How might Native Science inform "Informal Science Learning"?

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To address the Informal Science Learning for Indigenous communities raises a number of issues. What is "informal" and how does this notion influence the everyday lived lives of Indigenous peoples? Can we separate the informal from the formal, and is the nexus of the two a productive place from which to explore, teach, and pursue science in Indigenous communities? This commissioned paper attempts to begin addressing these questions. In so doing, our hope is to outline a number of definitions of Native Science and to demonstrate the ways that it is both similar and dissimilar to western notions of science. In the process, we hope to trouble the binary between western and Indigenous forms of science, between formal and informal, and to point to the issues around contextualized knowledges when considering notions of Western Science. We will also address issues of what works in regard to teaching and thinking about science in Indigenous communities and consider the implications for what we have outlined here.

Our intention is not to be antagonistic to the aims of our commission; rather, we want to more closely examine the ways that the location of the collision between Indigenous and western notions of science may be informative for thinking about the use and implementation of science in Indigenous communities. If we consider the fact that Indigenous peoples in the Americas created toboggans to carry the heavy carcasses of deer and caribou, kayaks and canoes that were river and sea worthy, snow shoes, and snow goggles; domesticated a wide range of plants including corn, potatoes, squash, beans, and peanuts; built architectural masterpieces in which they lived and ovens in which they cooked; used petroleum to create rubber and stars to successfully navigate the continent; and found ways to dry meat for storage and future usage, it

becomes evident that Indigenous peoples have been scientist and inventors of scientific ideas for a long while. Our point here is that while an "informal" body of science, defined by the LSIE as "emphasizing certain aspects of science *other than* a codified body of knowledge—scientific practice, puzzling over observations and phenomena, etc." (Emphasis in the original, in "General assumptions of the paper's content and process", p. 1), we want to point out that some of the ways that Indigenous peoples have conducted science includes these notions of "science," but have happened outside of a school and a laboratory. Indeed, many Indigenous peoples would argue that their laboratory is the world and that their survival rested on puzzling over observations and phenomena and coming to make sense of them in ways that allowed them to survive.

In the following pages, we will offer an overview of science education for Indigenous youth, trouble binaries between western and Indigenous sciences and epistemologies, and point to what we know works in teaching Indigenous sciences, before ending with the issues and implications and future directions for research. First, however, we will provide a brief review of the literature on culturally responsive schooling (CRS) for Indigenous youth in order to orient the reader to this larger body of work and to highlight how the commission's interest in Native Science is closely linked to conversations occurring in other curricular areas as well.

It is important to keep in mind throughout this discussion that there is not one Native culture. There are, in fact, over 500 different tribal nations in the United States alone, each with a unique history, language, and culture. There is a tendency in the U.S. to essentialize tribal cultures, and we fear that some of the scholarship on Native Science falls prey to this trend. We recognize, as do many scholars, that there are some similarities in the epistemologies and ontologies of culturally different tribal peoples, but we want to be clear that we do not mean to

imply a single or unified "Native Science" or "Native epistemology" that necessarily characterizes all tribal nations and all Indigenous people. Nevertheless, we will share what the scholarship has to say about Native Science and its relation to Western Science.

Culturally responsive schooling for Indigenous youth:

Culturally responsive schooling is certainly not a new phenomenon or a passing fad; instead it has been central to tribal nations' calls for improved schooling since at least the early part of the twentieth century. Culturally responsive schooling is widely viewed as a promising strategy for improving the education and increasing the academic achievement of Native students in U.S. schools. Coming largely out of the cultural difference literature, culturally responsive schooling assumes that a "firm grounding in the heritage language and culture indigenous to a particular tribe is a fundamental prerequisite for the development of culturally-healthy students and communities associated with that place, and thus is an essential ingredient for identifying the appropriate qualities and practices associated with culturally-responsive educators, curriculum, and schools" (Alaska Native Knowledge Network, 1998: no page (online)). This educational approach requires a shift in teaching methods, curricular materials, teacher dispositions, and school-community relations.

The literature on culturally responsive schooling for Indigenous youth is a substantial and still growing body of scholarship. It also comes out of other, even broader, bodies of literature on multicultural education, cultural difference, and improving the academic achievement of youth who are not members of the dominant cultural group in the United States. One of the most general but direct definitions provided is that culturally responsive schooling is that which "makes sense" to students who are not members of, or assimilated into, the dominant social group (Klug & Whitfield, 2003: pg. 151). In a similar vein, CRS has also been described as that

which "builds a bridge" between a child's home culture and the school in order to effect improved learning and school achievement (Pewewardy & Hammer, 2003: pg. 1). In general, what we learn from all of the definitions, lists, and summaries is that culturally responsive schooling entails a number of important elements that relate to curriculum, pedagogy, school policy, student expectations, standards, assessment, teacher knowledge, community involvement, and many more. Three topics that are rarely included in discussions of culturally responsive schooling are sovereignty, racism, and epistemologies. We suggest that any discussion of culturally responsive schooling for Indigenous youth must take into account issues of sovereignty and racism, as well as the worldviews and epistemologies of Indigenous people and tribal communities.

A number of reasons are cited in the scholarship as to why educators should engage in culturally responsive schooling for Indigenous youth. These reasons are essentially about first, what students come to school with, and second, what we want students to leave school with. Culturally responsive schooling is seen by many scholars as necessary because Indigenous students come to school with different learning styles and cultural practices that result in incongruity between teaching and learning. The learning styles and cultural differences of Indigenous youth and tribal communities are perhaps the two most common themes addressed in the literature on culturally responsive schooling for Native students. It is important to note, however, that these two emphases place the focus of the "problem" on Indigenous people rather than on schools or educators. Culturally responsive schooling is also viewed by many scholars are necessary because its goal is to produce students who are bicultural and thus knowledgeable about and competent in both mainstream society and tribal societies.

In general, scholars have found that efforts at CRS for Indigenous youth result in students who have enhanced self-esteem (Agbo, 2004; Cleary & Peacock, 1998), develop healthy identity formation (Trujillo, Viri, & Figueira, 2002), are more self-directed and politically active (Garcia & Ahler, 1992), give more respect to tribal elders (Agbo, 2004), have a positive influence in their tribal communities (Cleary & Peacock, 1998; Department of Education, 2001; Pewewardy, 1998), exhibit more positive classroom behavior and engagement (Cleary & Peacock, 1998; Lipka, 1990), and achieve academically at higher rates (Apthorp, D'Amato, & Richardson, 2002; Demmert, 2001; Demmert & Towner, 2003; Klump & McNeir, 2005; D. Smith, Leake, & Kamekona, 1998; Swisher & Tippeconnic, 1999; Taylor, Stevens, Peregoy, & Bath, 1991; Zwick & Miller, 1996). A smaller body of scholarship points to the importance of recognizing all voices in the classroom and ensuring that Indigenous students are not silenced in the schooling process (Belgarde, Mitchell, & Arquero, 2002), which in turn leads to more meaningful educational experiences and student empowerment (Gay, 2000; Nieto, 2004; Reyhner, 1992).

None of the scholarship on culturally responsive schooling indicates that Indigenous youth should learn tribal cultures and languages at the expense of learning mainstream culture and the typical "academic" subjects generally taught in schools. This is an important point because the shared assumption by most scholars, parents, and educational leaders is that schools should facilitate the acquisition of all of these knowledges and skills—what we might call a both/and approach rather than an either/or approach. What this amounts to is the need and desire for Indigenous youth to become bicultural and the important role of the school in facilitating that process. This is perhaps the most fundamental goal of culturally responsive schooling addressed in the literature. When teachers, curricula, and schools provide a challenging and high quality education that is intimately connected and relevant to tribal communities, they will be far more

likely to graduate youth who are academically prepared, connected to and active members of their tribal communities, and knowledgeable about both the dominant and their home cultures.

Two aspects of schooling that have a significant and direct impact on students are pedagogy and curriculum. Accordingly, a significant amount of the literature on culturally responsive schooling focuses on pedagogical techniques and curricular materials teachers can use in their classrooms with Indigenous youth. With all curricular material, teachers must become diligent reviewers of the texts they are given to use in their classrooms. While curricular and pedagogical issues are certainly important for an understanding of culturally responsive schooling for Indigenous students, there are a number of teacher characteristics that are also necessary in order for CRS to be made a reality. Teachers must possess a particular set of dispositions, attitudes, values, and knowledges in order to be successful with Native students. An unfortunate reality of American Indian education is that the vast majority of teachers lack much of the necessary knowledge to provide an effective, high quality, and culturally responsive education to Indigenous youth (Agbo, 2001, 2004; Belgarde et al., 2002). The most obvious, but also most lacking, knowledge among teachers is an awareness and understanding of Indigenous cultures, histories, and political issues. In addition, teachers must know the community in which the school is situated, interact with community members, and support community agendas. On the other hand, members of the community must also be invited and welcomed into the school and be given plenty of authentic opportunities to connect with the school and the work of educators in the school.

A number of scholars have noted the limited nature of conclusive evidence supporting culturally responsive schooling for Indigenous youth. There is a plethora of scholarship consisting of case studies, program descriptions, and anecdotal calls for CRS, but the causal links

in this work are weak and very few studies make strong claims about how students' academic performance is impacted by efforts at culturally responsive schooling (Apthorp et al., 2002; Demmert, 2001; Demmert & Towner, 2003; Klump & McNeir, 2005; Lipka, 2002; Powers, 2006; Yazzie, 1999). Despite the nature of the scholarship, all of the recent reviews agree with the conclusion that "congruency between the school environment and the language and culture of the community is critical to the success of formal learning" (Demmert, 2001: pg. 9).

Our point in sharing this brief overview on culturally responsive schooling for Indigenou youth is to draw attention to the parallels that exist between schools and other "informal" learning contexts serving Indigenous youth. Just as schools are cultural sites, so too are other locations in which education occurs. The argument that schools must adapt in order to provide more culturally relevant, and thus effective, education to Indigenous youth is supported by a substantial body of scholarship. We suggest that this same argument be at the center of conversations about "informal science learning."

Defining the problem:

An understanding of science education for Indigenous youth is important for a number of reasons. Studies have shown that Indigenous students perform lower on standardized measures of science achievement than their peers, that there is inadequate science instruction in most elementary schools and especially those serving students of color and children from low-income and rural areas, that many Native youth avoid science by the time they reach middle school, that many older Indigenous students are counseled away from science courses, and that learning science can be especially challenging because of the specialized language involved (G. Allen & Seumptewa, 1993; Cajete, 1988; MacIvor, 1995; Snively, 1995). Awareness of the need to

improve science education for Indigenous students is not new; according to Ovando (1992), the American Association for the Advancement of Science issued a number of recommendations in 1976 for improving science teaching and learning for Native youth. These recommendations included using an ethnoscientific approach to teaching science and using a bilingual approach in particular contexts. While the use of ethnoscience and language issues are still an important part of this discussion and will be addressed in this paper, we will add a number of other themes and issues that must be considered. We are particularly interested in the concept of a Native or Indigenous Science, its relation to Western Science, and what it might add to the knowledge base of culturally responsive science education for Indigenous youth. We agree with Nelson-Barber and Estrin (1995) about the centrality of the following considerations:

> In considering what would constitute a curriculum and an approach to instruction that is valid for a given cultural group, we must first consider the customary ways of knowing and acquiring knowledge of that group. We are faced with essential epistemological questions such as, "What counts as important knowledge or knowing?," "What counts as evidence for claiming something to be true?," and "How and when should knowledge or understanding be expressed or shared?"…A blanket approach to students that fails to take sociocultural factors into consideration is not likely to succeed in reaching all students. (pg. 22)

Thus, we will suggest that epistemological concerns and sociocultural factors must be central to the discussion of Native/Indigenous Science and to efforts to provide a more culturally responsive science education to Indigenous students.

In the next two sections we discuss relevant definitions and the assumed superiority of Western Science over Native Science. A discussion of definitions and the hegemony of Western Science is related to and necessary for this larger discussion on informal science learning for a number of reasons. Simply taking the dominant conceptions of Western Science out of the "formal" classroom and into more "informal" settings will have little impact on Indigenous students if the same assumptions about the nature of science are maintained. Scholars have suggested that part of the reason Indigenous students have consistently underperformed in science classrooms is because of science's lack of relevance to their lives, its presumed superiority over other epistemologies, and the resulting cultural conflict that ensues for many students. These problems can be easily replicated in informal science learning. By providing a discussion on these issues, we hope to illustrate why the formal-informal distinction may actually be less important than issues of epistemology and sociocultural issues if the primary goal is more effective science education for Indigenous students.

Definitions:

Garrison (1995) frames science as a "way of knowing" and a "certain style of thinking and a certain way of asking questions and finding out answers" (pg. 4). Central to mainstream Western Science is the Scientific Method and the assumption that we can learn about the world around us through observation and experimentation of hypotheses. The goal is to develop new hypotheses that provide more comprehensive and more accurate explanations of data. Garrison (1995) argues that science ought to be thought about as "a tool" that "helps in understanding and communicating information" and that all students benefit from having the facility of multiple tools from which to choose (pg. 4).

> A Navajo student who is informed about Navajo ways of understanding the world (and the universe in general) has more than one explanation for things. To put this another way: a Navajo student who knows his or her cultural knowledge, in addition to Western cultural/scientific knowledge, already has an advanced foundation for the development of the highest level of scientific thinking, i.e., hypothesis-building, or, perhaps even more important, alternative hypothesis-building. (Garrison, 1995: pg. 5)

In a similar vein, Garroutte (1999) argues that science is characterized by the study of things "which impinge on the wakeful senses from the physical world" (pg. 92), that value is placed on evidence that can be repeatedly observed and on general principles and laws, that prediction is expected, and that words and people are separate from that which they observe and describe. Indeed, science appears to assume one truth arrived at through empirical observation and application of appropriate methods to address the hypothesis. This one truth is generalizable and the methods and process used to reach the truth can be replicated in order to prove the universal truth.

In contrast, a Native or Indigenous Science allows the possibility that there are multiple ways of obtaining knowledge. Snively and Corsiglia (2001) note, "Ogawa proposes that every culture has its own science and refers to the science in a given culture as its "Indigenous Science" (Ogawa, 1995: pg. 585)" (Snively & Corsiglia, 2001: pg. 7). This concept of an Indigenous science recognizes the role of culture, subjectivity, and perspective in making sense of the world, and it draws attention to the notion that we all interpret reality through a particular cultural lens. Baker (1996) also talks about the concept of an Indigenous Science, but his discussion implies a deficit view of indigenous science as compared to Western Science.

According to Baker (1996), "indigenous science differs from 'western' science in its method and rigor, but not in its essential nature" (pg. 18). Baker goes on to say that Indigenous Science employs a more "informal" method, which conveys the sense that perhaps it isn't as advanced or legitimate as Western Science. It is important, from our perspective, that we be careful about how we use words like "informal" and how we make judgments about the method and rigor of various ways of knowing.

Baker does offer a helpful discussion about the various perspectives on whether an Indigenous Science even exists. In his words:

> If you were to explore the question of indigenous science among colleagues, or within published literature, I suggest that you would find variations of three major views. The first is shaped by the logical empiricism that is usually identified with scientific inquiry. This view requires verifiable evidence in order to support any knowledge claim, so it usually rejects the notion that science can exist outside of the scientific community. Examples of this view can be found in the writings of Good (1995) and Williams (1994), who, while happy to respect the values of indigenous people, deny that an indigenous science can exist separate from what is often called 'western' or 'modern' science...The second view is expressed by supporters of multicultural science, including many from within indigenous communities…[This view] supports the notion of a distinctive indigenous science and its ability to inform indigenous people, and to enrich 'Western Science' (Deloria, 1992). Other researchers in this field include Stanley and Brickhouse (1994), and Dennick (1992)…A third

> view is the socio-cultural perspective as expressed by Christie (1991), and its derivative, worldview theory, as expressed by Bill Cobern, who has conducted excellent research on the effect of worldview in science education. Cobern does not consider that separate indigenous sciences exist, but rather, that different worldviews interpret 'reality' in different ways (see Cobern, 1994). (Baker, 1996: pg. 18)

We believe it is necessary to trouble the characterizations offered by Baker above. Consider Nobel Prize winning physicist P. W. Bridgeman's argument that "there is no scientific method as such" (Dalton 1967 as cited in Bogdan & Biklen, 2007). He continued by stating "many eminent physicists, chemists, and mathematicians question whether there is a reproducible method that all investigators could or should follow, and they have shown in their research to take diverse, and often unascertainable steps in discovering and solving problems" (Dalton 1967 as cited in Bogdan & Biklen, 2007: pg. 41). Similarly, consider MikMac scholar Marie Battiste's (2002) characterization of Indigenous knowledge systems as: "a knowledge system in its own right with its own internal consistency and ways of knowing, and there are limits to how far it can be comprehended from a Eurocentric point of view" (2002: pg. 2). She goes on to argue that Indigenous knowledge systems' characterizations by some western thought are also problematic when she writes, "Eurocentric thinkers dismissed Indigenous knowledge in the same way they dismissed any socio-political cultural life they did not understand: they found it to be unsystematic and incapable of meeting the productivity needs of the modern world" (pg. 5). Finally, Maori scholar Linda Smith (1999) wrote this in her book: "[u]nderpinning all of what is taught at universities is the belief in the concept of science as the all-embracing method for gaining an understanding of the world" (pg. 65). Our point here is not to dismiss the Western

or formal sense of science; rather, it is to demonstrate that many Indigenous peoples have recently questioned the superiority of Western Science.

Differences between Western and Native Science:

There are a number of differences between Western Science and what we will call Native Science. Here again, we want to remind the reader to be cautious of essentializing this discussion to assume that there is one, single, unified "Native Science." Different tribal nations and individuals within those communities may have very different understandings of this topic.

According to Ollerenshaw and Lyons (2002), science has never been something to study for Indigenous people; instead, science "was life" and what we would call science education was meant to ensure the survival of a people (pg. 20). This historical difference is important because it draws attention to different goals and purposes of science; it also draws attention to the sociocultural context of science and science education. Whereas Western Science presumes that the physical world is knowable and that we obtain this knowledge through observation, Native Science presumes that knowledge can be received through various means and that the physical world is mysterious and intimately connected to the spiritual (Aikenhead, 1996; Deloria, 1992; Garroutte, 1999). Though observation is valued highly within many tribal cultures, observation is not regarded as the only way to learn about one's surroundings (Kawagley, Norris-Tull, & Norris-Tull, 1998). Native Science also does not separate the observer from the observed as is necessary for the presumed objectivity of Western Science, and the presumed universalism of Western Science is also neither valued nor sought after in Native Science (Nelson-Barber & Estrin, 1995). Unlike Western Science, Native Science does not attempt to generalize observations to universal laws or to combine observations in order to make predictions about nature. Furthermore, Native Science is more likely to see individuals as parts of a community—

a community which includes a particular culture, history, place, and time (Nelson-Barber & Estrin, 1995). Some scholars suggest that this lack of attention to community stems from the failure of Western Science to recognize the fifth element of spirit within the universe. For example, Kawagley (1998) has found that within the Yupiak culture, science is not separated from daily life, that there are no words in their native language to describe many of the objective and technomechanistic concepts that are central to Western Science, and that Yupiak science is not segregated from other realms of knowledge nor subdivided into various categories the way Western Science is. Along these same lines, MacIvor (1995) notes, "Aboriginal peoples' knowledge of the natural world and their religious traditions are so closely interwoven that Vine Deloria suggests we speak of metaphysics rather than of science or religion" (pg. 75). Although some scholars have suggested that this more holistic and interconnected science of Native people is equivalent to the Western Science of ecology (Pierotti & Wildcat, 1997), this does not change the fact that it is quite different from conceptions of Western Science as a whole. Indeed, according to Cobern and Aikenhead (1998), "Native Americans traditionally analyze nature rationally and empirically, but their rationalism and empiricism are guided by spirituality, holism, mystery and survival (Battiste & Barman, 1995; Knudtson & Suzuki, 1992). This disparity between Native American cultures and Western Science creates *hazardous* or *impossible* border crossings for Native American students" (pg. 44). The chart below highlights some of our stated differences between Indigenous/Native Science and Western Science models.

Differences between Indigenous/Native Science and Western Science:

Indigenous/Native Science	**Western Science**
A component of life	As a field of study
Physical world is a mystery	Physical world is knowable
Knowledge gained through both empirical and spiritual realms	Knowledge gained through observation
Subjectivity tied with interactions with	Presumed objectivity

place and space	
Knowledge and science are contextualized	Presumed universalism/generalizability
Exploration of experiences and phenomena occurring in the real world and examination of recurring patterns	Hypothesis and prediction oriented
Five elements: water, fire, earth, air, spirituality	Four elements: water, fire, earth, and air

These differences between Western and Native Science often lead to what Harris (1978) calls "conceptual interference" for Indigenous students. When two different systems of knowledge, ways of knowing, or epistemologies interact, it can be difficult to make sense of the resulting conflict. This conflict cannot be overstated for some students and within some communities given the very different natures of Western and Native Science and the very different goals associated with each (Aikenhead, 1996). Haukoos and LeBeau (1992) relate this to science education and note why these differences are significant:

> While changes have been occurring in science and science teaching, there are few reports that actually demonstrate the integration of science and culture into local culture and curricula. For example, science is still taught in most American Indian community schools using the conformity and assimilation strategies from the turn of the century. Yet, American Indian cultures do not accept the separation of science from other aspects of their life as do most Anglo-Americans. In fact, there is no word in any traditional American Indian language that can be translated to mean science as it might be defined by Western culture (Cajete, 1986). Yet, expressions of science thinking are abundant throughout traditional American Indian agriculture, astronomy, ecology, and medical practices. In addition, processes of science which include rational observation of

> natural events, classification, and problem solving are woven into all aspects of American Indian culture (Cajete, 1986). (pg. 2)

Benally (1988) provides an illustrative example from the Navajo Nation. He explains that whereas the Navajo focus is on preparing students to reach a state of *hozho* (which is a balanced life in harmony with everything around you), the lack of connectedness and fragmentation of Western Science works against *hozho*. Thus, it is easy to see how Native Science and Indigenous epistemologies are in conflict with and distorted by Western Science within schools (Aikenhead, 2001; Cajete, 1999). These conflicts and distortions help explain why some Indigenous students may avoid Western Science or reject the claims of Western Science altogether—outcomes which must be addressed by science educators (Aikenhead & Jegese, 1999; Snively, 1995).

It appears fairly common in the science education literature for epistemologies to be conceptualized as either right or wrong. In other words, there is a common assumption that there is an epistemological stance for science and when students' epistemologies match that of science, then they learn science more easily. But when students have "misconceptions" or "misbeliefs" or epistemologies that are "naïve," "counterproductive," or "unsophisticated," then they don't learn science as well. We believe that it is important to point out that the general tendency to see epistemologies as either right or wrong rests on an assumption of the epistemic privilege of Western Science. An alternative perspective is that students' epistemologies are contextualized and shift depending on the circumstances, and that teachers must come to see student epistemologies as resources from which to draw in order to teach science more effectively—what some scholars have called a "resources-based view" of epistemology (Hammer & Elby, 2003; Rosenberg, Hammer, & Phelan, 2006; Sandoval, 2005).

Hegemony of Western Science:

Related to the definitions of science and Native or Indigenous Science is the notion of the hegemony of Western Science. Because science occupies such a revered place for most Americans, it can be difficult to validate any other ways of knowing with the same legitimacy. There is, in fact, a tendency to "accept as true all scientific ideas and research" and to judge other ideas and research by the same standards and values (Snively, 1995: pg. 55). But this assumed superiority of Western Science limits the context of discovery and the range of ideas that are considered (Cobern, 1996). Importantly, the culture of science "permeates the culture of those who engage it" and "this acculturation can threaten Indigenous cultures" (Aikenhead, 1996: pg. 15). Scholars have found that science teachers also possess this strong allegiance to Western Science and the values and standards associated with Western Science (Aikenhead, 1985, 2001; Brickhouse, 1990; Gallagher, 1991; Gaskell, 1992)—thus making it likely that students in science classes are subject to this very limited view of what counts as science and legitimate knowledge. Indeed, "most of us do not even realize, when we think as the science classroom has taught us to think, that we are proceeding according to a particular set of assumptions at all" (Garroutte, 1999: pg. 103). Aside from the limited perspective this presents to students, the hegemony of Western Science is also problematic because it fails to consider the sociocultural environments in which students and communities live, it presents scientific knowledge as objective and universal, and thus fails to recognize that scientific knowledge is itself socially constructed (Cajete, 1999; Nelson-Barber & Estrin, 1995). This presumed objectivity and universalism of Western Science rationalizes our failure to acknowledge other ways of knowing. And, as Snively and Corsiglia (2001) have pointed out, "many scientists and science educators

continue to view the contributions of Indigenous science as 'useful,' but outside the realm of 'real science'" (pg. 15).

Rather than replicate the hegemony of science in informal learning contexts, we must come to see that there are multiple ***legitimate*** ways of knowing that must enter the science "classroom." The epistemologies and sciences of tribal nations have enabled them to survive for thousands of years, and this knowledge is relevant to contemporary science learning (Kawagley et al., 1998). Garroutte (1999), however, cautions us about simply inserting Indigenous knowledge and science into science educational contexts in which the presumed superiority of Western Science is unchallenged. When this occurs, the possibility of alternative worldviews and ways of knowing about the world that Indigenous or Native Science offers is no longer a ***viable*** alternative. Little parity between and among competing ideas can be achieved if the hegemony of Western Science is upheld. Simply inserting other knowledge does little to change the status accorded to various ways of knowing. Instead, teachers and students must be clear about the assumptions that are often made about valid scientific knowledge and that there are other ways of thinking about and engaging in science. MacIvor adds:

> The history of the colonization of the Americas has an important role in the science education of our children. Scientific and technological developments have served to benefit the few at the expense of many. Science education, through its avoidance of the social, political, and economic contexts in which science and technology are developed and applied, and through its promotion of the scientific and technological fix, sustains these inequities. Educators should question assumptions about

> who benefits and who suffers from scientific and technological development. (MacIvor, 1995: pg. 82-83)

As we noted above, the discussion about a Native or Indigenous Science is part of a much larger discussion and body of scholarship on culturally responsive schooling for Indigenous youth. Given the persistently low achievement of Native students in schools, a number of educators and scholars have argued for a more culturally responsive approach. It is generally argued that, regardless of curricular area, when pedagogy and curricula are more aligned with students' cultural norms, experiences, and worldviews, that interest in school and achievement levels improve. A number of scholars writing about science education for Indigenous youth concur with these conclusions (Aikenhead & Huntley, 1997; Nelson-Barber & Estrin, 1995). The work of these scholars, and those in the field of multicultural education broadly speaking, suggests that culturally responsive educational approaches are effective not only because they make schooling for relevant for kids from culturally different backgrounds, but also because they "humanize" school and "equalize" relationships within school (Bartolome, 1994; Nelson-Barber & Estrin, 1995). For Indigenous students this is particularly important because of the long history and current patterns of marginalization within U.S. schools.

Goals of science education:

Part of what needs to occur is a re-envisioning of the goals of science education. Scholars writing about Native or Indigenous Science argue that science education should, first and foremost, "encourage students to learn both Aboriginal and Western Science and technology in a way that empowers them to make everyday choices between (1) participating in a First Nations cultural setting, and (2) participating in a dominant…cultural setting" (Aikenhead, 1996: pg. 17). This has also been referred to as "multiscience" or "multicultural science" education,

and it emphasizes learning about what constitutes reality for various cultural groups, establishing communication about nature between and among competing perspectives, the role of science in different cultural contexts, establishing or maintaining a positive attitude towards both Western and other conceptions of science, acquiring an enlarged repertoire in the language of science, and understanding multiple and competing worldviews and epistemologies (Aikenhead, 1996, 1997a; Cajete, 1988, 1999; MacIvor, 1995; Snively & Corsiglia, 2001). Fleer (1997) poses the goal of this sort of science education well:

> For science, does the curriculum allow a range of world views to be expressed and valued or are they framed to be considered seriously only as alternative views to that of Western Science? Can we help children to understand how culture has framed and constructed our understandings? Moving between world views creates high level thinkers. We need actively to bring together the world views found in particular classrooms and early childhood centers. (pg. 17)

Thus, the goal of science education through a multicultural or culturally responsive lens is not only to connect science to Indigenous students' lives, but also to create better scientists and students with stronger critical thinking skills. These goals are shared by scholars and tribal community members alike. Kawagley (1998) and Martin (1995) have found that tribal elders from Yup'ik and Iroquoian communities want their youth to learn multiple worldviews and be able to operate within both the dominant and tribal communities. A further goal of science education ought to be to foster more positive attitudes towards science among Indigenous communities. Indeed, researchers have found that incorporating culturally responsive

approaches into science education results in these attitudinal changes, which also impacts academic achievement (Matthews & Smith, 1994; Ritchie & Butler, 1990).

Connected to these goals, however, is perhaps the most important goal of all. Science education cannot continue to operate under the assumption that all students must adopt the perspective of "scientists." As we have illustrated throughout this paper, mainstream science presents a number of differences and conflicts for some Indigenous students and tribal communities because of the assumptions, values, and hegemony it continues to perpetuate. Science learning, whether in "formal" or "informal" contexts, must aim to facilitate the learning of the culture of science without also facilitating the assimilation of students into that culture. This is not an easy task, but Snively (1995) suggests that it is possible:

> When I studied the effects of science instruction on both Native and non-Native students in a small coastal community in British Columbia (Snively, 1986, 1990), I found that it is possible to increase a student's understanding of marine science concepts without altering substantially his or her preferred spiritual orientation to the seashore. This is important. Educators need to know that it is possible to teach scientific concepts to Native students who hold a traditional spiritual view of the world without changing—in the sense of replacing—the students' preferred orientation. We can increase a student's scientific knowledge so that it can be utilized in appropriate situations. It makes sense to talk about increasing Native students' knowledge about science concepts so they can be successful in school, but we need to be careful about changing students' culturally grounded beliefs and values. (pg. 63)

A further goal of science education for Indigenous youth must be to assist in the goals of tribal communities' efforts towards economic development, environmental responsibility, cultural survival, and self-determination. Effectively exposing students to multiple worldviews without requiring the adoption of any particular one can aid in their acquisition of the skills needed to better serve their communities (Aikenhead, 1997a; Aikenhead & Huntley, 1997; J. Allen & Crawley, 1998; Cobern, 1996; Cobern & Aikenhead, 1998).

And finally, science education should aim to show its own limitations as much as it currently is critical of other ways of knowing (Snively, 1995). Students should come to know that all systems of knowledge are limited and fallible, and they should gain the skills to recognize such limitations in order to be critical consumers of knowledge. Aikenhead (1996) sums up these goals well:

> We should develop curriculum and instruction that: (1) make border crossings explicit for students, (2) facilitate these border crossings, (3) validate students personally and culturally constructed ways of knowing about nature, and (4) teach the knowledge, skills, and values of Western Science and technology in the context of societal roles (for example, social, political, military, economic, and ethical roles). Curriculum and instruction should be embedded in the everyday culture of Aboriginal students (where learning Aboriginal science and technology is simply enculturation), and students should be taught to appropriate Western Science and technology in order to further the goals of First Nations peoples. (pg. 18)

All of these goals presuppose, of course, that Indigenous students are learning what they need to effectively compete in the dominant society if they chose to do so. Unfortunately, it is easy to lose sight of this when the discussion revolves around cultural relevancy and competing worldviews. But Beck (2004) reminds us of this important consideration:

> If what the Navajo children are doing and being supported for doing in their classrooms, however pedagogically sound it may be, is not consistent with that found in Anglo classrooms, if it will not enable the Navajo children to perform well on Anglo constructed standardized tests, if it will not make it possible for them to eventually compete with the Anglo students for jobs or positions in colleges and universities, then Navajo learner friendly classrooms will not be serving the Navajo students well. (pg. 10)

Effective practice for science education:

It is important to recognize that science is itself a subculture of western culture, and that engaging in science education is thus a crosscultural event for many students (Aikenhead, 1998; Cobern & Aikenhead, 1998). Because of the differences discussed above, for many Indigenous students, learning Western Science requires crossing cultural borders and acquiring facility in another culture. Such cross-cultural experiences may present "cognitive conflicts" for students (Aikenhead & Jegese, 1999: pg. 271), and attempts to assimilate students into the culture of Western Science may lead to "alienation and an anti-science element" within Indigenous communities (Cobern & Aikenhead, 1998: pg. 41). Because of the potentially hazardous nature of these border crossings, scholars have recommended that science curricula be designed in culturally responsive ways and with practical, real-world application in mind (Aikenhead,

1997b). It is also recommended that teachers adopt the role of "cultural brokers" in which they identify the culture of their students, introduce Western Science as another cultural point of view, and maintain explicit and clear communication with students about which culture they are operating within and that multiple cultures have value (Aikenhead, 2001). This stance can be likened to Delpit's (1988; 1995) work in the field of multicultural education. Delpit argues that teachers must explicitly teach their students the norms and codes of the "culture of power" so that students who are not members of that culture obtain the necessary skills to negotiate the culture when they choose to do so. Recognizing Western Science as a particular culture—and indeed a culture with much power and prestige in the United States—we can see why this teaching strategy is important.

Thirty years ago, the American Association for the Advancement of Science noted that one of the primary obstacles to Indigenous people's participation in science was the lack of relevance of science to their lives. Since that time, "the knowledge, skills, and values found in the typical secondary science curriculum have been widely criticized throughout the world for being isolated and irrelevant to everyday events that affect economic development, environmental responsibility, and cultural survival (Knamiller, 1984; Layton, Jenkins, Macgill, & Davey, 1993; MacIvor, 1995; Simonelli, 1994; Swift, 1992)" (Aikenhead, 1997b: pg. 227). In response to these critiques, scholars have called for science education that has direct relevance to the lives of Indigenous students and tribal communities. Most scholars agree that to be most effective, curriculum needs to be connected and relevant to the local community rather than some perceive unitary Indigenous community (Aikenhead, 2001; G. Allen & Seumptewa, 1993; Cajete, 1988; Davison & Miller, 1998). Educators can work towards this goal by seeking advice from tribal elders and other community members, commissioning local people to develop or co-

develop curricular materials, and drawing on the local activities and resources in one's community. As Cobern (1996) notes, "as a science educator, I cannot help but think that there is something awry with the implicit argument that scientific literacy, which all people are said to need, is to be achieved by breaking with the everyday world in which people live and presumably where they will use their scientific literacy" (pg. 582). Starting with students' everyday lives might mean integrating their worldviews and epistemologies into the curriculum, drawing on ecological themes in science, using oral stories and elders in the classroom, employing more naturalistic observations of nature, using authentic assessments of student knowledge, and adapting the classroom to look and feel more like the local community (Kawagley et al., 1998). Importantly, this work cannot be achieved through relying on textbooks alone; teachers will need to cast a much wider net for learning materials (Ovando, 1992). MacIvor (1995) also recommends science activities that contribute to the local community; this approach not only makes learning more relevant for students, but it also facilitates greater relationships between educators and community members and empowers students to be active members of their communities. When science teachers make these connections and show students that science can be relevant to their lives, students are likely to be more engaged, eager to learn, and have more positive attitudes towards science (Ritchie & Butler, 1990).

Perhaps one of the most important questions in the discussion around effective science education for Indigenous youth is the following: "How can science teachers enable all students to study a Western scientific way of knowing and at the same time respect and access the ideas, beliefs, and values of non-Western cultures?" (Snively & Corsiglia, 2001: pg. 24). Snively and Corsiglia (2001) provide one answer by proposing that effective science teaching should aim not at convincing students to accept the validity or legitimacy of the scientific information, but rather

to help them understand the information and then consider the similarities and differences between the science information presented and their own epistemology and understanding of the world. In other words, science educators need to engage in pedagogy that presents science as one way of knowing. Cajete (1999) agrees and advises science educators to first introduce students to the basic skills of science through familiar objects and events, then compare with students the ways science is employed in the mainstream culture and in their own culture, and then look at various and competing explanations for natural phenomenon—all while not presenting any one way of knowing as superior. Such discussions about competing worldviews and epistemologies not only help students understand the nature of science, but also draw on their previous knowledge, spark their interest, and encourage critical thinking (Cajete, 1999; Harris, 1978; Snively, 1995; Snively & Corsiglia, 2001).

Other aspects of effective science education for Indigenous youth include learning in an environment that is rich with the language of science, curricular content that is interesting and relevant, beginning with the natural environment of the students, including elders and community members in curriculum development and presentation, incorporating oral traditions as a source of knowledge about the natural world, and supplementing textbooks with other curricular materials (Cajete, 1999; Harris, 1978; Kawagley, 1990; Snively, 1995; Sorensen, 2001). In addition, educational approaches that are holistic in nature, build on student strengths, ask students to participate in activities that are meaningful for the local community, engage students in cooperative learning activities, and make use of hands-on learning are also suggested to be effective with Indigenous students (J. Allen & Crawley, 1998; Butterfield, 1994; Nelson-Barber & Estrin, 1995; Ritchie & Butler, 1990; Ritchie & Kane, 1990). Research by Zwick and Miller (1996) indicates that Indigenous students achieve at higher rates on standardized science

tests when involved with educational programs that utilize these strategies. Garroutte (1999) cautions, however, that making relatively simple and straightforward adjustments to science curricula and pedagogy is not enough. In her words,

> Writers sharing the assumption of the basic sameness of Indian traditional and scientific thought tend to subscribe to the optimistic opinion that relatively straightforward solutions—the introduction of elders or special tutors into the science classroom, attention to issues of learning styles, the use of teaching materials featuring examples more familiar to Indian children, some tinkering with placement practices and presentation of material, more encouragement for students to study harder and more efficiently, concentration on environmental or technological issues of direct relevance to reservation communities, and the like—are the central means to achieve increased Indian participation and success in science. They will agree, more or less, to business as usual in the science classroom so long as selected items from traditional teachings or practices are permitted to coexist alongside accepted scientific dogma. (Garroutte, 1999: pg. 102)

Garroutte (1999) argues that those who advocate these sorts of changes assume that there are few differences between classroom science and Native Science.

An unfortunate finding in the scholarship is that many science teachers ignore the cultural backgrounds of students and the influence this background has on their participation in the schooling process (MacIvor, 1995). This is somewhat surprising given the plethora of research from anthropology, sociology, history, linguistics, and education that illustrates the significant

impact culture has on the teaching and learning process. As with any other curricular area, students bring with them a wealth of knowledge and experience that relates to science and teachers should draw on this background and on student strengths. As Ovando (1992) notes,

> All children bring with them to school a base of scientific knowledge, skills, and experiences. And this base can be related to the school's curriculum. For example, Indian children may have had firsthand experience with issues such as soil erosion, conservation, the use of pesticides, and consumption of traditional verses mainstream non-Indian food. These experiences can be applied to such formal fields of science as ecology, ethology (the study of animal behavior), genetics, geology, and nutrition. (pg. 224)

Other scholars have noted similar strengths that many Indigenous students bring to science learning, including knowledge about preserving and maintaining the environment, knowledge of nature in general, knowledge of technologies enabling survival in nature, observation skills, and valuing the knowledge inherent in nature (Cajete, 1999; Kawagley, 1990; Kawagley et al., 1998; Nelson-Barber & Estrin, 1995).

It should be obvious from the preceding discussion that in order for teachers to engage in culturally responsive science education for Indigenous youth, they need a particular set of knowledge that they do not currently receive in teacher training programs. The three most fundamental areas that teachers need more knowledge about are the nature of science, epistemology, and knowledge and cultural competency within tribal communities (J. Allen & Crawley, 1998; Haukoos, Bordeaux, LeBeau, & Gunhammer, 1995). Importantly, this knowledge will not be gained through a one-time professional development series. Instead, it

will require sustained and continual education. Research by Haukoos and colleagues (Haukoos et al., 1995; Haukoos & LeBeau, 1992) has shown that even after just one year of a professional development that brought about immediate change in teachers' perceptions about teaching science to Indigenous youth, that knowledge was lost and they had returned to their "business as usual" (Sleeter & Grant, 2003) practices.

Examples of science education:

The literature we reviewed for this paper includes three examples of particular educational approaches to science for Indigenous youth. We will briefly describe each of the three here. After reviewing these three examples, we will share some examples of how the issues raised might unfold in actual science lessons with Indigenous youth.

The first science curriculum is suggested by Aikenhead and is called science-technology-society (STS). This curriculum was developed internationally over 25 years ago and emphasizes cultural border crossing between mainstream Western Science and Native or Indigenous Sciences (Aikenhead, 1997b). In STS science education, students and teachers both become cultural border crossers with the goal of learning the culture of Western Science in order to use it for "practical action toward economic development, environmental responsibility, and cultural survival" (Aikenhead, 1997b: pg. 229).

The second science approach is also described by Aikenhead (2001) and is called the Rekindling Traditions curriculum. Within this curricular approach, the teacher begins with an "Aboriginal framework" and then introduces Western Science concepts "as useful knowledge from another culture" (Aikenhead, 2001: pg. 343). Again employing his concept of border crossing, Aikenhead argues that the final step in this approach is the facilitation of students' understanding of the Western Science concept—thus crossing the border from their own

conceptual framework to that of Western Science. Within each curricular unit, both native and western knowledge, values, and assumptions are made explicit so that students always know which framework or epistemology they are working within. Some teachers even use two different blackboards to indicate when they switching from one to the other. Aikenhead offers the following explanation of the benefit to this curricular approach:

> Sometimes Western Science can powerfully clarify one small aspect of Aboriginal science. For instance in the Snowshoes and Trapping units, the technologies are originally studied from historical and cultural perspectives of the local community. Then the class takes a closer, in-depth, Western scientific look at the pressure exerted by snowshoes on snow and by traps on animals. By understanding the scientific stories about force, pressure, and energy, students learn to predict more accurately the effects of variations in the technology. While the Western Science concepts do not improve students' know-how for snowshoeing or trapping, the concepts clarify one small aspect of the overall topic. Western Science does not replace Aboriginal science, it enriches a small aspect of it. (Aikenhead, 2001: pg. 347)

The goal of Rekindling Traditions is for Indigenous students to gain access to Western Science without losing or devaluing their own cultural identity and epistemology.

The final example, and also the most often cited one, is ethnoscience. As discussed earlier, ethnoscience is an approach that makes science relevant to and consistent with students' background knowledge and experience (Davison & Miller, 1998). The following provides a clear picture of what ethnoscience might look like:

> Ethnoscience can be interpreted as being the body of science used by the culture to make the curriculum relevant to the individual. Yet, more than making curriculum relevant, it must interface with every aspect of the students' lives. For example, identifying indigenous plants, complete with scientific names, is consistent with western scientific procedures and is a relevant activity. But it is not an ethnoscience approach. Merely identifying plants by scientific names does not include aspects of American Indian culture such as religion, medicine, and even American Indian language…An ethnoscience approach to the same lesson would appear to be quite different in content, though accomplishing the same objective within the classification context. For example, students on the Crow Reservation may study plants indigenous to their area. However, they could classify these plants based on their use by the native culture using the Crow language names, religious beliefs, and the medicinal values of the plants as identifiers. This activity is culturally relevant to the Crow people, but on the Northern Cheyenne Reservation a few miles away, it would not be relevant. (Davison & Miller, 1998: pgs. 261-263)

At least a few scholars recommend an ethnoscience approach as the most promising strategy for teaching science to Indigenous students, but they also acknowledge that ethnoscience is not as straightforward as it might first appear (Davison & Miller, 1998; Nelson-Barber & Estrin, 1995).

Examples of using Indigenous Sciences and Western Science in Concert

There are a number of examples where we have seen the use of multiples ways of thinking about science in classroom use. We offer a few of them here to orient the conversation

on what, precisely, this could look like. Essentially, we are arguing that multiple forms of science can be wedded and that both "formal" and "informal" uses of science can work together.

Lipka (1990) shares a case study of a successful Yup'ik first grade teacher. This teacher, Mrs. Yanez, adapted her classroom to resemble the local community in terms of communication styles, values, praised behaviors, and curricular content. She taught students "the 3 R's while teaching them to be Yup'ik" (Lipka, 1990: pg. 25). Her success is highlighted in one particular lesson where she used a local activity to teach literacy and math skills.

> From the choice of activity, smelting, to presenting the lesson through demonstrating and observation, to connecting the importance of the lesson to community-based activities and kin, to the interactional style of the teacher all contribute to contextualizing this lesson. The implications of this case are that contextualizing classroom lessons and building on students' prior knowledge can positively affect students' classroom performance. (Lipka, 1990: pg. 18)

Many of the elements discussed throughout this paper are employed by Mrs. Yanez. Barnhardt (1990) also shares an example of a school serving Yup'ik youth that integrates Yup'ik cultural values, employs a bilingual curriculum, and maintains strong community support.

Klump and McNeir (2005) provide four case studies of exemplary culturally responsive educational programs for Indigenous youth across the nation—one of which is particularly relevant to science education. The Russian Mission School in rural Alaska integrates Native knowledge with academic standards through a hands-on curriculum centered around subsistence activities indigenous to the local community. Students engage in learning experiences related to

real activities that are of high interest to the community and draw on local resources, materials, and knowledge. As Klump and McNeir (2005) explain:

> Traditional knowledge is carefully integrated with academic standards. A unit on berry picking, for example, asks students to study and identify five types of berries, learn where those berries are traditionally harvested, and then use the berries to create traditional Yup'ik foods. The berry picking activity incorporates benchmarks from science, health, and personal/social skills standards. Students then demonstrate what they have learned through writing assignments and using technology to create a PowerPoint presentation about making traditional foods. "We're very aggressive about using the standards," notes Hull [a local educator]. "But we see Native culture as the pathway to that." (pg. 12)

The results of the Russian Mission School's efforts have been positive: enrollment rates have gone up; crime in the community has gone down; stronger connections between students, teachers, and elders have resulted; students are rediscovering aspects of their cultural heritage; and subsistence activities have increased throughout the community (Klump & McNeir, 2005).

Another example from Brayboy's research (2006) highlights how an Indigenous student teacher would teach a typical science lesson differently in her home community. In the fourth grade classroom where this student teacher did her preservice work, the students were conducting experiments where they attempted to grow bean plants in different kinds of soil (one in dirt, another in sand) with different amounts of water (one got more, another less). There were multiple points of the lesson, which included a scientific component of examining what happens when certain seeds are planted in particular soils and watered with particular amounts, an

empirical component tied to mathematics where students were measuring the growth of the plant and the daily amount of water provided to the plant, and a written component that consisted of the students entering journal amounts and describing what they saw happening. The idea was to use this as a way to further examine the role of photosynthesis and to integrate reading and writing skills across subject areas. The assignment was prescribed to occur in a particular way, and the conditions were intended to closely mimic work in a science lab with the idea that students would gather some additional knowledge of how science works in particular places. The assignment is, in many ways, used universally in its approach to teaching children about plant growth and in developing measuring and writing skills. The student teacher, who is in the American Indian Teacher Training Program at the University of Utah, describes how she might teach this lesson in her own community:

> Well, first off, I wouldn't do it this way. I'd have to start at the beginning…I would get a bunch of seeds that we plant over the course of a year and lay them out on a table and show them what the differences are…so, you know, a bean seed is different than a corn kernel, and is different than a seed for pumpkins and other melons we might grow. [The students] have to know what is what before they go planting these things….Then I would talk about what each of the seeds did.

The conversation continued with her outlining what each of the list of seeds she described to us would "do." Brayboy asked why she would tell the students what the "seeds did." She responded:

> Well, they are going to plant them, right. So, you don't just plant any seed at any time. You need to know what you're planting, because you

> don't want to waste seeds, but you also don't want to plant something you don't know what it will be. In my culture, we are very careful to make sure that every decision we make is thought about before we act. You don't plant some seed just because. It has a purpose and carries more stuff with it…You know, once I described the seeds and what they did, I would then ask them to come in one night to school. We would probably do this a few times a year. Then we would look at the sky and the patterns of the stars. The constellations tell us when to plant certain things. So, I would tell them that when [a constellation] reaches the most eastern part of the sky, it is time to plant the corn, and that when [another constellation] reaches the apex of the sky, it is time to plant pumpkins. We can't do it earlier, or nothing will grow, or it won't grow right. We have to do it that way…it's the way we do things….These students have to know the right way to do it, and they can't plant these seeds at any time…. after the first frost, I'd tell them some stories to understand the importance of these things so that they know. Sometimes these White teachers come in and want us to tell the stories at a time that doesn't work, or they'll try to tell the stories during the wrong time of the year.

After the student teacher discussed her own thoughts about this in more detail, Brayboy asked her about measuring the growth of plants and writing them down and if she would do the assignment this way. In response, she told Brayboy:

> Well, this is a little trickier. I'd not normally have them do it this way. You can look at it and know if it is growing; you don't need a ruler for

> that. And we wouldn't plant it in sand anyway; things don't grow well in sand, and everyone knows that. We'd plant the bean where we always do and have fieldtrips to make sure it's growing. I'd check in between to make sure it was ok, and if I had to do something to the plant, I'd take the class and show them, but they'd know how to do this by watching their parents or aunties and uncles, you know….But with No Child Left Behind, and the other testing, I'd have to do this any way, or at least I'd teach them how to read a ruler and to be ready for the test. They'd write other things down. I think our students have to be able to write and keep journals, and know why they do that….Our tribe is for education, and we know that we have to do better, but sometimes this does not make any sense. We have other ways of doing this, but I understand this much better now and think that I've learned a lot [at the university]…but me and [the other two student teachers who are members of the same tribe] have something to teach you all too.

There are several important points from the ways that the Indigenous student teacher made sense of the lesson that are worthy of further elaboration. Importantly, the student teacher begins by making clear that she "wouldn't do it this way." The lesson itself is somewhat foreign, and lacks a particular context from her perspective. Contextualized knowledge that is local and localized to the setting is a central feature of culturally responsive schooling. In her analysis of the exercise itself, this student teacher points to the fact that all knowledge cannot necessarily be universal in its application. She continues by arguing that she "would start at the beginning" and offers a way to contextualize the lesson itself. The process of contextualizing what is being

learned and tying it into the lives of the children whom she will teach is important. By utilizing the seeds as being "different," the student teacher also takes the time to not just stay on script to teach measurement and science, but to also point to the categorizing role of knowing what seed grows into what plant. She simply says, "They have to know what is what before they go planting things." She points to the practical nature of this education, and moves away from the abstraction of planting something just to watch it grow and be able to measure it. The plant itself potentially represents something that is more than just a learning tool and medium through which to engage in "scientific practices," but is something that must first be known. There is a sanctity of the knowledge and its use here that is an inherent part of Indigenous epistemologies and ontologies. The importance of purpose in and purposeful actions is important in this discussion, because it is rooted in the beliefs of communities of people. It also points to the nature of responsible use of knowledge. Because all things are interrelated and connected, planting something that serves no other purpose than for learning, isn't logical when a plant can be grown with the purpose of both learning and feeding makes more logical sense from an Indigenous perspective.

The student teacher continues to point to the epistemic and ontologically based ways that she is recognizing the purpose and role of teaching this lesson. She immediately points to the fact that students are going to do more than measure the plants; they must plant them first. Importantly, students must be aware of what they are planting before engaging in the process. For some Indigenous people, knowledge is the basis of power, because it must be used toward a greater aim and goal. To plant something that is unknown potentially creates problems that could have been avoided. She points to the deliberateness of her own cultural norms before acting. She says, "In my culture, we are very careful to make sure that every decision we make

is thought about before we act." This quote highlights the notion that knowledge and its concomitant power must be handled with care. Importantly, the idea of "more stuff" to which the student teacher refers also ties in directly with the spiritual aspects of planting something for its nourishment and the nourishment of others. There is a direct tie here with the idea that Indigenous notions of spirituality require that the metaphysical nature of things be considered in the daily lives of students and teachers. Curriculum and subject matter must be tied directly to the lives of students and their Indigenous teachers. Separating the two makes them arbitrary and fails to recognize the epistemological bearing that is rooted in the ways of the community. These materials become more than a simple individual exercise. For many Indigenous people, they are connected to their community and the ways that the achievements benefit the community. Separating the spiritual from the everyday is not only a false separation, but is largely inconceivable.

The student teacher continues with the connections between the curriculum and her own sense of native religion. She suggests that she would have the students "come in one night to school" where she would discuss the native cosmology and make direct links to the seeds and when they get planted. In this way, few tasks at school are simple or unrelated to the everyday lives and spirituality of the students. When the student teacher says, "It is the way we do things" she points to the ontological basis that connects the everyday with the sacred—there is little disconnect and she takes seriously her role to provide students with the basis to participate in school. School activities are mediated by the community norms and the way that things are done. She elaborates on this point when she argues that "These students have to know the right way to do it" and points to the fact that seeds and planting occur at particular times in particular places with the appropriate use of time and space. This description is culturally responsive

teaching at its best, and it highlights the fluidity between the home and school. Finally, the student teacher highlights some of the conflicts between an Indigenous informed way of teaching, the utility of doing things, and the standards that drive the curriculum and teaching that happens in schools. She points to the fact that growing a plant is basic in that you plant it in something that will grow, and you plant it where it always gets planted. She points to the fact that she would check on the growth of the plant and highlight for the class what is happening and how her work is driven by the fact that "you can look at it and know it is growing." Importantly, however, she notes that because of legislation like No Child Left Behind, she must assist her students in meeting the demands of the test. She starts by telling us that the process of doing some of the work required in schools "is a little trickier" and points to tensions created by a standards movement that is not based in community beliefs and epistemologies. Ultimately, this student teacher makes the most profound statement of all when she says that her "tribe is for education…but sometimes it doesn't make sense." In this statement, she is not arguing that education does not make sense; rather, she points to the one size fits all, and the achievement rooted in individualism, form of education that may not be valued in Indigenous communities.

Concluding thoughts and issues to consider:

In addition to the discussion presented here, there are a few other issues that may need to be considered when thinking about science education for Indigenous youth, Native Science, and informal science learning. This list is certainly not meant to be exhaustive, but it represents some additional points noted in the scholarship. The nature of knowledge and competing epistemologies has been a central issue in this paper, but we would add the point that care must be taken to consider appropriate protocols when non-Native educators attempt to "borrow" Indigenous knowledge for use in other contexts (Michie, Anlezark, & Uibo, 1998). We must

think about issues of ownership of knowledge and how to engage in a culturally responsive science education without engaging in theft, exploitation, or distortion of Indigenous knowledge. In a related way, Ovando (1992) notes that there is a "need for a two-way interchange between the traditional American Indian learning environment and the school's formal science curriculum" (pg. 239). Ovando (1992) also calls our attention to the issue of second language learning within the context of science education; science teachers must think about times and situations in which it is most effective for students to learn in their native language and how to transfer knowledge and concepts from one language to another. And finally, some science educators fail to recognize "traditional knowledge and wisdom as science because of its spiritual base" (Snively & Corsiglia, 2001: pg. 21). Given the discussion above about different epistemologies and worldviews and the deep connections between spirituality and the natural world for many Indigenous people, this tension must be given serious consideration among science educators. It is probably not possible to engage in a culturally responsive science education for Indigenous youth without admitting spirituality into the discussion.

While much of what we've discussed thus far has implications for current science education efforts and the predominantly White educators currently working with Indigenous youth, we would be remiss not to also note that there is a significant need for more Indigenous people working in Western Science contexts. Just as the relatively recent increase in women in the sciences has had a large impact on the science that is done, an increase in Indigenous men and women in the sciences would likely have a similarly significant impact on the science that is done.

The need for more Indigenous scientists is related to another important point that we hope has been clear throughout this discussion. If the goal of the commission is to improve the

learning of science for Indigenous youth, then Native Science and lessons from the literature on culturally responsive schooling must be taken seriously. Though there are likely a number of reasons Indigenous students are currently marginalized in Western, "formal" science contexts and underperforming on standard measures of science achievement, we suggest that some of the most significant reasons relate to epistemological tensions, the lack of relevance to students' lived realities, and the hegemony of Western Science. Native Science and Indigenous epistemologies must be more legitimate and viable parts of science learning and all science must be more culturally responsive.

And finally, we would like to end by weighing in more explicitly on the discussion between formal and informal science learning. We are very much aware of the fact that we were commissioned to write about Native Science in order to inform the practice of informal science teaching and learning, and we believe that our discussion in the previous pages has done that—albeit perhaps in a more implicit rather than explicit way. We have concerns about the formal-informal dichotomy and the way in which it may inadvertently reproduce the very hegemony of Western Science that we have discussed above. As we have already noted, the formal-informal dichotomy is very much a false distinction within many Indigenous communities and tribal nations. If the commission is using this language to reference school-based and out-of-school learning experiences, perhaps this language would be more accurate and would avoid some of the concerns we have raised in this paper.

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