Place-Based Science Education for Indigenous Students

Place-based education (PBE) situates curriculum and instruction within the context of the geographic, cultural, and social spaces that students inhabit. PBE has been associated with the fields of geography, anthropology, art, architecture, psychology, philosophy, and history (Semken, Ward, Moosavi & Chinn, 2017). It is equally powerful as an approach to many aspects of science education, such as earth, ecological, and environmental sciences (Tuan, 1977).

A primary goal of PBE is to promote deep learning in one or more content areas, but equally important is the goal of supporting students to succeed in sustaining the "cultural and ecological integrity of the places they inhabit" (Chinn, 2012, p. 327, citing Woodhouse & Knapp, 2001). In service to this second goal, PBE is consciously used to increase students' attachment to place and enhance their sense of the meaning of place (Chinn, 2012). As a response to the vast under-representation of Indigenous peoples in science, technology, engineering and mathematics (STEM) fields, PBE has been a vehicle for increasing the participation and retention of Indigenous students in STEM education (Bang & Medin, 2010). Speaking of the "unhappy experience of schooling for a disproportionately large part of [the Māori]… population," Penetito (2009, p. 7) suggests that their education within mainstream institutions could be greatly improved by a place-based approach. "There is a clear link, I will argue, between problems of spatiality (identity and location) within mainstream education, to which the philosophy and practice of place-based education is a solution" (Penetito, 2009, p. 7).

In mainstream US education, the notion of linking instruction to place as a way to engage students goes back to the time of philosopher John Dewey, who encouraged teachers to situate instruction in local context and culture (Dewey, 1916). And deep concerns for the environment and ecologies of place were reflected in mid-twentieth century programs that continue to this day, such as Foxfire (Wigginton, 1972). There have been many tangents into place-based education, and interest in this approach continues to be strong today. Still, to be authentic, PBE must recognize the "meaning [imbued in a place] through human experience" (Williams & Semken, 2011, p. 50).

In this monograph, we focus on the potential of PBE for Indigenous students who are learning science. It should be noted that the science knowledge about a place, whether

Indigenous or Western, is only one aspect of place meaning. In the case of Indigenous peoples, who traditionally interpret the world using a holistic lens (Champagne 2014; Fixico 2013; Foley 2003), science is viewed as embedded in cultural and historical meanings and not as knowledge organized separately for examination in the way that Western science is (Cajete 1999). But it must be said from the outset: Western science and science teaching *are* cultural. They reflect a particular worldview. They are no more legitimate and no less culturally situated than Indigenous approaches to science, or ethnoscience (Bang, Medin, & Cajete, 2009).

Place-Based Education in Indigenous Communities

Place-based education, which lends itself well to interdisciplinary instruction, has a long history in Indigenous communities in the United States and around the world, in K-12 as well as post-secondary settings (Kawagley & Barnhardt, 1999; Penetito, 2009). A broad concept of place-based education includes defining "place" in terms of both environment and people—current and historical, geological and cultural—and dynamically changing relationships among these elements. As an example, in his seminal piece, *Wisdom Sits in Places: Landscape and Language among the Western* Apache, Keith Basso (1996) explains that "Apache constructions of place reach deeply into other cultural spheres, including conceptions of wisdom, notions of morality, politeness and tact in forms of spoken discourse, and certain conventional ways of imagining and interpreting the Apache tribal past" (p. xv).

Indigenous educators have long embraced teaching that is rooted in students' homelands as authentic and relevant (Semken et al., 2017, p. 549; Cajete, 2000). In fact, sense of place is fundamental to Indigenous identity. According to the Assembly of Alaska Native Educators (2003), with schools in Alaska considered "value- and identity-creating institutions" (p.2), they should make conscious efforts to mirror the values and knowledge of their communities. Factors such as culture, language, tradition, and place continuously inform student knowledge, filial and community relations, communicative activity and other elements of daily life. This cumulative identity regulates whether and how students benefit from the academic programming they receive. Complications can arise for Indigneous students in US schools when mandated educational practices do not align with their cultural ways of knowing and learning.

For example, a global approach to teaching about scientific phenomena may not successfully engage Indigenous students (Williams & Semken, 2011).

Historically, Indigenous elders and others have utilized culture-based learning, context-adaptivity, and place-based learning to pass on to new generations the knowledge, traditions, and practices of their peoples. Today, as Indigenous communities and educators assert their sovereignty, they "reintegrate their own knowledge systems into the school curriculum as a basis for connecting what students learn in school with life out of school," creating a "pedagogy of place that shifts the emphasis from teaching about local culture to teaching through the culture" (Barnhardt 2014, p.113).

Although Indigenous communities vary culturally and, of course, in terms of the physical landscapes they occupy, they tend to have strong common values of respect for the natural environment and reverence for places with cultural meaning. Successful PBE in Indigenous settings emphasizes learning not just *about* but *from* the land; promotes respect and responsibility for the land; focuses on real-world, important questions from the community's perspective; is situated in local values and draws upon local knowledge; is student-centered and fosters independent decision-making; uses and builds both oral and written language skills; and develops broad cognitive skills and deep knowledge through an inquiry approach. Above all it reflects a relationship between the land and human community. An exemplary model of effective Indigenous place based-programming is found in Figure 1.

Figure 1 : **The STAR School: Effective Indigenous Place-based Programming**

> *The Service to All Relations (STAR) School in Arizona is a K-8 Charter School located near Flagstaff and adjacent to the Navajo Nation, with a student population that is predominantly Navajo. Following the tenets of PBE, the program* ***honors the physical place where students and their families have lived sustainably for centuries. T****he local Navajo community is essentially an extension of the classroom, as its history, culture, ecology and values drive the academic program. Place-based lessons connect to everyday living and cover activities ranging from using a hooghan (traditional home) to study principles of mathematics, to commitment to sustainable living as active stewards of the environment growing food for the local populace, to using advanced technology to examine issues important to the community and then developing and carrying out community service projects. Traditional interactive protocols learned from an early age are incorporated in daily*

> *school communications and extend to disciplinary approaches that draw from heritage practices. These strong Navajo values and structures support identity and character development, preserve Navajo traditions (such as living in balance) and promote being of service to one's relations. Core school values—sustainable living, sovereignty through service, preservation of traditions, perpetuating physical and emotional health-- all benefit family, school, community and the Nation*[1].

A spate of recent efforts by geoscience science educators and researchers has used place and culture as the basis for instruction on a range of important topics in geoscience, many of them in Indigenous settings (Semken et al., 2017). Among these are an undergraduate course on Indigenous Physical Geology at the Diné (Navajo) Tribal College in Tsaile, Arizona; a similar course expanded to incorporate the perspectives and geography of a more diverse student body at a major university in the southwest; and a place-based natural science curriculum resulting from a collaboration between the Myaamia (Miami) Tribe and the National Aeronautics and Space Administration (Semken et al., 2017).

Place-Based Education in Indigenous Communities: Potential and Concerns

Engaging Indigenous Students and Promoting Indigenous Values

For those seeking ways to promote the academic success of Indigenous learners, PBE makes eminently good sense because it can meaningfully engage students in learning while supporting the values of Indigenous communities in the "sustainability of lifeways in the developed world" (Semken & Freeman, 2008, p. 1043). As illustrated by the STAR School's program, PBE has the potential to reflect the values and goals of Indigenous communities, such as respect and responsibility for the land, interconnectedness of all things, and the unity of humans and nature, nature and culture (Chinn, 2015). Adapted to the goals of students and community, the meaning of PBE can be transparent to all stakeholders. It can be intimately linked to students' prior knowledge and community funds of knowledge. And there is no reason that instructional methods in PBE cannot be flexible, responsive to students' ways of learning, interacting with others, and preferences for demonstrating what they have learned. "In place-based learning, student questions and interests often serve as the focal point, thereby heightening student interest, content relevance, and interconnection of ideas" (Adams, Miller, Saul, & Pegg, 2014, p. 2).

A major means of making instruction meaningful and engaging is the use of students' heritage languages and home language varieties. Such language use may be enhanced by close connections with community, particularly persons able to model heritage language. Because it lends itself to multidisciplinary instruction, integrating concepts and methods, PBE is in greater harmony with Indigenous approaches to learning and organizing knowledge than a traditional Western approach that isolates disciplines and treats concepts out of context.

Education for Sustainability as Envisioned in the Next Generation Science Standards

The concept of sustainability usually entails notions of preserving natural resources and the environment through judicious use of resources and actions to protect the earth and its inhabitants. "[E]ducation for sustainability is shaped by competing values and informed by knowledge from a variety of disciplines that come together to consider the present and future state of human society, nature, and the planet" (Crocco, Marri, & Chandler, 2013, p. 170). The Next Generation Science Standards (NGSS) call upon students to demonstrate understanding of "human sustainability" (in relation to earth and space sciences). Students are expected to model solutions to problems of climate change, resource management, and preservation of biodiversity, among others.

It would seem that values common to Indigenous groups related to protecting the earth and anticipating how behaviors of living people are likely to affect future generations are in natural harmony with sustainability education. However, the NGSS approach sustainability from a global perspective, with little recognition of the meaning of individual places and the cultural, social, historical, and economic contexts of those places and how those contextual differences necessarily affect how people solve problems of sustainability (Feinstein & Kirchgasler, 2014). Attention to cultural and social contexts is largely limited to footnotes and some suggested activities for diverse settings through case studies presented in Appendix D, which is available only online. The approach represented by NGSS risks advancing "an oversimplified idea of sustainability that diminishes its social and ethical dimensions" (Feinstein & Kirchgasler, 2014, p. 123). It also reflects the view that universal solutions to sustainability problems can be solved by effective uses of technology, again, through application of primarily or exclusively science knowledge—ignoring how local cultural, social, and economic factors affect how people solve

problems. Nor do these standards consider the ethical and political dimensions inherent in solving big problems of sustainability (Feinstein & Kirchgasler, 2014).

Hence, educators looking to the NGSS for guidance about promising STEM education in Indigenous contexts will not find much. They will have to figure out how to facilitate students' learning of important science concepts embodied in the NGSS through their own knowledge of how sustainability problems play out and can be realistically addressed in their local contexts. For instance, addressing questions about the use and conservation of water involves an understanding of local needs and values, perhaps even competing interests that must somehow be reconciled. Place-based education on any important topic can bridge between the universal approach of the NGSS and local perspectives, interests, and needs.

What is needed is an educational approach that is both more realistic and compatible with Indigenous values, ideally both interdisciplinary (drawing upon both natural science and social science) and linked to local places and people. Social studies education is a natural place to look for general ideas of how to move from the global perspective of the NGSS to a more place-based approach, for example through using "issues-oriented pedagogical approaches" (Crocco et al., 2013, p. 170).

Importance of Access to Local Resources

Tribal communities and organizations can assist teachers and schools in learning about the cultural traditions and practices associated with the local environment. For instance, some school districts in Alaska host cultural immersion camps at sites that have particular meaning to the community (i.e., traditional hunting grounds, site of an old village, historical meeting place, etc.) (Assembly of Alaska Native Educators 2003; Barnhardt 2014). These activities bring together teachers, students, parents, and elders to heighten collective local and cultural understanding. According to Semken et al., (2017), many such communities have their own environmental management and protection agencies with concomitant expertise that can be tapped to design PBE appropriate for students (p. 551). These kinds of resources along with human resources represented by community members, in particular Elders, should be identified and tapped by the school community in culturally-appropriate ways.

Tapping cultural expertise means venturing well beyond community resources and the inclusion of members of a culture. It means that community preferences will be honored and authentically incorporated in the assemblage of educational interventions. As Nelson-Barber and Johnson (2016) observe, "most educational interventions have considered only the values and norms of the dominant, middle-class, white culture in their identification of "best practice"—leading to a standard that does disservice to both the scientific inquiry process and the students of color, who must stretch beyond their cultural repertoires to adapt to unfamiliar norms (p. 44). By incorporating the values, styles of learning, relationships, protocols, behaviors and so forth, of Indigenous communities, PBE likely offers the best promise for formalizing the incorporation of alternative perspectives in schooling.

Teachers will need to look beyond the standard sources of cultural archives found in school libraries. Historically Indigenous communities have been oral cultures, with much knowledge captured in "oral literature," such as place names, proverbs, and lengthy narratives (Basso 1996; Chinn, 2015). Though they may not have used an orthography, many of these cultures employed symbolic representations, such as petroglyphs, to capture important information and timeframes. Other Indigenous cultures, for example, the Cherokee and Kānaka Maoli (Native Hawaiians), have long traditions of written language dating back to the early 19th century. Cherokee Chief Sequoyah created a syllabary to represent the Cherokee language (ᏣᎳᎩ ᎦᏬᏂᎯᏍᏗ *Tsalagi Gawonihisdi*), which continues in broad use today. Early on, in Hawai'i, Kānaka were exposed to Latin transliterations of the Hawaiian language in the religious texts and hymnals produced by early missionaries. Following the lead of the Hawaiian Royal Family, who championed a vibrant culture of literacy among their populace, Kānaka have reclaimed responsibility for producing a more authentic and preferred orthography. Today, weekly Hawaiian language articles in local newspapers and Hawaiian language publications contribute to keeping the language alive. Similarly, at the University of Hawai'i-Mānoa, Hawaiian language newspaper articles from generations past are being accessed by community members, University faculty, scientists and educators for place- and culture-based geographic, geological, and cultural history materials development (Businger, Nogelmeier, Chinn & Schroeder 2018).

The Complexity of "Place:" Who Defines It?

On the surface, "place" seems to mean a definable geographic segment of the world. But, in reality, "place" is not just part of the physical landscape: it is a social construct (Semken et al., 2017; Tuan, 1977). As noted earlier, human beings have feelings about and attachments to pieces of the world that they define as a particular places with their own meanings (Cresswell, 2007). "Hence, a place is any locality that becomes imbued with meaning through human experience…[citing Van Eijck & Roth, 2010]… a 'lived entity' formed of the interactions between people and the physical environment at a particular moment in time (Semken, et al., 2017, p. 543). Basso (1996) contends that "senses of place, while always informed by bodies of local knowledge, are finally the possessions of particular individuals" (p. xv-xvi). Within any cultural community, different meanings will be attached to different places. Some will be designated as sacred places, with attendant expectations and rules for how to behave there (Meyer 2017). Others will have cultural or mythic meaning as the location where ancestors settled thousands of years ago (Basso 1996; Osorio, Muneoka & Fujikane 2015) or the area where agriculture thrives best and provides sustenance to the group (Sarmiento & Hitchner 2017).

One devastating consequence of colonialism in Indigenous contexts is the appropriation of "interesting" Indigenous sacred places as tourist sites. Carlos Mamani Condori, an Aymari Indian writer and researcher from Bolivia, describes how the Portuguese looted a sacred site, Tiwanaku, of its monoliths and then walled it in to serve as a tourist destination. "[Now] [t]he Aymara people have to pay an entrance fee to visit the ruins as tourists where they listen to invented accounts of the meaning of our history" (cited in Hubert, 1994, p. 10). Here, the cultural and historical meanings of place have been distorted—an outcome risked whenever an outside group interferes with the autonomy of a local group. Consider how the Grand Canyon, sacred to many Indigenous groups, has been infused with different meanings by the Department of the Interior (National Parks), geologists who have studied it, and tourists who regard it as a natural wonder to which they should have access (Williams & Semken, 2011). And let us not omit the continuing Kānaka Maoli (Native Hawaiian) opposition to the Thirty Meter Telescope on sacred Mauna a Wākea (also known as Mauna Kea) (Meyer 2017; Osorio et al., 2015). The land on which the telescope is to be built is held in trust for Kānaka Maoli and has

already been polluted, according to opponents, by the 13 telescopes built to date, which interfere with cultural and religious activities and serve as a constant reminder of western colonization. Still, not all Kānaka contest the installation of the telescope, citing pride in their history of navigation and use of astronomy (Overbye, 2019).

Cases like these and the one Condori describes are not unusual in Indigenous contexts; and to understand how and why Indigenous peoples may be apprehensive about place-based education designed by outsiders, they must be appreciated. In nearly 100% of Indigenous settings, educators from outside the community have tended to dominate and wittingly or unwittingly imposed their own meanings of place, as they have designed place-based education. As Nelson-Barber & Johnson (2019) explain, increased federal control over K-12 education through policies such as *No Child Left Behind Act* (2002), its replacement the *Every Student Succeeds Act* (Sharp, 2016), and the promotion of uniform ideas of excellence by the *Common Core State Standards* and *NGSS* have made it increasingly difficult for Indigenous communities to make deliberate decisions about education design from a place of alignment with their own Indigenous knowledge systems.

Addressing Curriculum, Instruction, and Assessment in Place-Based Education

It may seem easiest to focus on curriculum, that is, the content of PBE, including how it relates to relevant content area standards embraced by national or state leaders in a discipline. However, implicit in all the descriptions of PBE above is attention to the processes of instruction and assessment. Beliefs about how students learn and approaches to curriculum, instruction, and assessment are all grounded in cultural perspectives that are not always explicitly identified. For instance, from an Indigenous point of view, learning occurs through personal relationships. In the classroom, this often takes shape as collaborations between and among students (e.g., Nelson-Barber & Dull, 1998). Science itself is a cultural endeavor; ecological knowledge is developed through close observation and place-based subsistence activities that are meaningful to the cultural group (Chinn, 2015). “[S]seeing science as a body of knowledge derived from (acultural) practices is a very impoverished view that leads science educators to focus on methods and facts rather than motivation, fascination and personal

relevance" (Bang & Medin, 2010, p. 4). Figure 2 summarizes suggested characteristics of PBE that make it appropriate for Indigenous students.

Figure 2 : Characteristics of PBE Curriculum, Instruction, and Assessment for Indigenous Students

CURRICULUM

- is contextualized in terms of physical landscape as well as cultural and historical landscapes
- is based on local concerns and values regarding "place," as defined by teacher, students, and community
- incorporates real-world questions and issues important to the community
- is based on place(s) that afford(s) personal, emotional connections
- links to local, state, and national standards
- is broad enough to provide multiple ways for students to connect via cultural knowledge, values, and goals

INSTRUCTION

- provides direct experiences in and about local natural and physical settings (Semken & Freeman, 2008, p. 1043)
- affords rich cognitive activity, is open-ended, allowing for student inquiry
- draws on students' funds of knowledge as a foundation for new learning and relates academic knowledge to community knowledge, i.e., connects to students' prior knowledge and experiences
- promotes multiple interpretations of place meaning and different ways of knowing place (Semken & Freeman, 2008)
- links both to past and present (with concern for the future), recognizing relationships among land, people, history, and culture
- fosters respect and responsibility for the land
- provides opportunities for learning *from* the land as well as *about* the land
- uses culturally-responsive methods (reflective of students' interactive styles, orientation to the classroom group, roles and relations among peers and between students and teacher)
- includes intergenerational learning involving teacher, peers, elders and other community members
- links school discourse to family and community ways of using language, of talking about place and its meaning
- incorporates students' languages and language varieties in classroom and field activities
- promotes examination of different world views and knowledge systems

ASSESSMENT

- is transparent to students in terms of purpose and potential use
- links assessment closely to the taught curriculum

- allows for multiple ways of showing learning, including non-pencil and paper or keyboard, peer collaboration in presentations, verbal and non-verbal demonstrations
- uses interactional processes that are culturally harmonious
- uses open-ended formats (vs. multiple choice, true-false), if students show preference for this?
- allows for student choice in demonstrating learning (timing, format, language and language modality, individual and group participation)
- taps diverse representations of cultural and scientific reasoning
- produces accurate information that can guide student and teacher in future learning goals and instructional choices

Successful Place-Based Education Efforts in Multiple Settings

Though not abundant, there are programs devised to provide explicit illustrations of culturally appropriate curriculum, instruction, and assessment, and in which teaching and learning processes are culturally aligned. STEM content areas offer rich possibilities. For instance, *Math in a Cultural Context* is a series of supplemental curricula developed from ethnographic work. with Yup'ik elders and teachers in Alaska (See for example, Lipka, Hogan, Webster, Yanez, Adams, et al. 2005).This series focuses on everyday Yup'ik knowledge related to mathematical thinking and is directly linked to student's cultural experiences.

Yup'ik communities have always lived a traditional subsistence lifestyle—one that is optimal for connecting school STEM with their own lived experiences. From an early age youth immersed in their surrounding environment begin to acquire deep local, ecological knowledge that models problem solving and ways of knowing. Mathematical activities implicit in their everyday life ways (e.g., hunting, fishing, star navigation) include number and operations, patterns, functions and algebra, geometry and spatial sense, measurement, data analysis, statistics, probability, reasoning and proof, representation, and on and on. Teachers' linking everyday Yup'ik knowledge related to mathematical thinking to student's cultural experiences not only involves familiarity with local values and traditions, but also requires some understanding of culturally defined preferences for thinking and interacting. In other words, teacher's instructional approaches are rooted in Yup'ik learning and systems of problem solving, tapping into a more sociocultural dimension of student knowledge. The instructional principles underlying this program are applicable to science instruction as well.

Because knowledge construction is not simply an individual act, but something that occurs within a social and historical context, the focus of designing effective PBE extends beyond curriculum content to organizational structures, interpersonal communication approaches, and instructional tools, and how these reflect world views and values of the school and the intended students. Not only must teachers and curriculum developers be able to appropriately juxtapose subject matter content and sociocultural issues, they must be able to build from the cultural perspectives of the communities and groups involved. An index of "cultural attunement and conflict," i.e., whether teachers' instructional strategies are culturally effective, is the level of student participation (Gratier, Greenfield, & Isaac, 2009). If student engagement wanes, a teacher needs to take stock of why that might be the case. Even younger students can be asked (in small groups, for instance) whether they are finding instruction interesting, whether they understand what is being presented, and what might help them participate and understand more.

An educator in Hawai'i, Margarita Alo-Chu, designed an NGSS-linked instructional unit for grade 4 or higher on the Hawaiian watershed that is situated in the Hawaiian context and uses culturally appropriate methods (Alo-Chu, ND). Figure 3 gives a synopsis of the unit.

Figure 3. Hawaiian Watershed, Ahupua'a[2]

> *NGSS Disciplinary Core Ideas: MS LS 2: Ecosystems, Interactions, Energy and Dynamics*
>
> *Evaluate competing design solutions for maintaining biodiversity and ecosystem services*
>
> *The unit is intended to help students explore the purposes of watersheds , which are catch-basins for rain and condensate funneled into stream beds. In the conceptualization of ancient Hawaiians, the concept of "watershed" is broader, including "tide pools and ponds, near-shore waters along the beach, and the sea out to and including the coral reef" (Alo-Chu, ND, p. 3). Goals related to the development of intellectual excellence, sense of responsibility, commitment to community, and sense of belonging and total well-being are laid out in addition to the scope of science content in the unit.*
>
> *Instruction begins with a video introducing students to the Waianae Mountains watershed and wetlands and then goes on to elicit students' prior knowledge and engage them in the concepts, processes, and skills to be addressed in the unit. In the next several days, students take field trips to relevant sites and*

interact with cultural experts, scientists, and educational specialists. Familiar cultural practices such as the use of stories and learning from elders are incorporated in instruction. Students learn about the watershed system from both Western and Indigenous Hawaiian perspectives through place-based and experiential learning (Alo-Chu, ND, p. 3). The cultural history and meaning of place are explored.

Students are to be assessed through a variety of activities, including a research report, reflections, sharing knowledge at community events, a school fair or exhibition, and letters to political leaders or public service announcements related to environmental concerns.

The Ahupua'a unit is designed with a great many of the features of PBE content and instruction shown in Figure 2. Least-detailed are plans for assessment, as is often the case. Considering how students will be assessed early on in the process of designing instruction is important, particularly in terms of formatively assessing students' learning at key points in the instructional process, in order to revise instruction as needed to ensure learning goals are met (Ward, Semken & Libarkin, 2014). Preferred methods should vary according to local preferences for demonstrating learning (Trumbull & Lash, 2013; Trumbull, Sexton, Nelson-Barber & Johnson, 2015).

Issues to Contend With

Teacher Preparation and Professional Development

Teachers, particularly non-Indigenous teachers, cannot be expected to launch into effective place-based education in science without a grounding in the cultural values and knowledge of their students and an understanding of how their worldview differs from a Western one. It is not only coursework or workshops that can constitute professional development. Teachers' participation as collaborators in research can be a powerful source of professional learning (see, e.g., Lipka, Mohatt, & The Ciulistet Group, 1998; Trumbull, Rothstein-Fisch, Greenfield, & Quiroz, 2001). The potential for two-way learning is great, as university researchers learn from teachers about how any research question or intervention must account for local context.

To carry out effective place-based science education, a teacher needs a sense of the place that will form the focus of instruction, both in terms of its physical features and of its meaning to the people or peoples who have lived there over time, including the current cohort of students.

Teachers need to be able to contextualize instruction and understand students' needs (Chinn, 2012), but for non-Indigenous teachers or those who have not grown up in the place serving as a substrate for instruction, special preparation will be necessary. A critical issue that must be addressed if PBE is to be successful in Indigenous settings is the inclusion of both cultural experts and subject matter experts (Gibson & Puniwai, 2006). Cultural experts with scientific knowledge applicable to the locality are invaluable (Cajete 1999; Kawagley 2006; Medin & Bang 2014). Professional development can also be useful for Indigenous educators by supporting their empowerment as experts, helping them make their existing cultural knowledge explicit, and clarifying differences between Western and Indigenous science.

One issue that teachers need to anticipate is that Indigenous students with considerable knowledge of place and the science associated with place may not recognize knowledge embedded in their experiences as "science." In a study with which the authors were associated, upper elementary and middle school Alaska Native students interviewed sometimes questioned whether Native science knowledge, such as of animal behaviors in the wild, counted as science knowledge (Nelson-Barber, Trumbull, Sexton, & Johnson, in press). Likewise, they did not necessarily connect what they were learning via school science instruction and their own experienced-based science knowledge. A male high school junior said, "I don't think about what I learned at school [when using Native knowledge]. It is two separate worlds" (Nelson-Barber et al., in press, p. 8).

This state of affairs is not uncommon in Indigenous communities in particular--given the aggressive assimilationist structures these groups have withstood for centuries as "explorers, armies, traders, missionaries and teachers have imposed their world view and ways of living onto the peoples they encountered in their quest for colonial domination" (Barnhardt 2014, p.113). However, today sovereign Indigenous groups continue to reclaim and reinstate their own unique locally-grounded, place-based processes with a greater degree of self-determination.

Studies have shown that teacher preparation and professional development can result in teachers' increased understanding of and attachment to a place (Williams & Semken, 2011; Chinn, 2006; Chinn, 2012). In one study, 60 mostly non-Indigenous pre-service and in-service

teachers in Hawai‘i (pre-school through grade 12) participated in a five-day immersion professional development program on place-based science education in which they learned about both Hawaiian and Western approaches (Chinn, 2006). In this and another study conducted with 19 secondary mathematics and science teachers and administrators from the Far East and US (Chinn, 2007), educators' attitudes and ideas regarding Indigenous science changed to reflect greater understanding and acceptance. Teachers who had previously regarded Native Hawaiian science as less valid than Western science changed their minds.

The preparation and professional support of elementary teachers to teach science in culturally aligned ways is of special interest because (1) they often lack adequate knowledge and, hence, the confidence to teach science and (2) their approaches to science instruction are thought to affect students' declining interest in science over the course of the elementary school years (Adams et al., 2014). A promising university-based teacher preparation program designed for teachers who would be teaching in a local tribal community showed that using a place-based approach in methods courses was very effective in promoting teachers' "understanding of place-based approaches, their perceived ability, and projected intent to design and implement place-based STEM learning activities" (Adams et al., p. 1). So, the PBE approach may serve as a way to engage elementary teachers in building STEM knowledge and skills.

Presenting Both Indigenous and Western Views of Science

According to Aikenhead (2001), teaching a Western version of science is a cross-cultural endeavor. Teachers need to be able to explicitly support students' understanding of how Indigenous knowledge systems and Western knowledge systems differ and overlap by exploring multiple models of knowledge of the world with students. Indigenous knowledge has long been ignored or denigrated by Western educators (Aikenhead, 1997; Shizha, 2008). Indigenous approaches to developing science knowledge (inductive, based on experience and observation in context) may conflict with Western approaches (deductive, based on principles and generalizations). Yet, we are cautioned to " resist placing western modern science and Native science in an oppositional dichotomy because it has the effect of inappropriately simplifying both ideas of western modern science and Native science" (Bang & Medin 2010, p. 13).

Meaning should be co-constructed among students and teachers, as they explore similarities and differences between the two approaches and how to make choices about which approach to take, depending upon situational goals. (See Semken & Freeman, 2008, for an example of how educators cast the Diné view of geologic change as interactions between a dynamic Mother Earth and Father Sky, to bridge between Diné and Western views). Educators who regularly face the challenge of representing both Indigenous and Western perspectives, like those participating in a 2014 study in Hawai'i, report that "incompatibilities between science and local knowledge have presented no obstacle to their work" (Rudiak-Gould 2014, p. 17). Careful observation of phenomena is a common denominator of both approaches for instance. And modern methods of science instruction may begin with the observation of a problem in context.

The Ethical Dimension of Cross-Cultural Place-Based Education

The ethical dimension is often not explicit in discussions of how to provide effective instruction for Indigenous students. Yet, it is at the heart of concerns for fair, equitable, and excellent education for students whose families and ancestors have routinely been deprived of schooling of their own design that meets their own needs. In any effort to design meaningful place-based curriculum, instruction, and assessment for Indigenous students, making the ethical dimension explicit can support professional development providers and teachers to address such issues as the following:

- power differences between dominant culture teachers and administrators in contexts where Indigenous educators are in the minority
- accordance of appropriate status and respect for elders and other community leaders
- the appropriateness of research or evaluation techniques (decolonizing methodologies)
- the immediate and long-term impact on students' sense of belonging and empowerment of particular practices, such as standardized tests and other mainstream approaches to assessment

For non-Indigenous educators, cultivating awareness of these and other ethical issues will require a willingness to feel ignorant and uncomfortable and to remain silent at times. When

they are able to focus on their own goals of learning and promoting student success, they may find that they are energized and excited about the prospect of applying new knowledge to their practice (Trumbull et al., 2001).

Final Thoughts

The potential benefits of place-based education extend beyond improved science learning. Not least is the infusion of Indigenous-based principles of stewardship, ecological consciousness and ecological literacy into science education (Deloria, Jr. & Wildcat 2001; Penetito, 2009). PBE can promote greater inclusion of Indigenous students, social justice, and local sustainable development (Chinn, 2012). PBE will look quite different from place to place, but the common denominators will be evident— instruction situated in local context, addressing topics meaningful to students in culturally relevant ways, and tapping students' prior knowledge through rich cognitive activities. A measure that teachers can use to gauge its success is the degree of student participation. Because of its potential for multiple modes of participating, PBE should be able to engage students—not only those who have felt alienated from traditional Western instruction but also those with learning difficulties who may not succeed with narrow instructional approaches.

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End Notes

[1] For more information on the STAR School see Curtis, J. (Mar 6, 2017). Curious about place-based education? Let the STAR school be your guide. https://www.edsurge.com/news/2017-03-06-curious-about-place-based-education-let-the-star-school-be-your-guide and Arizona Charter Schools Association. (Apr 27, 2016). STAR School's Story Arizona Charter Schools Association. https://azcharters.org/star-schools-story/

[1] Ahupuaʻa is a historic Hawaiian system of land division stretching from the mountains, through the fertile midlands to the sea, following the natural boundaries of the watershed and providing the varied resources needed for communities to thrive.