the students in my research understood that to survive in the context of the university, Eurocentric sciences were privileged and rarely were other ways of knowing ever broached (Brandt 2006). Several students found courses in Native American Studies that provided a space for developing a language from which to critique the grounds of Eurocentric science, and although well-versed in these skills as a result of these classes—they dared not bring these critiques into their biology or science courses. These students' search for that "bridge" among epistemic paradigms proved to be illusive and frustrating.

As Aikenhead and Ogawa note, epistemologies—ways of knowing—are inseparable from the languages through which they are communicated. Language, in turn shapes the spaces in which learning takes place and orchestrates social interaction. Sheehy and Leander (2004) look at the tandem processes of how speaking/writing shape space, and conversely, how spaces shape discursive practices. Rather than seeing space as "settled" and static, they emphasize the "unsettling" of discourse by emphasizing the fluid and dynamic qualities of space, time, place, and location. Space, according to these researchers, is both socio-cultural product *and* process. With the exception of Sheehy and Leander, few researchers in education have emphasized the spatialization of discourse, or used "discursive space" to

describe the mutually constitutive relationship between place, participants, and discursive practice. These authors look at space as dynamic, fluid, and changeable, and they view space from a critical perspective, as part of the political struggle in people's daily lives.

Epistemic common ground

Rather than emphasizing bridges, a more fruitful metaphor for seeking understanding between Eurocentric sciences and Indigenous knowledge is that of "common ground" in Aikenhead and Ogawa's Table 1. Common ground implies that one does not have to relinquish either position, but like the Indigenous women in my research, can simultaneously embrace elements of Eurocentric sciences and Indigenous knowledge.

Ecological restoration is one disciplinary field within Eurocentric science in which Indigenous knowledge has found common ground (Turner et al. 2000). Ecological restoration from an Indigenous epistemology is inherently place-based and works with the landscape and local resources with the goal of rehabilitating damaged environments. Ecological restoration is one field that acknowledges cultural process and practitioners in this field view social science as central to their work. Mascia et al. (2003) note that even though scientists may get the biology right, restoration requires more than the power of science behind its work. "The disconnect between our biological knowledge and conservation success has led to a growing sense among scientists and practitioners that social factors are often the primary determinants of success or failure" (Mascia et al. 2003, p. 649). After all, intervention by scientists and the writing of policy is a social activity and is the product of human behavior and decision-making. Similarly, Eurocentric science is as much about people, activities, communication, and social groups as it is about a body of knowledge. The authors argue that positioning social science research as central to conservation is critical to preserving the natural heritage of the world. And too, this shifting of power and authority demands that the boundaries between Eurocentric science and other epistemologies blur and merge.

Cabin (2007) reminds us that Eurocentric science can have different meanings, even for those with mainstream backgrounds in positions of authority: land use managers identify science with careful, systematic data collection and recording, while academic scientists define science with hypothesis testing, sampling, and statistical rigor. Cabin critiques the theoretical, narrow view of Eurocentric science: "Is this kind of science necessarily an effective framework and methodology for designing and implementing ecological restoration projects?" (pp 1–2). As a research ecologist with U. S. Forest Service in Kaupulehu, Hawai'i, Cabin began to question the practical value of the scientific research he encountered that was designed to assist in conserving and restoring species. He found that the goals and practice of science often conflicted with those of ecological restoration whose outcomes were directed by common sense, local knowledge, and informal trial and error. When it came to the many kinds of land use decisions that needed to be made, Cabin realized that Eurocentric science alone could never resolve the critically important issues.

> "Perhaps there will always be some if not many cases where our square grids simply do not fit the real world; thus, the best we can do is develop more organic and holistic grids, lend our support to other ways of knowing and doing, and/or get out of the way!" (Cabin 2007, p. 6)

In ecological restoration, time/space frames of reference contrast with the linear, data-driven production of Eurocentric science. In their study of ecological restoration practices,

Davidson-Hunt and Berkes (2003) describe learning as neither an individual nor collective activity. Rather, they contextualize educational processes within a socio-ecological system. The authors portray knowledge as being attached to a set of beliefs, and both as being amassed through evolving adaptive processes through generations of cultural learning. This knowledge is revisited through "social memory," a communal act that requires a long-term understanding of place, environmental change, and cultural practices. "Social memory describes how an individual thought, emerging out of a specific experience, can become part of the collective knowledge of a group. Social memory frames individual practice and creativity, and in turn is changed by individual practice and creativity" (p. 5). There is a co-constitutive dynamic in this adaptive learning model in which humans draw from memory (perception, cognitive knowledge, technology, institutions, and worldview) as the move through their daily lives. Davidson-Hunt and Berkes describe "research" as a landscape:

> The landscape, in this perspective, becomes a network of nodes and trails that orient a person in physical, social, and cultural space. Thus, spatial patterning does not exist independently of the journeyer nor does it exist until the journey occurs. As both the journeyer and journey are physical, social, and cultural in nature, the knowledge of the spatial pattern of a landscape requires access to these three axes. (p. 10)

Final thoughts

All of my examples above draw from learning in informal contexts beyond the classroom, and yet they represent locations where significant personal growth and understanding of the natural world occurs—all of which have critical implications for science education in schools. The configuration of time/space frames of reference for Eurocentric science contrasts radically with Indigenous epistemologies; in my examples I presented the great difficulties encountered by American Indian women who embraced multiple epistemologies. I wonder if our efforts in science education are misdirected by attempts to build bridges. Rather, I advocate that we continue to look for those elements of common ground and bring to light the ways in which space and time are ordered through our educational practices.

References

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

Appadurai, A. (1996). *Modernity at large: Cultural dimensions of globalization*. Minneapolis: University of Minnesota Press.

Bourdieu, P., & Passeron, J. (1990). *Reproduction in education, society, and culture* (2nd ed.). London: Sage Publications.

Brandt, C. B. (2006). *Narratives of location: School science identities and scientific discourse among Navajo women at the University of New Mexico*. Unpublished doctoral dissertation. University of New Mexico, Albuquerque.

Brandt, C. B. (2007). Scientific discourse in the academy: A case study of a Native American undergraduate. Under review.

Cabin, R. J. (2007). Science-driven restoration: A square grid on a round earth? *Restoration ecology, 15*(1), 1–7.

Davidson-Hunt, I., & Berkes, F. (2003). Learning as you journey: Anishinaabe perception of social-ecological environments and adaptive learning. *Conservation Ecology, 8*(1). Accessed May 18, 2007. http://www.ecologyandsociety.org/vol8/iss1/art5/.

Deyhle, D. (1998). From break dancing to heavy metal: Navajo youth and identity. *Youth & Society, 30*(1), 3–31.

Hughes, C. (2002). Beyond the post-structuralist-modern impasse: The woman returner as 'exile' and 'nomad.' *Gender and Education, 14*(4), 411–424.

Mascia, M. B., Brosius, J. P., Dobson, T. A., Forbes, B. C., Horowitz, L., McKean, M. A., & Turner, N. J. (2003). Conservation and the social sciences. *Conservation Biology, 17*(3), 649–650.

Nespor, J. (2004). Educational scale-making. *Pedagogy, Culture, and Society, 12*(3), 309–326.

Sheehy, M., & Leander, K. M. (2004). Introduction. In K. M. Leander & M. Sheehy (Eds.), *Spatializing literacy research and practice* (pp. 1–14). New York: Peter Lang.

Turnbull, D. (1997). Reframing science and other local knowledge traditions. *Futures, 29*(6), 551–562.

Turner, N. J., Ignace, M. B., & Ignace, R. (2000). Traditional ecological knowledge and wisdom of aboriginal peoples in British Columbia. *Ecological Applications, 10*(5), 1275–1287.

Carol B. Brandt is an assistant professor of social foundations in the Department of Teaching & Learning at Virginia Polytechnic Institute and State University in Blacksburg, Virginia. After completing her PhD in Educational Thought and Sociocultural Theory at the University of New Mexico, she conducted postdoctoral research with the Center for Informal Learning and Schools at the University of California, Santa Cruz. Her research explores the sociocultural dimensions of learning science beyond the classroom and the ways that language structures participation as youth and adults move between home, community, and school. Her research and teaching draws upon cultural geography and feminist post-structural theory to address the social construction of gender, race, and other aspects of identity and belonging.

Towards authentic forms of knowledge[3]

Michiel van Eijck

University of Victoria, Victoria, BC, Canada
e-mail: vaneijck@uvic.ca

In their paper "Indigenous Knowledge and Science Revisited," Glen Aikenhead and Masakate Ogawa present an alternative view on knowledge systems and ways of knowing colloquially known as the dyad "Indigenous knowledge" and "science." They recognize that this dyad is problematic and requires "more authentic categories such as the triad *Indigenous ways of living in nature* (plural), *neo-indigenous ways of knowing nature* (referring to a cluster of Asian cultures, including for instance, Islam and Japan, described in detail below), and *Eurocentric sciences* (plural)." Thus, the authors claim "to offer insights of value to science educators so they can build bridges between their own Eurocentric knowledge system and other ways of knowing, thereby spanning the colonial false dichotomy between science and Indigenous or neo-indigenous ways of knowing nature."

The guided tour certainly recognizes ways in which the two terms *Indigenous knowledge* and *science* become problematic. It reminded me of a discussion we had in a meeting of our research group some time ago. This research group is very heterogeneous and composed of people from various origin (Roth et al. in press). In the heat of a discussion on Indigenous knowledge and science, I posed the question how we could name the life sciences in highly developed Asian countries, like Korea and Japan. On the one hand, Eastern life scientists apply many research methods originally developed by Western scientists. For example, in the International Rice Genome Sequencing Project the research methods of both Eastern and Western scientists can be rooted in the Western molecular biological research tradition that emerged after the discovery of the genetic code (International Rice Genome Sequencing Project 2005). On the other hand, it is not appropriate to name Eastern life scientists, therefore, "Western life scientists." Like my Taiwanese colleague said, "at least we are Easterners and conduct Eastern science." What then, I asked, makes "Eastern science" not Western? Such questions are commonly asked in science education when other knowledge systems are compared with science, like Indigenous knowledge. However, given recent debates, this appeared to be highly problematic (e.g., Siegel 2002). Dichotomies like Eastern science/Western science or Indigenous knowledge/science therefore need refinement, adjustment or replacement. This is exactly where Aikenhead and Ogawa made a unique step forward in the debate and introduced their three new categories Indigenous Ways of Living in Nature, Neo-Indigenous Ways of Knowing Nature, and Eurocentric Sciences.

Certainly, these descriptors reflect "more complex ... concepts than those conveyed by the colloquial dyad Indigenous knowledge and science." It is an exceptionally profound and comprehensive text that surely will "expand readers' understanding of Indigenous and neo-indigenous ways of knowing nature." For example, the authors introduce the concept seigyo-shizen, a Japanese neo-indigenous way of knowing nature, and therewith provided me with new insights about what I formerly named with the platitude "Eastern science." In this way, many readers will benefit from this paper, varying between "a highly Eurocentric reader who embodies Eurocentric knowledge and likely has little appreciation or understanding of Indigenous or neo-indigenous knowledge systems" and "in-depth bicultural

[3] This article is to be cited as: van Eijck, M. (2007). Towards authentic forms of knowledge. *Cultural Studies of Science Education, 2*, DOI 10.1007/s11422-007-9067-8.

readers who embrace Indigenous or neo-indigenous knowledge systems and who appreciate and understand Eurocentric knowledge."

Yet, closer reading of the text made me question to what extent such insights are "of value to science educators so they can build bridges between their own Eurocentric knowledge system and other ways of knowing." The comment I wish to make here concerns the *authenticity* of the newly introduced categories. Particularly, I will point out how and why the authors, by introducing these new categories, did not fully span "the false dichotomy, Indigenous knowledge versus science, found in colonial discourse with its subtext of winners and losers (Macedo 1999)."

A multilayered "exposure of an error"

The authors depart from a postcolonial framework, which focuses on the structures in the discourse that either privilege or silence particular voices (cf. Spivak 1988). It attempts to reveal the underlying assumptions that make possible the meaning that appears "natural" and to displace the voices that are powerful due to articulating such "natural" meanings (Spivak 1990). The unraveling of the articulated meanings is usually done through the identification of dichotomies which are considered fundamental to our ways of thinking and being, and usually consist of one term that dominates over another. While discussing the East/West dichotomy with my Asian colleague, for example, I might not have been continuously aware of its colonial servant/master subtext that silences the authentic contributions of Eastern scientists in the current global scientific enterprise (Spivak 1988).

In this paper, the authors thus aim to analyze the underlying assumptions by which the false dichotomy Indigenous knowledge/science and, particularly, its subtext of winners and losers, is maintained. Aikenhead and Ogawa clearly identify these assumptions, which are in turn also dichotomies, like nature/culture, holism/reductionism, and the Cartesian dualism of mind/matter. Such dichotomies are problematic in the sense that they, as part of common language, deceptively can be put forward to establish or reinforce colonial thinking. For example, the "natural" Cartesian dualism in Western science silences the voice of "people who do not subscribe to it and perceive it as destroying their unity of existence." After this "exposure of an error" (Spivak 1990, p. 46), that is, the identification of problematic dichotomies that make the notion of Indigenous knowledge versus science possible, the next step in the postcolonial critique is: "the displacement of such thinking. In other words, how does one re-think these fundamental ideas? How does one displace those assumptions that make 'natural' meaning possible?" (McKinley and Aikenhead 2005, p. 903). Thus, I would have expected the question how in this case these "fundamental ideas," i.e. the dichotomies underlying the Indigenous knowledge/science discourse like nature/culture, holism/reductionism, and the Cartesian dualism of mind/matter, might be rethought. In this context of multi-layered subtexts, such rethinking certainly requires a lot of rigor and exposing these problematic dichotomies is therefore already an accomplishment in itself. It is thus not surprising that Aikenhead and Ogawa continue focusing on replacing the categories "Indigenous knowledge" and "science" rather than, *to begin with, the underlying dichotomies that made such "natural" categories possible*. The new categories, i.e. Indigenous Ways of Living in Nature, Neo-Indigenous Ways of Knowing Nature, and Eurocentric Sciences, therefore still build upon the same dichotomies that were identified as problematic. I therefore doubt to what extent these newly constructed categories are more authentic than the former. Because I am neither Japanese nor Indigenous, I cannot appropriately determine the authenticity of both the categories Japanese Ways of Knowing Nature and Indigenous Ways of Living in Nature. However, being originally trained

in the "Western life sciences," the newly created category "Eurocentric science" appeared to me as inauthentic when, for example, focusing on the use of the nature/culture dichotomy.

Rousseau already introduced the nature/culture dichotomy in the 18th century as a utopian contrast between urbanization and materialism and the "savage" and his unmolested, unadulterated surroundings. This dichotomy is one of the most problematic constructs identified by postcolonial theory (Vogel 1996). In colonial texts, the "savage" nature of the colonized was maintained by emphasizing his unmolested, unadulterated surroundings. Therewith, for example, a subtext was established that silenced the highly developed cultures of many colonized peoples. In the paper of Aikenhead and Ogawa, we see this principle working the other way round. When explicitly discussing the position of "nature" in Eurocentric Science, it is repeatedly articulated as something man "wants to have power and dominion over." This is repeatedly contrasted with the position of "nature" in Indigenous Ways of Living in Nature and Neo-Indigenous Ways of Knowing Nature, like: "To understand nature is to live in harmony with nature, not to dominate any part of nature." This appeals to our current thinking in which for example extensive urbanization is conceptualized as negative and in which, due to modern ecological thinking (e.g. global warming), "harmony with nature is certainly not a romanticized notion" anymore. Thus, ambiguous usage of the term "nature" still maintains a subtext of winners and losers. It silences, for example, that Darwin's theory of evolution has already altered Western natural philosophy by introducing the notion of human as a part of nature. More recently, indeed, "review of major interpretations of the history of the dualism in Western thought indicates that the legacy is more multistranded than is usually admitted ... The dualism thus evaporates in actual research practice" (Haila 2000, p. 155). This is clearly observable in modern ecology, which explicitly conceptualizes humans as being part of nature (Worster 1994). More or less the same can be said of the other dichotomies identified by Aikenhead and Ogawa, like holism/reductionism and mind/matter. For example, the current success of the life sciences draws upon the *combined* use of holistic and reductionistic approaches (Mayr 1997) and current cognitive sciences doubt Cartesian dualism (e.g., Damasio 1994).

My observation can be seen as a deconstruction of the deconstruction by Aikenhead and Ogawa and something similar has been the topic of a recent debate in science education research before (e.g., Carter 2005). This is nothing new; the work of deconstruction is never complete because one can always deconstruct the critique itself (I am aware that this commentary might be the subject of deconstruction as well). To show colonial structures in the work of Aikenhead and Ogawa is a purposeless task if it should stop there and it is thus not the single aim of this commentary. On the contrary, the step made by Aikenhead and Ogawa is a leap forward in the sense that they further challenge science educators like me to overcome the false dichotomies that *underlie* the Indigenous Knowledge/science debate. Their paper enabled me to better understand why former categories like "science" and "Indigenous knowledge" *and* the newly introduced categories Indigenous Ways of Living in Nature, Neo-Indigenous Ways of Knowing Nature and Eurocentric Science, though profoundly and comprehensively illustrated, still fall short in authenticity. The question is thus: how can we rethink the dichotomies underlying these categories?

Rethinking dichotomies

My rethinking starts with the implicit structuralism by which underlying dichotomies are *introduced* (rather than identified). For example, when presenting literature from Indigenous scholars, the authors "eclectically draw from it to identity *fundamental features* that

help clarify similarities and differences between Indigenous ways of living in nature (IWLN) and Eurocentric sciences" (emphasis added). Inherent to this aim is the idea of deeper "structures" inside knowledge systems and which must be identified to be able to clarify similarities and differences. However, such "structures" are exactly what is at stake in postcolonialism. In his famous *Play, Sign and Structure*, for example, Derrida showed that the fundamental "structures" the anthropologist Levi–Strauss aimed to identify in the myths of different cultures were inherently biased by a Eurocentric perspective (Derrida 1978). Thus, he showed

> that the concept of structure and even the word "structure" itself are as old as the episteme – that is to say, as old as Western science and Western philosophy – and that their roots thrust deep into the soil of ordinary language, into whose deepest recesses the episteme plunges to gather them together once more, making them part of itself in a metaphorical displacement. (p. 278)

Indeed, Aikenhead and Ogawa, to be able to identify "fundamental features" *introduce* rather than identify dichotomies. This is observable when the authors replace, again, the category "science" with "Eurocentric science." The authors point out that "the origins of science go back to ancient philosophies (e.g., Egyptian and Greek)" and that "its evolution can be marked by major social transformations in Europe." Having this said, they continue as follows:

> The first social transformation in Europe was the Renaissance movement. It eventually created the need for 17th century natural philosophers (e.g., Galileo, Kepler, Descartes, Wallis, Leibniz, Roberval, Huygens, Halley, and Newton) to establish a knowledge system predicated on the authority of empirical evidence, as opposed to the authority of the church and royalty.

Here, we can observe how "Eurocentric science" is constructed by using "natural" dichotomies. First, the sciences are distinguished by articulating rather its *European* foundation. Although "ancient philosophies" are mentioned as well, they are not clearly distinguished. Yet, these ancient philosophies emerged as a result of the lively exchange of ideas between the formerly separated Semitic and non-Semitic peoples in the empire of Alexander the Great. This can therefore be called "a major social transformation in Europe" as well. During this time, for example, Aristotle, the so-called "father of science" (Bakunin 1916/1882, p. 72), founded his Lyceum. Thus, the very foundation of "Eurocentric science," therefore, is in itself the result of a mélange of many peoples from the empire of Alexander the Great, including from then-current countries like Persia, Anatolia, Syria, Phoenicia, Judea, Gaza, Egypt, Bactria, Mesopotamia and even Punjab. Although the authors point out that "Eurocentric sciences possess a powerful way of knowing about nature, and this includes knowledge appropriated over the ages from many other cultures (e.g., Islam, India, and China)," they subsequently claim that "such knowledge was modified sufficiently to fit Eurocentric worldviews, epistemologies, and value systems." Thus, rather than the mélange of different peoples' worldviews, they emphasize the purity of a "European" foundation by which the "Eurocentric science" becomes more "European" and less "Eastern." Therewith, the text introduces a questionable East/West dichotomy.

Second, the text roots Eurocentric science in the names of *particular* natural philosophers (e.g., "Galileo, Kepler, Descartes, Wallis, Leibniz, Roberval, Huygens, Halley, and Newton") and *particular* methods of research ("a knowledge system predicated on the authority of empirical evidence"). Again, such texts ignore the holistic approaches commonly found in the life sciences and scientists like Darwin who applied such approaches.

As a result of such ignorance, the life sciences have for long been presented as an inferior science compared to the physical sciences (Mayr 1997). Due to this privileging, standard accounts of the philosophy of science rather concerned the approaches of the physical sciences (e.g., Nagel 1961). Indeed, avoiding the classical heroic story of big names of physicists leads to the conclusion that the "scientific method" is highly plural and that the empirical-experimental method, which emerged in the renaissance, is only one of the several styles of doing science (Crombie 1994). The text introduces thus a reductionism/holism dichotomy incongruent with current and past scientific practice.

Again, it is not my primary aim to show colonial structures in these texts, particularly knowing that Aikenhead and Ogawa in their paper attempt to overcome dichotomies like the above, for example when they state that "the existence of multiple paradigms, some of which may be incommensurate, illustrate the extensive diversity within Eurocentric science." Rather, the difficulty I want to show here concerns *the nature of the voices* that speak in this text. A voice can be conceptualized as the articulation of an existing identity—Descartes' *ego existo*. Postcolonialism, then, aims to distinguish the ignored voice—the re*cognition* of the "one" that is silenced. However, the key issue here is not to confuse this "one" with the substance in which it is founded:

> But the more this "one" is clearly distinct and distinguished, the less it may be its own pure foundation. Undoubtedly, the task is wholly a matter of not confusing distinction and foundation; in fact this point contains everything that is at stake philosophically, ethically, and politically in what is brewing [*se trame*] around "identities" and "subjects" of all sorts. Thus the absolute distinction of the *ego existo*, provided by Descartes, must not be confused with foundation in the purity of a *res cogitans*, with which it is joined together. For example, the "French" identity today no longer needs to found itself in Vercingétorix or Joan of Arc in order to exist. (Nancy 2000, p. 152)

This confusion between distinction and foundation is exactly the difficulty in the paper of Aikenhead and Ogawa. The problematic dichotomies are introduced when they aim to make a distinction between Indigenous Ways of Living in Nature and Neo-Indigenous Ways of Knowing Nature on the one hand and Eurocentric Science on the other hand by explicating the foundations of the latter and when they state, for example, that "natural philosophy *was* imbued with the value of gaining power and dominion over nature" (emphasis added). This mixing up of distinction and foundation introduces dichotomies by which colonial discourse is, in this case, altered rather than displaced.

Towards an ontology of difference in science education

> Furthermore, can deconstruction as a critique lift itself off the page to have any practical application? We suggest that these questions are ones at issue for many people. (McKinley and Aikenhead 2005, p. 903)

The key thing in overcoming the dichotomies underlying the Indigenous Knowledge/science debate, therefore, is to distinguish between different forms of human knowledge without relying on their foundations. This requires a dynamic, heterogeneous, plural notion of human knowledge and culture.

Thus, when Aikenhead and Ogawa motivate their study by stating that "an increasing number of science educators want to understand *the* cultural influence on school science

achievement by students *whose* cultures and languages differ from *the* predominant Eurocentric culture and language of science" (emphasis added), they already conceptualize the term (a) as a "theoretically defined category or aspect of social life that must be abstracted out from the complex reality of human existence" or (b) as a "concrete world of beliefs and practices" (Sewell 1999, p. 39). Both notions of culture, however, are essentially static. Culture is seen as rather stable and new members are conceived as "newcomers" who are "socialized" and "enculturated" to it along trajectories that range from peripheral to core participation, at which point they are part of a group of "Neo-indigenous" or "Indigenous" people or "Eurocentric scientists." While I do not downplay the importance of a cultural identity for individuals and groups here (*ego existo*), I emphasize again the difficulty of a distinction by focusing on its foundation (*res cogitans*).

Take, for example, the comprehensive treatment of seigyo-shizen, showing that current people in Japan live "in a stratified amalgam of culture components from present and precedent Japanese cultures" and move *seamlessly* between, for example, "modern" information technology type of seigyo on the one hand, and "traditional" Yayoi type of seigyo, and Jomon type of seigyo on the other hand. Indeed, "the separation between traditional and modern cultures is eroding as each finds a place in today's cultural and economic practices" (Gaskell 2003, p. 235). In this sense, culture has a dynamic rather than a static nature. Although the current Japanese culture is surely one, it is at the same time in a state of permanently mixing up "traditional" with (but not disappearing in) "modern" society. Rather than to perceive culture as a mélange, therefore, "it would be better, then, to speak of *mêlée*: an action rather than a substance" (Nancy 2000, p. 150). Cultural identity then, is "a 'production' which is never complete, always in process, and always constituted within, not outside, representation" (Hall 1990, p. 222). Even the "stratified amalgam model" Ogawa proposes in order to understand Japanese Ways of Knowing Nature falls essentially short to grasp the dynamic, heterogeneous, and plural nature of human cultures because it is perceived as a mélange rather than the *mêlée*, the *ego existo*.

Likewise, the paper of Aikenhead and Ogawa approaches knowledge as a static, singular, and homogeneous corpus as they, for example, invite the reader to contemplate the discussed features of science "through the lens of *their own professional* knowledge." Knowledge, as integral to human being, is also a *mêlée* of voices, texts, procedures, tools, constructs, and so on; it exists only in and through its continuous production and reproduction in the concrete praxis of real human beings. Even the most transcendental and deductive sciences, such as geometry, only exist in the dialectical relationship with human practices. As a continuous ongoing process subject to collective human practice, knowledge emerges and disappears as it is constructed and deconstructed, shaped and reshaped, produced and reproduced, forgotten and reminded, reinvented and taught. More so, even if we perceive knowledge as a body, as a singular identity in itself, it is so in the midst of other bodies of knowledge and therefore never on its own. Knowledge is, like human bodies, singular plural and, consequently, heterogeneous in nature (Roth 2006).

The Indigenous knowledge/science dichotomy emerges due to static, homogeneous, and singular notions of knowledge. When perceived as something dynamic, plural, and heterogeneous, categories like "Indigenous knowledge" or "science" make no sense because they can never cover all the differences and the dynamics inherent to the process of knowledge production. Combined with a static, singular, and homogeneous notion of culture, one runs into questions about where knowledge belongs and, hence, which knowledge should be taught to which people. More so, one runs into difficulties of providing good arguments for teaching specific knowledge, given that there always is too

much to teach everything. Answering such questions requires precise definitions of the foundations of cultures and the knowledge inherent to this culture—an impossible, endless task of revisiting all kinds of knowledge (to which Aikenhead and Ogawa indeed invite their readers). To overcome this problem, therefore, we should think both culture and knowledge dynamically. This can be done by beginning with an ontology of difference, where nothing is the same—which is a lesser presupposition than assuming sameness between any two items (Roth 2007). Any identity and commonality, then, is the outcome of a constructive process. Rather than a guided tour through static bodies of knowledge, we need thus guided tours through the different norms that the forms of knowledge have for legitimizing themselves and the different processes by means of which they are produced, evolved, and reproduced. Then we can formulate questions about the usefulness of different forms of knowledge for students and teach ways of evaluating knowledge claims and processes of knowledge construction and evolution. This process may lead to the experience that science is not all that glitters and that, for example, the forms of knowledge resembling aspects of seigyo-shizen or Indigenous Ways of Living in Nature better suit students' local needs. Thus, decolonization is enacted in practice rather than on papers like this, that, to begin with, are composed of ink or pixels and not knowledge itself (cf. Husserl 1939). Only then we can overcome the critique "that the master's tools will never dismantle the master's house, so that it may all be academic anyway" (McKinley and Aikenhead 2005, p. 905).

References

Bakunin, M. (1916). *God and the state* (Original work published 1882). New York: Mother Earth Publishing Association.

Carter, L. (2005). A place for alternative readings: Can they be of use? Responding to comments on Thinking differently about cultural diversity: Using postcolonial theory to (re)read science education. *Science Education, 89*, 913–919

Crombie, A. (1994). *Styles of scientific thinking in the European tradition*. London: Duckworth.

Damasio, A. (1994). *Descartes' error: Emotion, reason, and the human brain*. New York: Avon Books.

Derrida, J. (1978). Structure, sign and play in the human sciences. In J. Derrida (Ed.), *Writing and difference* (pp. 278–294). London: Routledge.

Gaskell, J. (2003). Engaging science education within diverse cultures. *Curriculum Inquiry, 33*, 235–249.

Haila, Y. (2000). Beyond the nature-culture dualism. *Biology and Philosophy, 15*, 155–175.

Hall, S. (1990). Cultural identity and diaspora. In: J. Rutherford. (Ed.) *Identity: Community, culture, difference* (pp. 222–237). London: Lawrence & Wishart.

Husserl, E. (1939). Die Frage nach dem Ursprung der Geometrie als intentional-historisches Problem. *Review Internationale de Philosophie, 1*, 203–225.

International Rice Genome Sequencing Project. (2005). The map-based sequence of the rice genome. *Nature, 436*, 793–800.

Macedo, D. (1999). Preface: Decolonizing indigenous knowledge. In L. M. Semali & J. L. Kincheloe (Eds.), *What is indigenous knowledge? Voices from the academy* (pp. xi–xvi). New York: Falmer Press.

Mayr, E. (1997). *This is biology: The science of the living world.* Cambridge: Harvard University Press.

McKinley, E., & Aikenhead, G. (2005). Comments On "Thinking Differently About Cultural Diversity: Using Postcolonial Theory To (Re)Read Science Education". *Science Education, 89*, 901–906.

Nagel, E. (1961). *The structure of science: Problems in the logic of scientific explanation*. London: Routledge and Kegan Paul.

Nancy, J.-L. (2000). *Being singular plural.* Stanford: Stanford University Press.

Roth, W.-M. (2006). *Learning science: A singular plural perspective.* Rotterdam: Sense Publishers.

Roth, W.-M. (2007, April). *Bricolage, métissage, hybridity, heterogeneity, diaspora: Concepts for thinking science education in the 21st century*. Paper presented at the Springer Forum on Globalization in/of Science Education, Chicago. Retrieved, March 1, 2007, from http://www.educ.uvic.ca/faculty/mroth/chicago/Roth.pdf

Roth, W.-M., Ardenghi, D., Boyer, L., Chen, P., Emad, G., Hsu, P.-L., Jaime, B., Kim, M., Pozzer-Ardenghi, L., Reis, G., Stith, I., & Van Eijck, M. (in press). *Being, becoming, belonging. life in an international research group.*

Sewell, W. H. (1999). The concept(s) of culture. In V. E. Bonnell & L. Hunt (Eds.), *Beyond the cultural turn: New directions in the study of society and culture*. (pp. 35–61). Berkeley, CA: University of California Press.

Siegel, H. (2002). Multiculturalism, universalism, and science education: In search of common ground. *Science Education, 86*, 803–820.

Spivak, G. (1988). Can the subaltern speak? In C. Nelson & L. Grossberg (Eds.), *Marxism and the interpretation of culture* (pp. 271–313). Urbana: University of Illinois Press.

Spivak, G. C. (1990). *The postcolonial critic.* New York: Routledge.

Vogel, S. (1996). *Against nature: The concept of nature in critical theory*. Albany: State University of New York Press.

Worster, D. (1994). *Nature's economy: A history of ecological ideas*. Cambridge: Cambridge University Press.

Michiel van Eijck is Research Fellow in Science Education at the Pacific Centre for Scientific and Technological Literacy at the University of Victoria. He is a former high school biology and general science teacher. His current research interests include scientific literacy, epistemology of science, educational technology, environmental education, and socio-cultural and cultural-historical perspectives on science education. His recent publications include "Keeping the local local: recalibrating the status of science and Traditional Ecological Knowledge (TEK) in education" to appear in *Science Education* and "The role of information technology-based research tools in students' development of scientific literacy" (2007) in the *Journal of Science Education and Technology*, both written in collaboration with Wolff-Michael Roth.

A reply to three thoughtful commentaries: the conversation continues[4]

Glen Aikenhead and Masakata Ogawa

Indeed, we in cultural studies of science education are a diverse community. Four dramatically different perspectives are represented by our article and the three thoughtful commentaries on it. Patricia Vickers advances sustainable development, sovereignty, and cultural survival of the Ts'msyen peoples by pointing out, "Our method of relating to the land and 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." This intimate connection, if found in science teaching, will help ameliorate "conflict between two human ways of being" (i.e., "academic society" represented by our article; and Indigenous "finding things out, the body of knowledge arising from the things found out, [and] the new things you can do when you have found things out," represented in her commentary and based on Richard Feynman's definition of "science"). Vickers clarifies what she calls "an intimate connection" by her writing from the center of her Indigenous world and by acting from her heart. Her article establishes "the need to dialogue and the need to present our world view as the Indigenous with methods that will transform oppression and add ancestral practice in the quest for knowledge."

Carol Brandt begins her piece by illustrating an intimate connection to the land, which we felt resonated with the Japanese *seigyo* (i.e., a neo-indigenous way of knowing nature, not unlike what Semali and Kincheloe [1999] described as Kincheloe's boyhood community's way of knowing nature). Brandt then moves the conversation to the enculturation of willing, Indigenous, female, university undergraduate students into Eurocentric sciences. She focuses on the way a student embraced multiple epistemologies, and Brandt concluded (in part), "The configuration of time/space frames of reference for Eurocentric science contrasts radically with Indigenous epistemologies." By quoting from research ecologist Robert Cabin (i.e., "Perhaps there will always be some if not many cases where our square grids simply do not fit the real world; thus, the best we can do is develop more organic and holistic grids, *lend our support to other ways of knowing and doing*, and/or get out of the way" – emphasis added), Brandt reinforces Vickers's wish for academic society to dialogue with Indigenous communities.

Michiel van Eijck extends the discussion in our article in several ways: by employing the analytical methodology of deconstruction, by adding important instances to our examples of heterogeneity within Eurocentric sciences (as does Brandt), and by continuing the quest for *more authentic* categories and metaphors that identify, replace, and displace unconscious ways of thinking that can privilege colonizers' ways of thinking. His movement towards an ontology of difference in science education (where nothing is the same, and identity and commonality are constructed anew) resides in "overcoming the dichotomies underlying the Indigenous Knowledge/science debate." He introduces the metaphor *mêlée* to displace several categories that appear in our article. From within a deconstruction genre of scholarship, he correctly concludes that our categories "still fall short in authenticity." A search for authenticity leads us again to Vickers's perspective centered in her Indigenous world. Similar to our article, van Eijck's academic genre of deconstruction

[4] This article should be cited as: BAikenhead, G., & Ogawa, M. (2007). A reply to three thoughtful commentaries: the conversation continues. *Cultural Studies of Science Education, 2*, DOI 10.1007/s11422-007-9067-8.

may seriously lack in authenticity in terms of Vickers's concern for how to recover from "oppressive violence inflicted through colonization and to restore the principles our ancestors left behind to guide us in our relationships with each other, with animals, the land, the supernatural, and other nations."

However as we see it, the issue here is not a contest for greatest authenticity, but instead: What can we learn from four diverse positions concerning a colonizing ideology that has resided in the so-called "science versus Indigenous knowledge" discussions within science education? More specifically, we ask: What can we learn about metaphors? About the domain of postcolonial scholarship? About dichotomies? About contexts of use? and About articles in international journals? Each of these questions is addressed in turn.

We academics often seem preoccupied searching for the best metaphor that we expect will explicate a complex idea in a new way. Brandt explicitly and sensitively mentions, "Rather than emphasizing bridges [as we do in our article], a more fruitful metaphor for seeking understanding between Eurocentric sciences and Indigenous [ways of living in nature] is that of 'common ground'." We do not disagree. Fruitfulness is a revered epistemic value. To the metaphors of building bridges and finding common ground, Vickers adds creating camping spots for dialogue.

Academics legitimately find inherent limitations in metaphors. One impetus to this scholarly convention was explained by Kawasaki (1996) when he drew upon structural linguistics to demonstrate the difficulty of translating "nature" by "shizen" (a translation discussed in our article). He concluded, "We can not grasp the meanings of the word 'shizen' without considering all other terms that surround it in Japanese" (p. 8). The surrounding terms include what shizen is not, that is, ideas that also delimit the meaning of "shizen." Applying a similar analysis to the metaphors of bridges, common ground, and camping spots, we recognize that academics immersed in different genres, paradigms, or cultures will not share the same set of surrounding meanings of a metaphor, because connotations are extremely context specific and rich in personal experiences. Differing surrounding meanings lead to disagreements over what is assumed and what is implied by a metaphor. Therefore, metaphors invariably fail to convey the precise meaning intended or assumed by an author. As a consequence, fruitfulness is pluralistic and we feel enriched by the multiple metaphors found in the three commentaries on our article.

One's choice of metaphor may seem to align more closely with a postcolonial perspective. Vickers's camping spots is a case in point. But so too are the choices made by her colleagues who she recognizes as Indigenous leaders, for instance, the choice of metaphor by Marie Battiste (2000) in her book *Reclaiming Indigenous Voice and Vision*. In our article, we introduced the metaphor of building bridges (qualified as "decolonizing bridges") by quoting Battiste ("by creating bridges between Indigenous and Eurocentric knowledge;" p. xvii), a metaphor also used by Yupiaq scholar Oscar Kawagley. We accept the interpretation by Vickers, Brandt, and van Eijck that this metaphor suggests to them dichotomous rigid camps, an interpretation based on their surrounding meanings of the metaphor. Our acceptance of their alternative metaphors is one of *and*, rather than one of *either/or* (to borrow from Brandt). Our understanding is enriched by contemplating additional interpretations. Our emphasis on building decolonizing bridges was simply predicated on giving priority to a metaphor invoked by some Indigenous leaders, rather than to a metaphor we have used in our own publications in the past. We are indebted to Brandt for drawing our attention to Donna Deyhle's work to illustrate the diversity of thinking among Indigenous scholars on the issue of biculturalism.

Postcolonial writers such as Deyhle, Vickers, Battiste, and Kawagley were the type of scholars we turned to for a *more* authentic (in the relative sense of authentic) account of

what "Indigenous ways of living in nature" means to these Indigenous postcolonial scholars (no consensus or homogeneity implied). Our notion of postcolonial scholarship, as evidenced by our choice of authors to quote and as evidenced by the list of Indigenous leaders composed by Vickers, is obviously much broader than van Eijck's notion of postcolonial scholarship in which a deconstruction methodology appears to monopolize. Although postcolonial scholarship does draw upon deconstruction as one methodology, Indigenous scholars are by no means restricted to applying this language-based methodology. Nevertheless, we are indebted to van Eijck for bringing his genre of postcolonialism to the Forum, particularly his apt analysis of dichotomies. We are, however, surprised to read that we embrace "static, singular, and homogenous notions" of both knowledge and culture, whereas we see quite the opposite in the total fabric of our article. Such is the nature of a deconstruction methodology, we conclude.

Concerning dichotomies, we find it informative to remember that diverse languages (including European based languages, Japanese, and Cree, for example) commonly employ dichotomies. One goal within deconstruction is to uncover how some dichotomies color power and privilege. For instance, Brandt reminds us, "Feminist research is deeply concerned with the dualistic nature of Western language, and the underlying power relationships that support these classifications." Thus, for instance, Vickers chooses the inclusive "humankind" (as in "working toward the betterment of humankind"). Van Eijck chooses the exclusive "man" (as in "it [nature] is repeatedly articulated [in our article] as something man 'wants to have power and dominion over'") although our choice was the inclusive "humans" (as in "humans have power and dominion over nature," in our description of an anthropocentric Judeo-Christian hierarchy found in Eurocentric sciences). Many dichotomies are found in the three commentaries on our article, for instance: authentic/inauthentic, east/west, mainstream/non-mainstream, Indigenous/non-Indigenous, and colonized/colonizer. Although dichotomies are a normal part of our communication repertoire, we benefit from a thoughtful deconstruction of them so we can contemplate and perhaps hone our own critical understanding and writing. This has been our experience in the past, and hence, we appreciate van Eijck's commentary.

We might also benefit from applying truth functional analysis from the field of symbolic logic, in which the truth condition of "either/or" does not negate the "and" condition; in other words, "either/or" includes "and." But this esoteric field in academe does little to illuminate the "conflict between two human ways of being" (Vickers).

One alternative to a dichotomy is found in the circle of life (the medicine wheel) adhered to by many (but not necessarily all) Indigenous nations of Turtle Island (Battiste 2000; Cajete 2000). The four directions of the circle of life represent the reality of the universe signifying how everything is interconnected ("all my relations"). For instance, coming to knowing nature by all humankind might be categorized by east, south, west, and north. As non-Indigenous authors we shall not conjecture further detail to this scheme; instead we cite a Cree community-based teaching unit "Iyiniw Maskikiy (Nature's Hidden Gifts)" as one example of the circle of life serving as an alternative to a dichotomy (Aikenhead 2000).

In our project to move away from the *singular*, hegemonic, stereotypic way of knowing nature conventionally called "science" to *pluralist* ways of knowing nature, we are indebted to Vickers for bringing Feynman's definition of "science" to the Forum. We think it parallels and clarifies the definition we offered. In our article that promotes pluralist ways of knowing nature, we felt it was incumbent upon us to present what we consider to be initial categories/metaphors. Readers were offered similarities and differences from our reasoned perspective. During contemplation and/or dialogue over these categories/metaphors, readers engage in coming to knowing; and as a result, we hope, readers will attain

their own insights of value. In doing so, readers will transform our initial categories/metaphors into others that seem more fruitful to them, as Brandt and van Eijck have done. We think that this type of transformation helps explain the heterogeneity and apparent contradiction of ideas within the community of postcolonial scholars. For example, Deyhle (1998, p. 10, as quoted in Brandt) and Battiste (2000, p. 202) offer what appear to be two very different metaphors, "living in one complex and conflictual world" and "creating a balance between two worldviews" (respectively), which we do not consider dichotomous. They may even be equivalent, once their surrounding meanings (Kawasaki 1996) are articulated and negotiated through dialogue. People do make sense out of what initially may seem to be dichotomous rigid camps (e.g., Indigenous ways of living in nature and Eurocentric sciences). We wish to discuss two closely related points about this issue.

First, we differentiate between, on the one hand, *initial* categories/metaphors that attempt to clarify epistemological, ontological, and axiological aspects of cultural landscapes; and on the other hand, categories/metaphors that *emerge* from coming to knowing (e.g., as a result of engaging in a camping spot dialogue). Brandt's in-depth research provides excellent evidence for the latter phenomenon. In a parallel sense, a curriculum enacted with students may be organized initially according to similarities and differences between two ways of knowing nature, but students nevertheless will make their own sense out of any perceived culture clash through their coming to knowing. Their own sense might reflect Deyhle's position, Battiste's position, or any number of other positions. We believe in the autonomy of learners (their intellectual independence, if you will). In summary, different contexts of use (e.g., how to describe? what to teach? how people actually come to their knowing?) can cause different categories/metaphors to be used when one talks about pluralist ways of knowing nature. We see no conflict between, on the one hand, the various ways students actually make sense of what many initially perceive as culture clashes, and on the other hand, an account of those perceived clashes by people communicating with colleagues. Both sets of ways (and others) belong in the literature.

Second, we wish to examine more closely Brandt's point about ways students actually make sense of what many students initially perceive as culture clashes, even though this topic was beyond the explicit delimitation of our article. As a student, Indigenous scholar Olugbemiro Jegede went through the process of making sense out of his initial cultural clashes between Nigerian ways of living in nature and the British school science curriculum imported into his country. He watched and listened to how he and others made sense of these (according to them) two ways of knowing nature. Eventually, he formalized his thoughts into a "collateral learning theory" (Jegede 1995). Collateral learning involves two (or more) culturally conflicting schemata held simultaneously in long-term memory. It is steeped in a cognitive perspective on learning, rather than, for instance, an identity-formation perspective that scholars are exploring today (e.g., Brown et al. 2005). His model comprises a spectrum of variations in the degree to which conflicting cultural ideas interact with each other and the degree to which conflicts are consciously resolved. We shall only summarize the two ends of Jegede's collateral learning spectrum. At one end, the conflicting schemata do not interact at all ("parallel collateral learning"), and people draw upon one schema or another depending on the context. At the other end, conflicting schemata consciously interact, and people resolve the conflict in one way or another ("secured collateral learning"). Examples of different resolution strategies for secured collateral learning (and other types of collateral learning) are found in Aikenhead and Jegede (1999). Even though Deyhle (1998) and Brandt assume a more sophisticated view of learning than Jegede, their descriptions seem to nicely illustrate secured collateral learning ("living in one complex and conflictual world" and "simultaneously embrace

elements of Eurocentric sciences and Indigenous [ways of living in nature]," respectively). These two descriptions represent a portion of the diversity in students' coming to knowing identified by Jegede's collateral learning theory.

We perceive at least two different contexts in the discussion above: a *description* of pluralist cultural ways of knowing nature (our article), and how individuals *come to understand* these ways (Brandt's commentary and Jegede's collateral learning theory). We see no conflict between the two contexts. Moreover, we encourage researchers to follow Brandt's productive and promising research program: to find out how different students come to define common ground (Brandt); to find out how different students create their balance between these two worlds (Battiste 2000); to find out how different students come to live in one complex and conflictual world (Deyhle 1998); or/and to find out how different students make border crossings smoother (Aikenhead and Jegede 1999). These four metaphors might take on very similar meanings if researchers dialogically discussed them; or alternatively, the metaphors may be associated with different contexts of use. The list of metaphors should expand, we think.

Our final "What can we learn?" arises from Vickers's well founded commentary. An academic article in an international journal does not comprise a camping spot for dialogue; an article can only address some of the issues that likely surface in such a dialogue. In our article, for instance, we define "Indigenous" in terms of the colonial violent oppression Vickers describes, and we quote copiously from Indigenous scholars who discussed various ways that respectful relationships entail responsibilities. These are two of the messages we heard in Vickers's commentary. However, articles in international journals do not, for instance, allow for gift offerings that express respect and represent the type of relationships of which she speaks. Without full participation in the protocols of an Indigenous community, we fall short in authenticity to help resolve conflict through dialogue at a camping spot.

We mention one academic sight that may come close to meeting Vickers's criteria. The project "Forests for the Future" occurred in Vickers's Ts'msyen territory where a community-based research and development project was undertaken collaboratively by the Gitxaala nation and diverse researchers at the University of British Columbia. A complete issue of the *Canadian Journal of Native Education* was devoted to this immense project (2004, vol. 28, issue 1/2). The project, in part, developed a school science curriculum also entitled *Forests for the Future*, which conveyed a central theme (Ignas 2004, p. 53): "the recognition of the many different ways that people create meaning." According to Veronica Ignas, the curriculum addresses many of the ideas featured in Vickers's commentary. For instance, the teaching materials are based on ancestral practice, and they explore "the *common* themes that emerge in the way that Indigenous Knowledge and scientific knowledge are acquired and communicated" (p. 54, emphasis added). Unit I, "Two Ways of Knowing: Traditional Ecological Knowledge and Scientific Knowledge," presents a table that compares the two so-called "knowledge systems" in two columns. We would have benefited greatly from reading Vickers's perspective on *Forests for the Future*, but this was not the purpose of her commentary.

A purpose of her commentary was to "transform oppression and add ancestral practice in the quest for knowledge" by incorporating guiding principles of the ayaawx into science education. Vickers is not alone. For instance, the Federation of Saskatchewan Indian Nations (FSIN) organized an elder's group to establish an ideology and collective worldview for teaching students about nature. These guiding principles are found in *Practising the Law of Circular Interaction* (Saskatchewan Indian Cultural Centre 1993), a publication that provides a clear vision for curriculum negotiation and nurtures a holistic continuity between Indigenous students' everyday life and their science classrooms.

Curriculum negotiations are currently underway in a partially federal funded, province-wide project, Indigenous Knowledge in the School Science Curriculum (Aikenhead 2006). As far away as South Africa, Cliff Malcolm (2007) proposed that guiding principles captured by *ubuntu* (a Zulu term that refers to a universe of interrelationships among everything, and that gives special roles to ancestors and spirits; "we are, therefore I am") should be used to blur categories [African thought and science] by "looking for relationships between [categories] – and taking account of context – [rather] than by setting one [category] up against the other" (p. 65). Vickers's purpose concerning ancestral practice is shared worldwide. We think we celebrated (in part) the addition of ancestral practice to the quest for knowledge, for instance, in our distinction between "knowledge" and "wisdom" and in our expression "wisdom-in-action."

We are most thankful to the Forum participants for crafting three very different commentaries on our article. Readers will benefit greatly from considering these academic critiques. We are consistently reminded that even the act (itself) of publishing in an English international journal can be construed by others as an act of promoting Eurocentric essentialism, in spite of the opposite messages in an article or commentary. The fact that Vickers was required to write in English, rather than in her Indigenous language, already compromises her wish to write from the center of her Indigenous world.

References

Aikenhead, G. S. (2000). *Rekindling traditions: Cross-cultural science & technology units*. Retrieved June 23, 2007, from http://www.usask.ca/education/ccstu/.

Aikenhead, G. S. (2006). Towards decolonizing the pan-Canadian science framework. *Canadian Journal of Science, Mathematics and Technology Education, 6*, 387–399.

Aikenhead, G. S., & Jegede, O. J. (1999). Cross-cultural science education: A cognitive explanation of a cultural phenomenon. *Journal of Research in Science Teaching, 36*, 269–287.

Battiste, M. (Ed.). (2000). *Reclaiming Indigenous voice and vision*. Vancouver, Canada: University of British Columbia Press.

Brown, B. A., Reveles, J. M., & Kelly, G. J. (2005). Scientific literacy and discursive identity: A theoretical framework for understanding science education. *Science Education, 89*, 779–802.

Cajete, G. A. (2000). *Native science: Natural laws of interdependence*. Santa Fe, NM: Clear Light.

Deyhle, D. (1998). From break dancing to heavy metal: Navajo youth and identity. *Youth & Society, 30*(1), 3–31.

Ignas, V. (2004). Opening doors to the future: Applying local knowledge in curriculum development. *Canadian Journal of Native Education, 28*, 49–60.

Jegede, O. J. (1995). Collateral learning and the eco-cultural paradigm in science and mathematics education in Africa. *Studies in Science Education, 25*, 97–137.

Kawasaki, K. (1996). The concepts of science in Japanese and Western education. *Science & Education, 5*, 1–20.

Malcolm, C. (2007). The value of science in African cultures. In D. Corrigan, J. Dillon, & R. Gunstone (Eds.), *The re-emergence of values in science education* (pp. 61–76). Rotterdam: Sense Publishers.

Saskatchewan Indian Cultural Centre. (1993). *Practising the law of circular interaction*. Saskatoon, Canada: Author.

Semali, L. M., & Kincheloe, J. L. (1999). Introduction: What is indigenous knowledge and why should we study it? In L. M. Semali & J. L. Kincheloe (Eds.), *What is indigenous knowledge? Voices from the academy* (pp. 1–57). New York: Falmer Press.

Glen Aikenhead is professor emeritus, Aboriginal Education Research Centre, University of Saskatchewan, Canada. His research and development projects over the years have emphasized relevance of school

science for students' everyday lives. During the past 15 years his work has focused on a cross-cultural perspective, particularly with Indigenous communities worldwide. Currently he is involved in the integration of policy, research, practice, and politics of science education for the recognition of Indigenous ways of knowing in Saskatchewan.

Masakata Ogawa is professor of science and technology education at the Graduate School of Human Development and Environment, Kobe University, Japan. His recent research interests lie in cultural contexts of science and science education (especially in Japan), as well as in science education policy studies. His major publications include "Science Education in a Multiscience Perspective" (1995) and "Reform Japanese Style: Voyage into an Unknown and Chaotic Future" (2001). He was a contributing editor of *Science Education*, and is a member of several editorial boards: *Cultural Studies of Science Education*, *Studies in Science Education*, and *Canadian Journal of Science, Technology and Mathematics Education*. He currently serves as the president of the Japan Society for Science Education.