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Native Science in Practice: Cases for Broadening Understanding and Engagement of Science in Education as a Plea for Future Generations

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Science education, as we have understood it in the U.S., has gone through many approaches to help students understand the "natural world" and to become "scientifically literate" (DeBoer, 2000). This latter term has come to mean many things to many people, from understanding how to apply scientific concepts to everyday life to recognizing technology's role in society and how to use it. It is clear that in the history of science education in the U.S., educators and scholars have struggled to find a cohesive narrative around which to situate their field. Since U.S. schools began formally teaching science, the field has found itself in argument over its aims and purposes. Currently, science educators in the U.S. have mobilized around the "Next Generation Science Standards" with its central theme of needing to prepare a workforce "to succeed in a global economy" (NGSS Lead States, 2013). Indeed, in the Standards section titled, "The need for standards," the economic argument term is presented five times and serves as *the* leading rationale for the standards.

We shift our attention from the arguments and undeniably rigorous work in the field of science education toward something that has only in modern times been described as, "Native science." Cajete (1999), one of the leading scholars of Native science, explains that the term was never needed in the past, but that using it is helpful in contrast to what he describes as the Western "mechanistic science." To be clear, Native science is also "the entire edifice of Indigenous knowledge" (Cajete, 2000, p. 3). Cajete (2000) explains that it is "a map of natural reality drawn from the experience of thousands of human generations" (p. 3). He goes on to explain that it thus includes "modern science" alongside Native science's engagement of perception, emotion, and symbols (p. 2). In this framing, science has existed as long as humans have been engaging their surroundings, and thousands of generations have helped us, as a species—and in sync with other species—to create a base of knowledge and a way of "coming to know" that extends beyond static knowledge.

We make a departure from the U.S.'s traditional "science education" in recognition of several stark realities. First, the genocidal practices that have eliminated so many indigenous populations in the U.S. have the heritage of gross underrepresentation of Native Americans in scientific careers, alongside other historically disenfranchised groups, including African Americans and Latinxs (Medin & Bang, 2013; NACME 2012). Medin & Bang (2013), among others, argue persuasively for the deep need to have the voices of scientists from varying backgrounds in the greater discussions of what science is and how we do it for the greater good of all peoples and our planet. Similarly, all of us could stand to gain from Native science as our planet faces such dire conditions of environmental degradation (Medin & Bang, 2013; Kasun, 2015). We are faced daily with a dissonance of knowing our planet needs our respect and care while at the same time bearing witness to "modern" lifestyles based in property rights and individualism, which, for instance, assert that the person has the actual right to the land that happens to be situated beneath one's feet if that person can lay claim to a "legal" title to it. Certainly, the legality of these claims can be highly contested in the U.S.'s fraught history of land rights with many populations, but especially indigenous peoples. Contemporarily, we look to the Dakota Access Pipeline and see once again how the "rights" of individual consumers can override Natives' claims to land and safe water (Archambault, 2016). In this article, we reclaim ancestral wisdoms by recognizing that land does not have to be owned and that the earth can be respected through our daily practices. These are core tenets, among so many others, of Native science we explore in our engagement of this literature.

Following, we review selected examples of academic programs that have incorporated Native science in indigenous communities by integrating concepts of Native science in the curricula. We center our review predominantly on science education in these communities in efforts to maintain cohesion with Western senses of "science," as we are writing in a special issue related to "STEM." Currently, the research on such programs remains limited, and it is almost exclusively centered on the approach of Native science education with indigenous populations. Before reviewing these cases, we more deeply explore indigenous epistemology. This section also provides a greater review of what Native science is. The following section then examines several instances where Native science has been implemented in both formal and informal contexts as well as outcomes associated with the various programs reviewed. We conclude with remarks specifying why this is crucial to the educational process for indigenous students and suggestions for future research.

We offer a note on terminology. There is discussion and debate about the terminology concerning indigenous students. Indian is a term that some in the United States might consider insensitive. With the rise of immigration, it also offers confusion about the heritage of these students—are they Indian from India or Native Americans? Some indigenous community members, particularly Western U.S. tribal members, prefer to be called Indian or American Indian; however, other communities resist this terminology. "Native American" also presents challenges since anyone born in the Americas can be considered Native American as well. For the purposes of this article we refer to students of Native descent in North America as indigenous except when quoting directly from other research, in which case the original terminology will remain unchanged. While we would never claim that all indigenous peoples are exactly the same or have the same thought processes and epistemologies, for ease of reference we have chosen this as a broad term to differentiate this group apart from other cultural groups present in the United States. We maintain this terminology throughout the paper to maintain continuity with existing research.

Native Science

Indigenous epistemologies, similarly referred to as "ways of knowing," understood as "the interconnectedness of all things through the wisdom of indigenous sources" (Kasun & Saavedra, 2016, p. 685) have existed for millennia. Cajete (2000) describes indigenous culture as one of interdependence where everything is connected on multiple levels of existence. Indigenous peoples of what is now the U.S. and Mexico, for instance, have known for centuries that the "Three Sisters" of corn, beans, and squash, can be planted and maintain a positive biofeedback cycle which requires no use of the "modern" agricultural treatments of, say, fertilizers or pesticides. Similarly, the destruction of the physical environment affects humans not only physically, but also spiritually, mentally and emotionally since all planes of existence are interconnected. Indigenous people understand the delicate balance of humanity and nature and how it is all interconnected. Indigenous peoples have historically been some of the best environmentalists, agriculturists and conservationists. For instance, the tribes in the Pacific Northwest knew exactly how many salmon they could harvest during the salmon's breeding season each year in order to maintain a sustainable growth in population (Cajete, 2000). Without the use of modern technology, they understood how many they could take in order to ensure that the salmon repopulated the following year. For millennia these tribes fished from the rivers without overfishing (Cajete, 2000). As a direct result of Eurocentric approaches to agri- and aquacultures, 85 percent of fisheries are pushed to the point of or beyond their capacities, leading to the direct threat of extinction of several species of fish and great disruption of social and economic systems which rely on fishing (World Wildlife Federation, 2016). After European contact, overfishing became commonplace and now laws must be made in order to protect some animals and plants because the new arrivals did not understand this interconnectedness of all things.

Relating this epistemology to science challenges the Western and reductionist epistemology that is largely grounded in positivist theory. This theory limits science to only what can be seen and/or measured and disregards other data points (Brayboy & Castagno, 2008). Thus, we further contrast Western science and Native science. This contrast becomes apparent when one examines the overarching epistemology of these ways. Simonelli (1997) explains,

> Indian science, or 'indigenous science' as it's sometimes called, is 'full-spectrum science.' It draws freely on all four of the gifts that have been given to us as human beings: the spiritual, emotional, mental, and physical. By contrast Western science dwells mostly on the physical and mental, often rejecting the spiritual and feeling or emotional qualities of life with great arrogance and finality. (p. 37)

As noted previously, Native science encapsulates all of Western science and expands upon it by including the spiritual and emotional realms as well as the physical and mental dimensions of human existence. Cajete (2000) argues that "science" is much broader than what it has been defined as in the academic world and should include both the spiritual and emotional realms as well. Cajete (2000) argues, "no divisions exist between science and spirituality" (p. 69) and that for indigenous tribes science and spirituality are tied together, you cannot speak of Native Science without engaging indigenous spirituality. The use of indigenous epistemology requires that the larger picture be taken into account. A simplified metaphor for this would be studying a tree's relationship to the forest rather than the individual parts that make it a tree. In this case one is seeking the knowledge of what is the purpose of the tree rather than what makes the tree a tree.

In Native science the experience of knowledge seeking is given much more consideration than it is in the Western paradigm. "Indians believe that everything that humans experience has value and instructs us in some aspect of life. The fundamental premise is that we cannot 'misexperience' anything; we can only misinterpret what we experience" (Deloria, Deloria, Foehner & Scinta, 1999). In this fashion the researcher or scientist is not seen as some casual objective observer, but rather an active participant in the construction of knowledge. This is perhaps one of the greatest contrasts between Western and

Native science. Where Western science views the scientist as objective, Native science regards objectivity as an illusion and instead embraces the scientists' subjectivities because his or her experience in seeking knowledge is equally as important as the knowledge itself.

In Native science, meaning is co-constructed with others out of experience and each person formulates his or her own opinions from their own point of view. That is, two people can experience the same event and construct very different meanings from the event. Medin and Bang (2014) refer to this phenomenon as "pluralism." It is their point of view that multiple voices and points of view or multiple "truths" strengthens the scientific discourse. They explain, "Pluralism thrives on diverse perspectives and cannot survive the 'one true way' orientation that is presented in some popular representations of the nature of science" (Medin & Bang, 2014, p. 54). A similar idea is echoed by Kawagley, Norris-Tull and Norris-Tull (1998): "We believe that there is no one way to do or think about science. Science is not strictly European in origin. Modern scientific knowledge is a blend of the observations and insights of many different cultures" (p. 139).

Many authors, including those cited above (Median & Bang, 2014; Kawagley, Norris-Tull & Norris-Tull, 1998), make the case for pluralism not only being beneficial, but necessary for the advancement of science. As science is not purely the territory of Euro-American academics, this necessitates the need to engage Native science as part of a pluralistic science paradigm. The authors cited here maintain that multiple voices would actually further advance human knowledge and science by bringing in diverse viewpoints and creating new theories based on differing opinions and paradigms. They argue that rather than relying on this single view of knowledge or science that is based largely in a positivist stance, bringing in more viewpoints will actually strengthen scientific methods. Brayboy and Maughn (2009) suggested that Native science and Western science do not have to contest one another, but rather they should supplement one another.

The "single science" viewpoint suggests that science itself is neutral or acultural, and since other ways of knowing are inherently cultural they do not qualify as science, or are at best pseudoscience or ethnoscience. But this is only a method of academic colonization. Aikenehead and Ogawa (2007) explain:

> 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.

Aikenhead has engaged Native science for decades and offers important arguments regarding the need to do "border crossing" between sciences. Implementing Native science in the classroom should help facilitate the "border crossing" indigenous students have to face when studying science in the classroom. Far too often the implicit goal of education for indigenous students has been focused on assimilation. By assimilation we mean replacing the students' socio-cultural understandings of science with "valid" Western understandings. However Aikenhead (1997) argues that implementing Native science within the classroom can be done in such a way that the indigenous student learns the concept without unlearning their culture. He suggests three things that must be present in this instruction:

1. Make border crossings explicit for students.
2. Facilitate border crossings.
3. Substantiate the validity of students' personally and culturally constructed ways of knowing (Aikenhead, 1997, p. 228).

By facilitating the border crossing the teacher can help to bridge the two paradigms, and in essence create a pluralistic model within their classrooms. Similarly, we believe students who represent more "Western" backgrounds could also learn from this kind of border crossing, especially if they are to be able to engage multiple views of what science is.

In regards to facilitating border crossing Aikenhead and Jegede (1999) drew upon prior research by Costa saying "that most students belong to one of three categories of border crossings: (a) *managed* for Other Smart Kids, (b) *hazardous* for "I Don't Know" Students, and (c) *impossible* for Outsiders" (p. 275). Students in the first category are able to cross between Western and alternate worldviews by constructing their scientific knowledge in schemata and recalling for specific uses depending on the setting. Those in the "I Don't Know" category basically used rote memorization in order to pass tests and showed no deep conceptual change. In the final category these students found it impossible to bridge the gap between Western and cultural science, they were unable to cross the border.

Extending upon his previous writings Aikenhead (2001) outlined some of the things a "cultural broker" teacher will do in the classroom in order to facilitate these border crossing. He suggests that there are three things a cultural broker teacher do: 1) acknowledge student preconceptions and their cultural worldview, 2) identify the students' cultural point of view and then present new cultural material in the context of that culture, and 3) be specific about what culture the teacher is talking in at any given moment (Aikenhead, 2001). According to Aikenhead (2001) the key to making these cultural border crossings explicit is less about the information presented and more closely connected to the social interactions within the classroom. He suggests allowing the students to present their own viewpoints with each other and to the class and also promoting discourse about the role of science in historical terms. "A culture-brokering science teacher identifies the coloniser and the colonised, and teaches the science of each culture" (p. 341).

To make these border crossings as smooth as possible it is important that the teacher be familiar with the culture of the students and then teaching scientific concepts within that context. This will allow for what Aikenhead (1997) calls "collateral learning." That is, two concepts can form simultaneously without one overpowering or replacing the other. For example, the Rain Dance is a sacred prayer offered up in some indigenous cultures in hopes of bringing rain to water the crops. Western scientific understanding would reject this claim as "unscientific." However, a teacher as a cultural broker might use this as a starting point to engage in a discussion of the water cycle. He/she might even engage community members to demonstrate a traditional rain dance and then engage in a discussion about how this belief compares to the scientific understanding of the water cycle. The purpose is to acknowledge the cultural knowledge and then present knowledge of a different culture without invalidating their traditional understanding. Rather than attempting to assimilate the indigenous students, one can augment their indigenous knowledge with Western science and conversely help Western science in its conceptualizations as well, perhaps by considering using the "Three Sisters" for planting instead of relying on supplementing chemical fertilizers to other crops, which are both costly and soil-depleting.

In the following section we review literature regarding cases where culturally relevant teaching methods were implemented by integrating Native science into curricula, and then we explore these cases through indigenous epistemology. These example programs were located through a search of top education databases using the terms "native science," "indigenous science," and "indigenous knowledge" coupled with "in schools," "programs" and "education." While there were dozens of results, each of these cases was selected purposely for the depth of the description of the program in the literature. Many of the cases found were anecdotal in nature; however, the selected cases were chosen because of the detailed description of daily practices within the programs.

Programs Implementing Native Science

We contextualize the need for Native science, beginning with the populations from which it emanates. Varma (2009) conducted in depth interviews with 50 indigenous college students to ascertain their motivations and challenges in seeking a computer science degree. The number one challenge identified by these students was economics (Varma, 2009). Qualitative data showed that many indigenous students came from communities lacking Internet connection, technology instructors, or even computers (Varma, 2009). It would be oversimplification, however, to suggest that the issue is purely one of access. As Heifitz, Grashow, and Linsky (2009) would argue, this would be a technical solution to an adaptive problem. Simply giving indigenous communities computers does not utilize culturally relevant instruction. This adaptive problem requires that people change their ways (Heifitz et al., 2009).

Fenichel and Schweingruber (2010) write that science is usually the domain of the white dominant class. That is, it privileges certain groups while working to keep other groups out.

To remedy that situation, educators deliver to non-dominant groups the same kinds of learning experiences that have served dominant groups. However, simply exposing individuals to the same learning environments may not result in equity, because the environments themselves are designed using the lens of the dominant culture (p. 120).

Simply giving other groups access to teaching will not automatically raise the achievement level of underrepresented groups nor is it "equitable" as decided by the U.S. Supreme Court in Lau v. Nichols (1974). One problem is that this solution does not take into account any cultural or social factors. Gay (2000) makes the case for the use of culturally responsive teaching in the classroom and asserts that teachers must be aware of the different cultures in their classroom. Aikenhead (2001), writing about Native science, extends this by suggesting that new scientific concepts can be taught in the context of these cultures. In the realm of science this might mean engaging Native science within the classroom. In order to provide indigenous students with effective educational experience, the whole of human existence—as it is encompassed within the understanding of Native science (Deloria, et al. 1999)—must be addressed in the curricula.

We thus explore various cases where Native science was instituted for indigenous students in formal education systems. The existing literature on such programs is still emerging, and in some cases no immediate data on outcomes was reported. Each case is situated in what is presently the U.S., and these cases, like all we have found, show that when Native science is taught sensitively, Native American students engage the subject far better than when they are provided traditional science curricula. In each case a brief description of the program is given followed by a discussion of outcomes. Throughout this section we will also discuss some challenges facing implementation of programs such as the ones described here. Each of these programs was selected purposely for the depth of the description of the program in the literature. Similar to Brayboy and Maughn's assertion (2009), we show that Western and Native science can be bridged together to enhance the learning indigenous students. These students must become skilled at what Aikenhead (1997) terms "cultural border crossing," when it comes to science. They become able to learn to cross the border between their everyday and cultural science experience and the science of schools.

Engaging American Indian/Alaska Native Students with Participatory Bioexploration Assays. This program examines the engagement levels of Native American/Native Alaskan students in Native science. While teaching Native science may not have been the overt purpose of the study, elements of Native science (hands on experience, community engagement, learning from elders, holistic education) were all present. Kellogg, Plundrich, Lila, Croom, Taylor, Graf and Raskin (2016) conducted a multi-site project that focused on the engagement rates of indigenous students while studying STEM subjects. This project collected data on students in North Dakota and Alaska ranging in age from middle school to college. Each session was administered in seminar fashion with a focus on bioexploratory lectures and laboratory experiments. To engage Native science, the researchers utilized hands-on activities over local knowledge of medicinal plants in their sessions and bringing in community resources by inviting elders into the seminar to share their knowledge and wisdom with the students.

The instruction of these seminars was focused on the students using a system of simple field bioassays to "explore the bioactivity of extracts from culturally-familiar wild edible or medicinal plants" (Kellogg, 2016). An assay is a way to test for the ingredients or quality of an object, usually an ore or mineral. In this case the students were responsible for testing whether the ingredients of these plants were useful as medical treatments for various health concerns relevant to indigenous populations (Kellogg, 2016). The bioassays were pre-developed with the help of elders and native schoolteachers and allowed the students to test the utility of these plants as medicine by observing the change to tissues when the plants were introduced (Kellogg, 2016). In this fashion the cultural knowledge of medicinal plants was bridged with Western biological and chemical laboratory principles (Kellogg, 2016). Utilizing the elders as teachers and guides takes this case beyond simply using hands on science to engaging the cultural knowledge of the tribes. This method allows for the exploration of the spiritual connection indigenous peoples have to healing plants. Cajete (2000) writes, "Because plants hold the power to heal, they played an essential role as conduits or bridges to the spiritual world of nature" (p. 119). Exploring the healing properties of plants with the guidance of elders allows for the students to learn new Western science concepts (bioassays and lab work) in the context of their culture. This is one of the main aspects of facilitating "border crossing" with students, according to Aikenhead (2001).

Kellogg et al. (2016) found that

indigenous students were more engaged with Western Science when Native science teaching methods were used in the classroom. These methods included hands-on activities such as identifying medicinal plants in the field. The researchers found that engagement peaked when hands-on activities were used and also when the community elders facilitated discussion about the traditional and medicinal properties of the plants (Kellogg et al., 2016). Student engagement appeared to wane during down times while students waited for other groups to catch up. Engagement indicators also decreased during lecture time; the researchers also noted that engagement typically decreases during lecture-based classes (Kellogg et al., 2016).

While this study focuses mostly on engagement levels during the workshops, it demonstrates some key aspects of Native science. The authors specifically cited the hands-on aspects of the study as leading to higher engagement (Kellogg et al., 2016). The teaching was culturally relevant by including Native elders in the leading of harvesting the plants and discussion about the traditional uses of these plants. Hands-on exploratory learning and intergenerational transfer of knowledge are both key aspects of Native science. The elder led discussions allowed for the students to make connections to their sociocultural history, identified as they explored the knowledge of their ancestors. The teaching also utilized "aspects of the students' lives" and "provided opportunities to talk about themselves and relate the content to their personal lives and interests" (Kellogg et al., 2016, p. 49) thus allowing for students to make associations between the learning and themselves. This approach exemplifies what Hall (2007) explained, "Indigenous educational approaches provide the foundation for learning based on context and relationship" (p. 16).

The Native Science Connections Research Project. The Native Science Connections Research Project tells the story of increasing achievement and positive attitudes of indigenous students towards science. This project was funded by the National Science Foundation, in which Gilbert posed a hypothesis that students would develop a greater positive attitude towards science and better learn the curriculum if their learning was grounded in their Native science concepts (Gilbert, 2008). Working on the Navajo reservation, Gilbert, himself an indigenous researcher, secured the blessing of the tribal council to conduct research and then implemented a quasi-experimental program to track science learning and attitudes. This design included two groups of students who both received instruction in the standard science curriculum. However, one group also received instruction from the Navajo Science Supplemental Curriculum (NSSC) during the twelve-week instructional period (Gilbert, 2008).

The NSSC was built around a four-stage learning cycle meant to examine the science topics through a culturally relevant lens (Gilbert, 2011). This model included an introduction to the concept utilizing both English and the heritage language of the students and needed "to be relevant to the Native American child's environment in order for the general purpose of learning to take place" (Gilbert, 2011, p. 49). The second phase of the model explored the new topic from a cultural perspective. This included selecting five to eight Navajo vocabulary words with English translations as well traditional stories, teachings and uses. During this phase, students also took field trips to local sites and also engaged community members in the classroom to focus on the traditional science teachings.

Phase three then presented the information using the Western Euro-American perspective, similar to what one would find in a public school off the reservation. The final phase allowed for "integration" of the concepts between the two paradigms where "the students are to organize the newly learned concept with other concepts that are related to it" (Gilbert, 2011, p. 53).

Using a pre-test/post-test model, Gilbert measured the performance of the students before and after the instruction using an open-ended achievement test—Full Option Science System (FOSS)—as well as the attitude of the students towards using a Likert scale on the Science Attitudes Inventory (Gilbert, 2008). Gilbert's findings were consistent with his hypothesis: the findings "illuminated the fact that after the students were exposed to the Navajo Science Supplemental Curriculum, they could comprehend the science concepts better than before" (Gilbert, 2008). The importance of including Native science in the curriculum was further highlighted by a greater increase in positive attitudes towards science for those students exposed the NSSC (Gilbert, 2008).

This case illustrates a clear use of Native science methods as well as explicit border crossing for the Navajo students. There was a concentrated effort to ground the learning within the social and cultural context of the students. This acknowledges the culture of the students as important and relevant prior to teaching the new scientific concepts. As part of this case the language of the Navajo people was emphasized as well with students learning the vocabulary in both Navajo and English. Finally, traditional Native science methods were used through the inclusion of storytelling in the classroom. "One might say that these and other stories are folk tales, not scientific theory. In reality, the stories are alternative ways of understanding…" (Cajete, 2000). This demonstrates that through the use of the teaching methods described in the case the students, including traditional native science methods, students made positive gains in their understanding of scientific concepts as well as their attitudes towards science.

The Ya Ne Dah Ah School. This program's data were collected from two different sources describing the Ya Ne Dah Ah School in Alaska. This program demonstrates how this school implemented culturally relevant teaching and Native science to help reinvigorate their cultural traditions, knowledge and language. This program worked to prevent cultural extinction by using the Native science tenet of transmitting knowledge from elders to youth in a school setting. In an effort to stave off cultural extinction, the community members of Chickaloon Village created The Ya Ne Dah Ah (Ancient Teachings) School in 1982 (Seelau, 2012). This school has been examined by multiple researchers for its efforts to bridge indigenous knowledge and Western ways of knowing (Seelau, 2012; Venegas, 2005). The purpose of this school was to preserve cultural heritage and language of the Athabascan people. This school started off simply with one community member volunteering to teach the Athabascan language to the students. The community members of the Chickaloon village considered language preservation as an important aspect in maintaining their culture.

After initial implementation, the program was expanded to include Athabascan language instruction in a variety of ways and also cultural experiences on daily basis (Seelau, 2012). The program grew in both size and influence and later engaged many community members in various ways and "connected traditional ways of learning and teaching with cultural values and high quality curriculum in mainstream subject areas like math, science, and social studies" (Venegas, 2005, p. 5). The curriculum began to include instruction in math, science, social studies and language arts fused together with traditional ways of knowing of the Athabascan people (Venegas, 2005). Key aspects of Native science were integrated in the curriculum such as hands on experience in learning botany, map making with tribal forestry staff and math instruction by learning to measure birch trees and map-making with tribal forestry staff (Venegas, 2005).

The concepts of native science and indigenous pedagogies were found throughout the entire curriculum of the Ya Ne Dah Ah School. The school has adapted the curriculum to teach new concepts as required by state standards through an indigenous lens. For example, when learning math, the students may be found outside in nature measuring birch trees and harvesting the sap (Venegas, 2005) rather than sitting in desks and learning from textbook. This method of instruction ties the cultural ways of knowing that are important to the Athabascan people to the learning standards necessitated by the state department of education. This type of cultural hands-on method is found in each subject taught at the school (Venegas, 2005). By linking these hands-on methods with the cultural significance students were able to learn new scientific concepts within the context of their own culture. There was also an emphasis on intergenerational knowledge transfer led by community elders.

Community elders were brought in as cultural experts to impart their cultural and scientific wisdom to the students (Venegas, 2005). These experiential learning methods are reflective of indigenous ways of knowing and transmitting knowledge. Fridays at the school were dedicated to cultural experiences that directly related to current challenges in the community (Venegas, 2005). Students were able to learn traditional knowledge from elders and community members and then apply that within the classroom. These efforts successfully led to a bridging of Western and Native science as evidenced by one graduate who returned to the school as the school's dance troupe instruction and as a computer technician for the tribe's educational department (Venegas, 2005). Seelau (2012) concludes that the effects of this program were largely positive and that, "The creation of the Ya Ne Dah Ah School has already begun to reverse the effects of more than a century of assimilative policies. Students enrolled in the school are no longer at risk of dropping out, and their standardized test scores are now higher than both state and national levels" (p.102). Venegas (2005) echoes this statement and points out that the risk of dropping out has significantly decreased as students became excited to go to school.

Providing access to these cultural experiences allowed for the students to learn both the traditional ways of knowing as well as the contemporary scientific concepts. One of the aspects of Native science demonstrated was the inclusion of traditional song and dance (Venegas, 2005). Indigenous music and dance is often connected to ceremony and are "artistic representations of all the things that matter" (Cajete, 2000, p. 102). It would be unusual to find science classrooms in Western style education that rely on music and dance as part of the learning process, but Native science methods regard this as an integral part of the process. Indigenous peoples' songs and dances were used as parts of ceremony in order to revitalize their understanding (Cajete, 2000). The singing and dancing are included in the ceremonies as a means of education and passing on knowledge. Making room for these activities in the curriculum works doubly to reinforce new concepts as well as sustain traditional cultural understandings as well.

The STAR School. Mark Sorenson describes the public charter school he helped found on the Navajo reservation (2013). This school was constructed around important concepts to the Navajo people including the idea that all things are related, the same interrelatedness that Cajete (2000) identified as foundational to Native science. This school was founded upon the historical and traditional ways of the Diné people. The founders chose to name the school the STAR School (Service To All Relations) to emphasize the importance of relationships to the Diné people. Sorenson explained, "inspired by the Diné (Navajo) concept called 'K'e,' we see relations as encompassing all life on this planet, including the rivers, trees, and animals. We also consider our relatedness to larger universe, seeing the sun and stars as relatives as well" (2013, p. 52). This sense of relationship is a key tenet of Native science. As Cajete (2000) explained, "The history of relationship must be respected with regard to places, plants, animals, and natural phenomena" (p. 65). It is through this emphasis on relationships that the STAR School exhibited core practices related to Native science.

To educate their students on the emotional and spiritual aspects of being, the school emphasized the relationship students had with their culture and with each other. At the beginning of each week every student met and greeted every other person in the school in a special ceremony (Sorenson, 2013). The importance of connection to others became evident with this practice. The culture of the school was such that confrontation between students had nearly disappeared. Sorenson (2013) reported that for the 2011-2012 school year there was only one physical fight between students. Students also reported feeling a sense of safety while attending the school. This school culture is supported by what Sorenson (2013) termed the "Four R's"—respect, relationship, responsibility and reasoning. Each student in the school could recite the Four R's and provide examples for how they are demonstrated throughout the school.

Sorenson pointed out that the land the school is built on has been Navajo land for hundreds of years, and yet it would not be considered prime land for farming (Four Arrows, 2013). As part of the culturally responsive curriculum this school instituted they examined traditional ways that the Navajo people have been self-sustaining and wove this into the curriculum. The school utilized local resources by working with a local farmer who provided produce to the school for their lunch and breakfast programs; any leftover food is then composted with the help of the kitchen staff (Sorenson, 2013).

With an emphasis on sustainability and recycling, the school itself honors its relationship to the land by being one of the first completely self-sustaining schools off the grid in the United States (Sorenson, 2013). For electricity, the school relied on wind and solar panels to supply electricity to the building. This method led the school to be able to reject coal and other fossil fuels that were unsustainable and focus instead on living in harmony with the environment (Four Arrows, 2013). The demonstration of living in harmony with the environment is an example of education on the physical level of existence as students are able to explore their relationship to the land and ideas of balance and harmony.

Formal accountability systems, a hallmark of Western approaches to schooling, remained a challenge for the school, situated on the edge of the Navajo reservation. For the 2011-2012 school year the state of Arizona graded the STAR School with the letter grade "D." Sorenson explained, "Although we have been very successful in helping to develop future citizens in this approach, we have not yet found a way to have the majority of our students perform well on the state standardized tests" (2013, p. 54). Sorenson explained his fear of the school charter being revoked when it went up for renewal in 2014 (Four Arrows, 2013). (Authors' note: the charter was renewed and the school is currently open and enrolling for 2016-2017.) There are other Western markers of achievement which remain laudable. For instance, graduates of the STAR School were recipients of two Gates Millennium Scholarships, an Arizona Board of Regents Scholarship, and several other scholarships and fellowships for advanced study (Sorenson, 2013). Several of the graduates also expressed the influence of the school in helping them choose majors related to environmental justice (Four Arrows, 2013). As Deloria (1999) suggested, these students appeared to be setting themselves up to become leaders in the field and transform scientific knowledge by grounding themselves in traditional and indigenous wisdom.

This school provides a clear example of one that grounded its curricula within traditional understandings and customs while attempting at the same time to teach to United States educational standards. The emphasis on relationships between the students, teachers, environment and knowledge was at the core of Native science. While the school has received mixed results regarding formal assessments, it also excelled at fostering relationships, as evidenced by the lack of physical confrontations and the ability to live sustainably. Native science is concerned with the idea of "interdependenc" (Cajete, 2000), that all things are related on the four levels of existence and the S.T.A.R. School exemplified and stressed this concept. With this emphasis the curricula in this school expanded the concepts of Native science beyond the science curriculum and weaves it into every practice. This method has shown great success at producing citizens of the Navajo reservation as well as minor successes in Westernized accountability measurements as well.

Alaska Onward to Excellence Program. The Alaska Onwards Towards Excellence Program highlights the curricular achievement that Native Alaskans made once the tenets of Native science were implemented in their school. Barnhardt (1999) conducted a review of the Alaska Onward to Excellence (AOTE) program in one school district where the majority of students were Alaskan Natives. This study focused on two aspects of the program: community involvement and contributions of Yup'ik proficiency to overall school achievement (Barnhardt, 1999). This program began with the intention of finding a way to reconcile the culture of schooling with the culture of the community. "For nearly 60 years the modus operandi of federal and state educational systems was to ignore the history, culture, and language of Alaska Native people and build what some have referred to as an 'iron curtain' between school and community" (p. 11). The AOTE program was designed to increase community engagement in all levels of schooling by bringing in local issues and culture into the classroom. This program moved to include the physical, mental, and spiritual planes into the curriculum.

One example of this process was offering students the chance to take an ecology class that focused on local environmental issues such as local salmon populations (Barnhardt, 1999). The Lower Kuskokwim School

District also opened several Yup'ik First Language (YFL) schools to accommodate the high number of kindergarten students entering who were more proficient in their heritage language than they were in English (Barnhardt, 1999). The YFL schools offered instruction primarily in the Yup'ik language with a gradual introduction of English language instruction in essence offering a dual language immersion program where English is considered the second language.

Kuinerrarmiut Elitnaurviat, one of the schools within the AOTE program, was so engaged in the community that it had become a true community center. Each day the school's announcements, *Daily Bulletin*, was faxed to the tribal office, community clinic and store (Barnhardt, 1999). This helped keep the community up to date on the school activities and vice versa. Included in this bulletin was the Yup'ik thought of the day written in the Yup'ik language. Community members were also hired by the school to prepare lunch each day and students have the option of staying or going home for lunch (Barnhardt, 1999).

Students in the elementary portion of the school performed their work in the Yup'ik language for all subjects and this work was displayed for visitors to see (Barnhardt, 1999). The school employed both an English Language Leader (ELL) and a Yup'ik Language Leader (YLL) to support the teachers during the day. Each grade level received support in both languages throughout the day in all subjects (Barnhardt, 1999). The school district also implemented an enhanced curriculum to engage the Yup'ik ways of knowing that was developed with the help of community elders who also assisted with some of the teaching (Barnhardt, 1999). This curriculum extended to the high school level as well where students took the Yup'ik Life Skills class that focused on traditional skills and activities including drum making, dancing and kayak construction (Barnhardt, 1999).

The science courses in the district used an approach that weaves both traditional ways of knowing and western models of science together. "Ecology is one of the required science courses that has the potential to help students meet the Alaska science standards while at the same time allowing them to use what they are learning as a real tool for understanding and helping to address local and regional science concerns" (Barnhardt, 1999). Through this ecology class students were given the opportunity to focus on local environmental issues such as local salmon populations through hands on projects (Barnhardt, 1999).

The results of this program showed promise in increasing Alaska Native achievement in the classroom. In the rural areas where this program was heavily implemented, the graduation rate for Alaska Natives rose to approximately 90% (Barnhardt, 1999). In urban areas where the program was not implemented as deeply or not at all, the graduation rate for Alaska Natives stood only at 65% (Barnhardt, 1999). This difference could be partly attributed to the success of the AOTE program. Beyond graduation rates, Barnhardt also reported in her study that in the 11th and 12th grade students in the Lower Kuskokwim School District who attended YFL schools, on average, had higher reading scores on standardized tests than those who did not (Barnhardt, 1999).

The AOTE program utilized culturally responsive teaching by knitting traditional teaching with Western methods to create a model of education closely resembling Aikenhead's theory of border crossing. For instance students learned the Yup'ik language throughout the day in all subjects (Barnhardt, 1999). This made the border crossing explicit by introducing new concepts in a cultural context familiar to the students. The inclusion of cultural experiences in the curriculum provided an opportunity for students to utilize the traditional knowledge brought by community elders to gain skills that would benefit them in the contemporary world without erasing their culture. The bridging of indigenous and Western educational models was highly successful for this school district which showed great improvement in tests scores as well as increased graduation rates.

Implications

It is highly effective, as evidenced in these cases, to engage Native American students through Native science toward their holistic learning of both science and community, with outcomes that are not only better than more traditionally Western approaches to learning science, but also that are more holistically engaging of youth and connecting them into their communities. These programs all showed that when teaching science within the classroom, the teacher could first introduce concepts through cultural approaches that resonated with Native science and its emphasis on the interconnectedness of all beings and things (Cajete, 2000). We note the teacher had to have knowledge of the local culture in order to engage it. For instance, the Native Science Connections Research Project provided an example of how to validate the students' personal and cultural ways of knowing and then facilitate their border crossing across sciences. The teacher first introduced the concept by engaging the local culture's traditional knowledge and then presented the Western model followed by an opportunity to bridge these two concepts together (Gilbert, 2008). Bridging the gap allowed for the students to see how the new concept fit within their own cultural lens and learning.

By explicitly facilitating these border crossings, teachers validated the knowledge the students already understood through cultural means and then expanding on them by providing new learning from a Western paradigm. The Ya Ne Dah Ah School taught Western concepts using a local language context while engaging local resources and knowledge to bridge the gap between Western and Native science. The STAR School used a similar model, and both emphasized the indigenous knowledge rather than the Western concepts being learned.

The AOTE and Bioexploratory programs illustrate how Native science was used with indigenous students to increase both participation and achievement. In a data-driven educational world, tracking student engagement and achievement are necessary in order to implement any new programs. The Bioexploratory program found that using Native science methods with indigenous students increased student engagement when compared with more textbook-based learning. Similarly, AOTE found that engaging Native science in the classroom could lead to greater achievement for indigenous students. It is important to note that these programs did not subtract either the students' cultural ways of knowing or the new Western concepts, but rather used them in unison to promote learning, engagement and achievement for indigenous students.

These programs all share an important emphasis on engaging the local community. In all of the examples the programs meticulously engaged community resources. Each program brought in the local community elders as teachers and guides to instruct the younger generation, one of the core aspects of Native science. Engaging the local resources and community brought the learning to a personal level for the students as they could see how it could be applied to their everyday life.

These programs highlight several important implications for classroom teachers.

1. To engage Native science in the classroom requires that the teacher have working knowledge of local indigenous culture. Utilizing this knowledge will help the students to cross cultural borders and bridge the gap between Western and Native science.
2. Native science can be used within the classroom to validate students' cultural identities and supplement the Western science curriculum creating a pluralistic science paradigm.
3. Devoting time and resources to Native science does not hinder the growth of indigenous students in their learning of Western science concepts.
4. Community engagement is key to successfully implementing a Native science curriculum.

Concluding Thoughts

The most successful instances of Native science implementation are community based (Barnhardt, 1999; Goulet and Goulet, 2015; Munroe, Borden, Orr, Toney and Meador, 2013; Seelau, 2012). This method requires real community engagement at all levels of education from classroom decision-making to curricula decisions. These programs are guided by local cultural concerns (Goulet and Goulet, 2014) and led by community members who can facilitate learning in all planes of human existence as illustrated in the cited programs. We wonder about the feasibility of a "pre-packaged" Native science curriculum, as every community is unique and faces unique challenges. Instead, we suggest approaches similar to the ones we have reviewed here, that are deeply contextual and respectful of local customs, cultures, and elders. In these cases, Indigenous students saw themselves, their elders, and their ancestors, in science, and it was thus meaningful. Bridging the gap between Western and Native science by engaging Native science within the classroom can thus help students to see how they fit into science paradigms.

This gives rise to question of how a Native science curriculum would benefit indigenous students beyond high school. In his interviews, Varma (2009) reported that the major challenges facing indigenous students in higher learning institutions are economic factors, social factors and cultural factors. Some indigenous students reported that the lack of job opportunities in indigenous communities in the science and technology fields compelled many indigenous students to abandon STEM fields and higher education. These economic pressures are exacerbated by other cultural influences as well. "The cultural discontinuity experienced by Native Americans in institutions of higher education is seen as creating obstacles for them to do well in science and engineering fields, including CS [computer science]" (Varma, 2009). This discontinuity stems from the cultural pressure to maintain tribal traditions and values that are often in conflict with Western preferences for individualism and market competition, the kinds of preferences for property rights, for instance, mentioned in the introduction.

Using the current model of education, the answer is to simply provide more opportunities for indigenous people to experience science-related activities. This mode ignores the larger cultural factors and discontinuity that act as barriers for indigenous students. When Native science is implemented these barriers can be examined and negotiated through the "border crossings" advocated for by Kawagley and demonstrated in several cases. Fusing Native and Western science together in the classroom can lead toward the discovery of ways in which the cultural Native science of the community can be bridged with Western science to create new STEM opportunities in the community. Educators practicing culturally relevant teaching, community members, and students can work together to examine local issues and then devise ways to engage both Western and Native science to engage the natural world.

Such a holistic approach could, quite possibly, help the Western scientific community with its problem of defining "scientific literacy" by recognizing the interconnectedness of all things and without false separations and dichotomies as they are often presented in Western science. This begins to speak to a bigger issue. What happens when Native science is taken beyond Native populations? There are many questions to engage here. Can more Western students be exposed to and respect the ancestral wisdoms of Native populations? Can wisdoms be reclaimed and re-engaged in ways that might be holistic and healing for all people, in a way that would not promote deeper settler colonialism (Tuck & Yang, 2012)? A question for researchers: Can scientists and science educators look toward a very different paradigm and perhaps decolonize their own approaches to science? We look at the state of the planet and believe it, its creatures, including its people, are in desperate need of healing. Perhaps only looking back toward ancestral wisdom which has facilitated survival is one of the only ways to look forward.

We argue implementation of Native science approaches to education for all should be considered seriously. Working to make changes to teaching methods is a complex process that will likely take time and additional training. Research shows the intensity of change in a teacher's methods is directly related to the amount of professional development he or she has participated in (Roehrig, Dubosarsky, Mason, Carlson, & Murphy, 2011). Roehrig et al. (2011) found in their study that even after 80 hours of professional development, teachers' modifications of their methods was still superficial, and it was not until two years of professional development on the same topic were completed (approximately 180 hours) that meaningful change was observed. In order to make the changes necessary to implement Native science, teaching it will take many hours of professional development for teachers, if not also a major epistemological shift. To be clear, we cite Four Arrows (2003) in that we are not advocating "corporations or entrepreneurs to utilize indigenous knowledge but to encourage school teachers to follow the guidelines…as best they can. It is time for courage and fearlessness to take hold in all of us for the sake of all future generations" (p. 76). We believe now, more than ever, our concerns for protecting future generations is perhaps our greatest concern.

Further research regarding examining the implementation of Native science among indigenous communities remains critical, if not perhaps essential for the further development of Native science for all. Deloria (1999) explained, "The next generation of American Indians could radically transform scientific knowledge by grounding themselves in traditional knowledge about the world and demonstrating how everything is connected to everything else. Advocacy of this idea would involve showing how personality and a sense of purpose must become part of the knowledge that science confronts and understands" (p. 39). If indigenous students are engaged with culturally relevant teaching through Native science, it may validate their cultural identity and encourage them to continue in STEM fields. Utilizing cultural knowledge of the environment and connection to land, this new generation of indigenous scientists could lead the way in stopping the threat of climate change that threatens to wipe out humanity. It is with this hope that we recommend further study in the integration of Native science through culturally relevant practices and indigenous epistemologies to cultivate a new pluralistic science paradigm.

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