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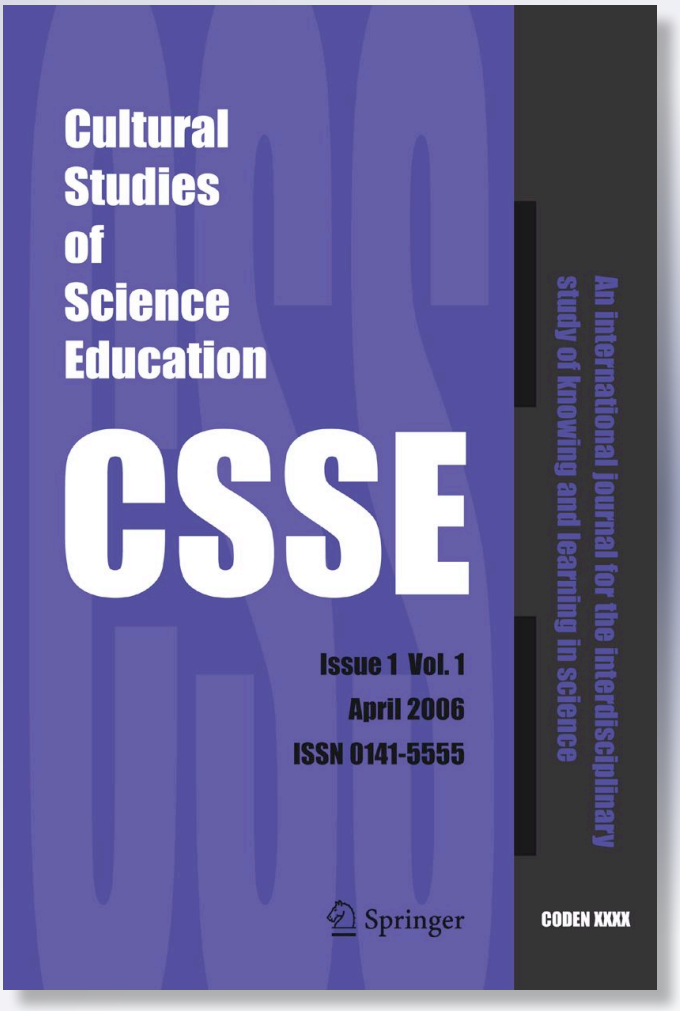


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# Effective practices for creating transformative informal science education programs grounded in Native ways of knowing

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**Abstract** There are a growing number of informal science education (ISE) programs in Native communities that engage youth in science education and that are grounded in Native ways of knowing. There is also a growing body of research focusing on the relationship between culture, traditional knowledge, and science education. However, there is little research documenting how these programs are being developed and the ways in

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which culture and Western science are incorporated into the activities. This study outlines effective practices for using Native ways of knowing to strengthen ISE programs. These effective practices may also be used to promote change in formal education. The authors combine an overview of current research in informal science education with personal interviews with educators engaged in ISE programs offered to youth both on and off tribal reservations as well as experts in Indigenous education. Participating individuals and programs included Native communities across the United States, including Alaska and Hawai'i. Keeping in mind that each community is unique, ISE programs that are grounded in Native ways of knowing will benefit by utilizing the effective practices outlined here as a guide for starting or strengthening existing ISE programs relevant to the needs of their communities.

**Keywords** Indigenous communities · Indigenous ways of knowing · Informal science learning · Native science · Science education · Effective practices · Traditional knowledge · Native ways of knowing · Indigenous youth

> When I weave a basket, I talk about the different dyes and how you make them and how the Oklahoma clay that we put on our baskets doesn't permeate the cell walls it deposits on the outside. It makes a very nice dye but if you cut through the reed you'll see white still on the inside of the reed, whereas if I make a walnut dye and if I use as my mordent alum and I use as my acid cider, that walnut dye will permeate the cell walls. You cut through the reed and it's brown through and through. Now what I've just described is the difference between osmosis and dialysis. That Western science calls those scientific terms is really wonderful, but it's not scientific terms if you are a basket weaver. Our culture incorporates so much of what people would call scientific knowledge and ways of thinking so naturally that we haven't parsed it out and put it in a book and said this is our science knowledge verses our weaver's knowledge. When I weave a basket I also tell the stories of the spirituality and not just the ways of which I dyed it. A basket weaver is as much a scientist, as an artist

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> and a spiritual teacher. We'd never think that you'd separate out just the science part, but you can't weave a basket without knowing the science.
>
> – Dr. Eric Jolly, Cherokee
> President of the Science Museum of Minnesota

The above quote demonstrates how a practice such as basket weaving can encompass both Western scientific methods and culturally relevant traditions. Though this marriage between traditional knowledge[1] and Western science has existed for centuries, research on Traditional Ecological Knowledge, Native ways of knowing,[2] and its integration into science and land management has been growing in the scientific community and science education field for just a few decades. Bryan Brayboy and Angelina Castagno posit that the practice of incorporating Native ways of knowing into education is here to stay, and is a "promising strategy for improving the education and increasing the academic achievement of Indigenous[3] students in US schools" (2008, p. 733). Many informal education programs for Indigenous youth incorporate Native language and culturally appropriate materials into their curricula. The goal of this project and paper is to outline the educational practices that have proven to be successful and effective for Indigenous informal science education programs. The effective practices summarized in this paper are a culmination of current research, interviews with educators, and the experiences of scholars who develop and teach culturally responsive informal science education programs with Indigenous youth. Our hope is that these effective practices will promote discussion, improve research on integrative and culturally responsive education, and help culturally based educational programs to achieve a high-standard of academics, resulting in sound educational practice in informal science education for Indigenous youth. The authors offer a set of effective practices determined through research and the experiences of quality Indigenous education scholars for the educational community to utilize, incorporate, and promote in the development and expansion of educational programs. Incorporating these practices can ultimately provide Indigenous youth with better opportunities to become professionals in science and environmental management, with a strong focus on their culture and the needs of their community.

## Why is culturally responsive education important?

The field of developmental science has often failed to recognize that the interaction between environment and development is variable, and can change how we look at, and measure the world. The environment in which a child is raised, the customs and practices utilized in childcare, and the mindset of a child's primary caregivers will greatly influence

[1] The term 'traditional knowledge,' used extensively throughout this paper, should be understood as knowledge about the natural world based on centuries of observation.

[2] Many terms have been used to describe the role of culture in education—'Traditional Ecological Knowledge', 'Native Science', and 'Culturally Based Education.' These terms usually do not encompass the entire Native worldview, only pieces of it. This article interchangeably uses the terms 'Native ways of knowing' and 'Indigenous ways of knowing' because they encompasses Native pedagogy, language, culture and knowledge.

[3] With respect to the language chosen by previous authors in their work, this article uses many terms such as 'Aboriginal,' 'Indigenous,' and 'Native American.' The authors recognize that everyone has an inherent right to define themselves.

that child's development (Super and Harkness 2002). What and how a child learns depends significantly on the context they live in, the experiences they have had and the ideas and values that they hold in their minds about a topic to begin with (Driver, Squires, Rushworth and Wood-Robinson 1994). In addition, social and cultural practices in a child's community and educational settings must be recognized as strong influences on how a child learns. Research indicates that children utilize information from their family and personal experiences as evidence in building arguments that clarify scientific understandings, to comprehend the physical world around them, and as a resource when learning new things in educational settings (Bell, Bricker, Lee, Reeve and Zimmerman 2006). Current research into learning and teaching suggests that learning begins with understandings, knowledge, skills, beliefs, and concepts that will significantly change and influence how we organize the world, and that if educators do not pay attention, new ideas and concepts that students develop could be very different from what is intended (Bransford, Brown and Cocking 1999). Educational programs that incorporate interactions between context and development can enhance the way that students learn and think about their environment. The effective practices outlined in this paper are based on the theoretical understanding that the knowledge students have and how they learn is influenced by their culture, context, and their everyday experiences.

Cultures around the world have different ways of looking at, experiencing, and relating to their environment, and hold different kinds of knowledge and interpretations of their surroundings (Berkes 2008). The ways in which we perceive the relationships in our environment, categorize organisms, manage our environmental resources, and place ourselves within these complex systems can vary greatly between cultures. For example, in a study that looked at how fundamental biological concepts are understood, Menominee participants were more likely to talk about nature holistically, spiritually, and traditionally, with an underlying respect for being part of nature, whereas European-Americans were more likely to talk about their role as caretakers and protectors of nature (Bang, Medin and Atran 2007). This illustrates how entire knowledge systems that develop out of different cultures can have fundamental differences and a strong effect on practice. Assumptions regarding the nature of time (linear vs. cyclical), or the determinants for what is considered a living being, can change the background information and beliefs that students bring with them into their learning environments, and consequently skew their interpretation of the materials being taught. Sharon Nelson-Barber and Elise Estrin (1995) point out that European-American culture tends to view science as evolving and moving through time linearly and sequentially into something more advanced and therefore better than what it previously was, whereas many Native cultures view time as circular and focus on interrelationships, observation, flux, and context, seeing progress in spiritual and ethical terms. Nancy Maryboy, David Begay and Lee Nichol (2006) echo this idea by identifying a linear perspective of Eurocentric epistemologies and a cyclical paradigm of traditional knowledge as one of the key fundamental differences between the knowledge systems that have developed from these two cultures.

Despite these differences, in recent years many Indigenous ways of understanding about the world have become accepted by scientific experts and are considered as adding value to science. For example, culturally transmitted traditional knowledge about caribou populations that has been shared for centuries between the Inuit, Cree, and Dené peoples of Northern Canada has helped to shape modern resource management practices regarding caribou populations today (Berkes 2008). Traditional knowledge is rooted in observations made over thousands of years, shared over generations, and valued by a particular cultural group. Gregory Cajete (2000) states that Native science is "based on the perception gained

from using the entire body of our senses in direct participation with the natural world." Some examples include: medicinal plant uses; understanding of growth cycles and interrelations of species; cosmology and star knowledge especially in navigation; understanding weather patterns; and the technology and physics of building tools and shelter like the kayak and tipi. Many scholars are thus beginning to value Indigenous ways of knowing and speculate that in order for science education to become truly culturally relevant, it needs to be more culturally inclusive (Patchen and Cox-Peterson 2008).

The objective for most culturally relevant science programs is not to put Indigenous knowledge and Western knowledge in opposition to one another, but to extend knowledge systems and find value and new perspectives for teaching and learning from both (Brayboy and Maughan 2009). In one example, Anaru Wood and Brain Lethwaithe (2008) note that in the past, Western science challenged Maori worldviews and beliefs in New Zealand's schools. Now, culturally sensitive science education programs in some schools use contemporary science to confirm and validate, rather than dismiss, traditional Maori knowledge. The goal is to promote and encourage both cultural and scientific knowledge in the classroom, creating students who are academically prepared and competent in both mainstream and tribal societies (Brayboy and Castagno 2008). Mi'kmaq elder, Albert Marshall, offers "Two-Eyed Seeing" as a means to build bridges and "to help these cultures find ways to live in mutual respect of each other's strengths and ways (Hatcher, Bartlett, Marshall A., and Marshall M. 2009)." Through Two-Eyed Seeing students may learn "to see from one eye with the strengths of Indigenous ways of knowing and from the other eye with the strengths of Western ways of knowing," and to use both eyes together. By integrating multiple ways of knowing into science classrooms, students will learn the value of traditional ways of knowing and Native language, learn to utilize a conceptual ecological perspective, and acknowledge that learning and understanding are part of a complex system that includes student experience, culture, and context, as well as mainstream materials that are taught in the classroom.

Multiple theories exist regarding the benefit of culturally relevant science education. William Cobern (1996) challenges the science teaching strategy of conceptual change, which concentrates on students adopting a scientific worldview because it is ultimately more plausible and credible than students previously held conceptual understanding. He addresses a concern that teaching science through conceptual change can lead to an unwarranted change or a dismissal of science for students whose worldview comes into conflict with the science concepts being presented. Indigenous youth in contemporary American science classrooms are faced everyday with circumstances where they are asked to leave their Native conceptions of the world behind. Trudy Griffin-Pierce (2000, p. 315) describes how this issue affected a Navajo student whose teacher's belief system conflicted with that of his Elders. He struggled between the choices of dissecting a frog—"should he focus on the precise measurement of each part of the frog's anatomy?" or honoring his Elders' reverence towards the frog—"should he step back to see the holistic overview of symbiotic relationships." This situation can create hazards for many students, hurt their self-esteem and sense of self-efficacy, and ultimately inhibit their learning (Aikenhead and Jegede 1999, p. 269). Glen Aikenhead (1996) argues that if school science is at odds with a student's everyday understanding of the world, science instruction may force them to abandon or marginalize their traditional ways of knowing, resulting in assimilation followed by the oppression of one's culture. As Ann Ryan notes, assuming that Western science has authority over other ways of knowing can lead to censorship of knowledge outside the Western worldview; in this way, science education contributes to a "cultural

invasion" (Ryan 2008, p. 684) The "border crossing" model posits that teachers need to recognize that learning can be a cross-cultural event.

Discussion regarding border crossing, as described by Lyn Carter and Nicolas Walker (2010), requires sensitivity to the many intricacies and complexities inherent to "boundaries in flux." Carter and Walker emphasize the necessity of this path of action towards promoting epistemological justice between diverse knowledge systems. Teachers can help students to negotiate this "border crossing" by creating culturally relevant frameworks for students to help them make a connection between mainstream science and their culture (Aikenhead 2001). At the Blackfeet Native Science Field Center, Indigenous youth learned most effectively about Western science concepts, such as plant structures and functions, when they began with cultural knowledge of plants (Augare and Sachatello-Sawyer 2011). Blackfeet language and traditional knowledge reinforced meaning and importance of the lessons for the students. In this way, traditional knowledge can be combined with various fields such as ecology, botany, or biology, and students can gain access to these scientific topics without losing sight of their cultural identity (Aikenhead 2001). Jennifer Adams (2010) incites us to further engage in conversations regarding the necessary steps to avoid repeating the abuses of colonialism. She emphasizes "encouraging indigenous knowledge systems inside the classroom, by embracing and valuing them, and blurring the "borders" artificially separating the classroom and community."

Youth need assistance to navigate differing worldviews. The Students' Multiple Worlds Study examined how students negotiate the differing contexts they live in such as friends or peer groups in their classroom and school, and within the context of their culture and their family (Phelan, Davidson and Cao 1991). Students who had no direct assistance negotiating the multiple contexts that they live in were only able to manage transitions between them smoothly when the culture and contexts were found to be similar (Phelan, Davidson and Cao 1991). This study found that with the help and support of educational programs that take multiple worldviews and culture into account, Indigenous youth are better prepared to transition between life at home or in their communities and life in academic settings and in their professional careers. Annemarie Hatcher and Cheryl Bartlett attest that an educational multiculturalism utilizing cultural bridges such as "Two-Eyed Seeing" in the classroom "is of benefit to all students, regardless of ethnicity as a preparation for their entry into inclusive workplaces or post-secondary education (2010)."

## Collective strategies across Indigenous education programs

Every Indigenous community is unique-with a distinct culture, history, and body of traditional knowledge (James 2006). In order to be effective, it is important that educational programs are tailored to a community's specific local culture and needs. However, there are some effective collective strategies used by mathematics and science education programs for Indigenous youth that have been documented in previous studies. These strategies show how Native ways of knowing can add value and improve academic success for Indigenous youth. For example, the Mid-continent Research for Education and Learning organization found that curricula and practices that acknowledge and build on traditional and everyday mathematics are associated with improved academic success for Native American students (Apthorp, D'Amato, and Richardson 2003). In another example the Alaska Rural Systemic Initiative developed and utilizes the Alaska Standards for Culturally Responsive Schools to promote an increased connection between what students experience in school and what they experience outside of school (Hill, Kawagley, and

Barnhardt 2006). Their Final Report Phase II reveals that this has a significant impact on student scholastic achievement as shown by consistent improvement in academic performance of students over the last 10 years (p. 23).

William Demmert and John Towner (2003) reviewed three studies on the Kamehameha Early Education Program and similarly found that Culturally Based Education added to the value of the program and improved student achievement. However, the study revealed that there was no evidence to support that Culturally Based Education alone produces this result. It must be accompanied by a high-standard academic curriculum and sound educational practices. The Maori *kura* (immersion school), in the northern region of the North Island of Aotearoa New Zealand runs a program that employs action research methods in order to integrate cultural relevance in the education of Maori youth. This program is based on assessing the current science education in the schools, identifying the community's wants and needs for the education of their youth, developing lessons that implement these aspirations, and performing program evaluation (Wood and Lewthwaite 2008). Wood and Lewthwaite (2008) found that using teachers who have a strong knowledge of both contemporary science and Maori epistemology, involving the extended community in students' day-to-day education, and acknowledging the validity and applicability of both traditional knowledge and contemporary science improved science education programs in Maori communities.

In addition to a high standard of teaching, place-based education is also important. Thomas Zwick and Kenneth Miller (1996) showed that Native American fourth graders in Montana who were taught with an outdoor, 'hands on,' group oriented activity-based curriculum, scored higher on science achievement tests than those students taught with a more traditional textbook-based curriculum with few or no activities. Manitoban educators participating in the SAGE (Securing Aboriginal Goals in Education) Conference in February 2008 also acknowledged that "approaching science education from a land-based experiential learning approach (where students incorporate science as a living, learning process as a part of their everyday lives) is not only positive for Indigenous learners but for all learners (Sutherland and Henning 2009)."

## Why informal science education?

The science knowledge taught in conventional western classrooms is largely the product of Eurocentric cultures. Masakata Ogawa posits that the "'science' in '[formal mainstream] science education' normally refers to Western modern science, which is only one of the sciences that civilization has produced" (1995, p. 583). He argues that formal science education fails to include "indigenous science," which is knowledge held by a specific cultural group which may be "tacitly transferred from generation to generation through daily social and cultural events" (Ogawa 1995, p. 586). In addition, formal science education largely fails to align the science being taught to the worldviews, contexts, and culturally appropriate learning strategies of the students who are learning it (Wood and Lewthwaite 2008). Though many scholars and some educational institutions do recognize that Indigenous youth bring extensive knowledge of science and the natural world into their classrooms, this knowledge is not always recognized in formal classroom settings.

Some formal educational institutions do recognize the need for culturally integrated schooling and work hard to incorporate culture into their curricula. For example, in 2002 the State of Montana passed an educational initiative called Indian Education for All. This initiative mandates that all educational personnel include both cultural heritage and

contemporary contributions specific to local American Indian tribes into the topics being covered (Montana Office of Public Instruction 2008). Another program, the Alaska Native Knowledge Network (ANKN), provides Alaskan educators with a place to share curriculum and promote inquiry-based pedagogy that employs local environmental and cultural resources. The ANKN maintains a database with units and lessons that follow both the Alaska content standards and the Alaska Standards for Culturally Responsive Schools, which were adopted in 1998. Internationally, New Zealand has an extensive science education program that incorporates the traditional knowledge and language of the Indigenous Maori. These programs range from the standard New Zealand curriculum taught in the Maori language, to Maori language immersion schools that follow guiding documents which include Maori epistemology and even knowledge unique to specific tribes (Wood and Lewthwaite 2008). At Cape Breton University in Nova Scotia, Canada the Integrative Science program guided by local Mi'kmaq elders, brings together Western and Indigenous ways of knowing "to generate an expanding ground of common understanding and a deepening respect for differences (Bartlett 2011)." Since its inception in 1999, this program has seen a significant increase in numbers of Aboriginal students pursuing postsecondary science. Although these programs are striving to create culturally relevant education for youth, it is important to recognize that formal education occupies only about 5% of an individual's total life time and to increase science understandings programs must reach people during the other 95% of their life (Falk and Dierking 2010).

The goal of ISE programs is to provide educational experiences that lead to further interest and enjoyment of science and a "sense that science learning can be personally relevant and rewarding" (Bell, Lewenstein, Shouse and Feder 2009, p. 11). There is a growing trend to not only value traditional knowledge but to design informal afterschool and summer programs that use traditional Indigenous knowledge to engage youth in academic science. These programs enable participants to connect their personal interests to subjects that relate to their experience, allowing for flexibility and creativity that is not always possible in a formal classroom setting. For example, in an after-school field trip, Blackfeet Native Science Field Center participants learn to gather willow in a respectful way based on their tribal traditions (Fenichel and Schweingruber 2010, p. 133). After their field trip they meet at the local college to engage in engineering technologies, building snowshoes and backrests in the same manner as their ancestors. Bryan Brayboy and Angelina Castagno (2008) write about the notion of informal science learning, the connections between "Indigenous" and "Western" science, and whether informal science learning is productive in Indigenous communities. Many Indigenous peoples "would argue that their laboratory is the world and that their survival rested on puzzling over observations and phenomena and coming to make sense of them in ways that allowed them to survive" (Brayboy and Castagno 2008, p. 732). In addition, there is strong emerging evidence that shows that interest in and acquisition of scientific knowledge begins in free-choice learning experiences as a child—that is, learning outside of school (Falk and Dierking 2010).

## A case study of effective practices for creating transformative informal science education programs grounded in Native ways of knowing

Through partnerships on the Blackfeet Reservation in Montana, the Wind River Reservation in Wyoming, and the Pine Ridge Reservation in South Dakota, Hopa Mountain, a Bozeman, Montana-based nonprofit cooperatively helped to establish Native Science Field

Centers to offer "afterschool and summer environmental science field programs for youth ages 8-18 that integrate traditional knowledge, [Native] language, and science (Augare and Sachatello-Sawyer 2011)." In 2006 these organizations began a research study to identify the effective practices used by successful, culturally integrated informal science education programs with Native American youth. Effective practices are defined as a series of actions or procedures that help to solve a central problem in context specific program development or community service that will lead to positive outcomes (Resource Center 2010). The studies mentioned here begin to tell a story about the importance of incorporating everyday practice, cultural traditions, and experiences outside of school into education for Native students.

## Methodology

To explore effective practices utilized by informal Native Science programs, Hopa Mountain staff conducted a nationwide search identifying individuals and organizations that engage Native American youth in science and environmental education. The search included a thorough Internet search, a review of relevant literature, referrals from museums, colleagues, universities, and any currently published scholars in the field, and a review of individuals and programs currently being funded by the National Science Foundation. Any individuals who were actively engaged, at the time of the study, in developing ISE programs that integrated Native culture and science were contacted and asked to participate in an interview regarding program development and experiences in the field. Twenty-one individuals running informal programs and projects that engage Native American youth in science and environmental education participated in the interviews. All of these programs worked with children and young adults on reservations or in predominantly Native communities, and were not part of a formal school instruction program. All worked with Native students to incorporate traditional culture, language and Native ways of knowing into their activities. The methods of incorporating these elements varied, but most of the programs were very holistic and had goals reaching beyond science education. For example, one organization working on the Crow Reservation operated a food bank, taught youth entrepreneurship skills, and provided a diverse range of community services. In addition, they were also educating youth about the local environment with a garden program that taught youth about the uses of Native plants, the Crow names of the plants, and the ceremony and traditions around growing and harvesting these plants. Many of the program leaders interviewed were hesitant to label their program as a science education program. They all agreed that they were teaching the youth about science and the environment, but most felt that calling their program a science education program was not inclusive of all they were teaching.

The following interview questions were designed by the research team. The first two questions elicit background information on the organizations and its programs. The objective of the third question is to learn about the practices used to integrate Native ways of knowing in the organization's programming. The fourth question addresses the interaction of students' environments and their science learning, and questions five through seven focus on programming assets. The overall aim of these questions is to gain a better understanding of science education practices that were successful in Native communities. Success of a program was defined and determined by the interviewee. The following questions were asked during each interview:

1. What is your organization's main purpose?
2. What ages do you work with?
3. Is traditional culture, language or Native ways of knowing being integrated with science and environmental education in your organization?
    - In what ways do you do this?
    - What makes these things successful?
    - What values do you incorporate?
    - What kind of community participation or input do you have?
    - How have you observed this work affecting the community?
    - What has been a challenge?
4. Have you observed Native participants struggling with the relevancy of Western science?
    - What helps with this?
5. Does your organization collaborate with any other groups or educational institutions?
6. What resources have been helpful to you?
    - What would be most helpful as far as training and resources for your organization to do this work in the future?
7. Are there any other people you know of that I should talk to in regards to these subjects?

In addition to the 21 interviewees described above, 9 experts in Indigenous education and science were selected and interviewed from across the United States including Alaska and Hawai'i. These individuals were deemed experts because they themselves are either Native or have worked closely with Native communities, they are experienced in developing culturally relevant ISE programs that teach Indigenous youth, and they are academic scholars who have published in peer reviewed journals on the intersection of Native ways of knowing and Western science. These interview questions were designed by the research team to learn how science education can be grounded in Native ways of knowing. The questions were designed to be open-ended and allow the interviewee to discuss their wide range of experiences with Indigenous science education. Unlike the first set of interviews, these questions were not focused on a specific program. The aim of this interview was to gain understanding on the theories guiding successful science education as opposed to specific practices used by programs. Interviewees were asked:

1. Do you think there is science in traditional Indigenous ways of knowing?
    - Can you give me an example?
    - Does this differ from Western science, if so how?
2. What do you think is the relationship between Western science and Indigenous ways of knowing?
    - How does this affect Native students learning Western science?
    - Do you think some kind of bridge or transition is necessary or helpful for a traditional Native student to learn science in a Western classroom?
    - Do these things also apply to students learning Western science in an informal setting?
    - What would aid in teaching science to a Native student?

- Can science be taught in a way that more clearly aligns with an Indigenous worldview?

3. What do Indigenous ways of knowing have to share with Western science?
   - What does Western science have to share with Indigenous ways of knowing?
4. Can Western science and Indigenous ways of knowing work together?
   - How would this work/What would it take?
   - Would this be beneficial to Native communities?
   - Would this be beneficial to non-Native peoples?
   - What do you think is the biggest challenge to this happening?
5. Are there any other people you know of that I should talk to in regards to these subjects?

Both sets of interviews were conducted over the telephone, recorded and then transcribed. Many of the interviewees spoke of lessons they had learned from their work, identified keys to their success, and summarized effective practices and the theories that guide these practices. The transcripts were compared and common themes and effective practices were identified. A list of key ideas was created for each interview. Then these lists were compared among the interviews to identify ideas that were repeated by multiple interviewees. The most consistent themes ascertained through this process were then compared to the literature for congruency. For example, many of the individuals interviewed told stories of how they utilize Native language in their programs and the benefits that have come from this practice. This practice has been confirmed by case studies in Arizona (Holm and Holm 1995) and Canada (Wright, Taylor and Ruggeiro 1996), and by a review on Native education (Deyhle and Swisher 1997), and was therefore added to the collection of effective practices. This collection was presented to a Consensus Advisory Committee which was created to review this work and agree on effective practices. The process that this committee undertook was modeled after the consensus study committee formed by the National Research Council of the National Academies to create *Learning Science in Informal Environments* (Bell, Lewenstein, Shouse and Feder 2009). Following this model, members began by discussing the current state of the field. Next, members of the Consensus Advisory Committee were presented with a collection of literature on ISE programs grounded in Native ways of knowing, transcripts of the 21 interviews conducted with current educational practitioners in the field, and transcripts of the expert interviews. The committee reviewed the published evidence, discussed themes of the interviews found by the researchers, and used this data to draw conclusions and agree on findings through the process of consensus.

The Consensus Advisory Committee included 12 (additional) experts in Native science from a wide range of tribal nations across the plains, the southwest, Alaska, and Hawai'i. The committee members were invited to be part of the consensus process because they had experience with Native-led ISE programs that engage Native youth in science and environmental education, and because they had an interest in publicizing the work that was happening across the country in the field. In the spirit of inclusion, the authors of this paper wanted to have at least one Alaskan Native and one Native Hawai'ian on the committee. Due to this, as well as the limited expertise in the field, one member of the Consensus Advisory Committee happened to also be one of the nine interviewed experts described above. Beyond these commonalities the committee members were diverse in age, tribal affiliation, and area of expertise. For example, some individuals were educators by

training, whereas others were scientists. Some individuals were retired whereas others were in the earlier stages of their careers. Having a diverse committee challenged the researchers to refine the identified effective practices and critically analyze the commonalities found in the interviews.

Members of the Consensus Advisory Committee critically analyzed and reviewed the findings from the interviews over a three-day period in Bozeman, Montana. The consensus meeting began with general feedback on the interview and research process. The committee agreed that this was important work to document because many individuals and organizations have been developing high quality programs that go unnoticed and undocumented beyond their community. Most of these organizations lack the time or resources to publicize the successes of their programs or conduct case studies on their work. The committee agreed that researching and publicizing this work is of great value to Native and non-Native communities. After discussing the research process, the committee began discussing each of the identified practices. Anything that was not agreed upon was discussed and revised until a final collection of effective practices that everyone agreed upon was determined. Discussion was organic and free flowing, calling upon the background information from the literature review, double checking the interview findings, and calling on the experiences of the committee members until consensus regarding the identified practice was found. For example, the following are notes from a discussion by the Consensus Advisory Committee on the practice of using Native language in ISE programs and how it should be approached:

A When you come to a Western science word like inertia, make a word for it using the Native language. Nativizing Western terms
B Yes, include that comment—nativizing
C This may be over simplified (referring to the wording of the proposed practice) – make it stronger, language is culture, culture is language
D Language as the stem of instruction
A Education should not take away language; the language and culture should facilitate the instruction. Emphasize that culture and language come first. The language has to be a choice. English should not be forced

This illustrates how the Consensus Advisory Committee came to a consensus on effective practices for creating transformative ISE programs grounded in Native ways of knowing based on the interview findings, the published research, and prior experience. The effective practices outlined in this article are designed to help organizations and programs to strengthen ISE programs for Indigenous students and hope to promote change in formal education as well. Hopefully, these practices will inspire discussion and further research on integrative and culturally responsive education.

## Effective practice for ISE programs grounded in Native ways of knowing

As research begins to provide evidence of the academic benefits of creating ISE programs based in Native ways of knowing, the focus must now turn to how to effectively do this. Through the consensus process, the Consensus Advisory Committee found three effective practices for successful ISE programs grounded in Native ways of knowing that repeatedly showed up in the literature, again showed up in the interviews, and were confirmed by committee member experiences. The first is creating hands-on, inquiry-based lessons that are reflective of the culture and the people in their aboriginal homeland. The second is to

utilize the community as an integral resource in the development of curriculum as well as in instruction of the materials. The third effective practice is to use the local Native language both to facilitate instruction and in understanding the local Native worldview.

Create lessons that reflect the culture and the people in their aboriginal homelands

The term aboriginal homeland is used here to refer to the places to which the Indigenous youth have connection. This includes the land where they live and places that have cultural significance to them. For example, many of the sacred sites of the Lakota tribe are beyond the reservations' borders in the Black Hills as well as south of the reservation in Nebraska. Although some Lakota youth have never had the opportunity to visit these sites, they still hold extreme significance and are a part of their aboriginal homeland. The literature review outlined above in this article gives two examples that support the first effective practice emphasized by the Consensus Advisory Committee. Research conducted by Thomas Zwick and Kenneth Miller (1996) exemplifies how students may benefit academically from a hands-on, place-based curriculum that is carried out in, and relevant to, the people in their traditional homeland. This is also supported by Eric Riggs (2005), who found that a common quality inherent in successful Indigenous Earth Science projects was a major emphasis on place-based curricula, emphasizing experimental, outdoor learning in familiar environments. Glen Aikenhead and Herman Michell's (2011, pp. 15–16) recent examination into cross-cultural projects similarly reflected the same results of an increase in classroom and community engagement, academic improvement and a more positive self image among Indigenous youth participating in culturally relevant education programs.

Utilize community as an integral resource

What defines a community varies by region and culture. To some, community refers to a group of people with a common culture or ethnicity, whereas others define community in terms of geography. Groups must self identify their community. Regardless, the community plays a vital role in successful science education. William Demmert and John Towner's (2003) review of descriptive and qualitative research on Community Based Education programs revealed that the most important factor in culturally based program design is the local community playing a strong and active role in developing curriculum and delivering instruction. This was again seen in Eric Riggs (2005) study where explicit involvement and cooperation of Indigenous community members, elders, and educators, in the design of the content and the location and delivery of curricula in programs, was central to successful Indigenous Earth Science projects. Research by Dorothy Aguilera (2000) and Wood and Lethwaite (2008) also confirms that community support is a common factor in schools with effective language and cultural programs.

Make use of Native language

Language is culture and culture is language. Education should never take away Native language; it should promote it. Native languages are rooted in nature and highly descriptive. Physicists working with Native Americans have noted that Algonkian tribal languages are very congruent with quantum physics and cutting edge science in that they both describe nature in terms of balance and flux, relationships and transformations of energy (Peat 2002). For example, in quantum physics an electron is both a wave and a

particle, and can be observed as one or the other depending on the context in which it is functioning. In Native ways of knowing, context is always important and all things happen within a web of interrelationships (Peat 2002). The Consensus Advisory Committee supports the use of this dual language approach when Native students learn a new scientific concept, in order to help them better understand its meaning. Research by Deyhle and Swisher (1997), Holm and Holm 1995, and Wright, Taylor, and Ruggerio (1996) confirms that when students are taught in their Native language they do better on standardized tests than students taught in English-only classrooms and often have more confidence. Through the three effective practices mentioned above, ISE educators can create successful programs that will promote local culture and support education not only with Indigenous youth but also within the community.

## Realizing effective practices

In addition, the Consensus Advisory Committee came up with the following recommendations that can assist in realizing the effective practices outlined above. Recommendations focusing on realizing effective practices were agreed upon using the same National Research Council model of consensus method described above (Bell, Lewenstein, Shouse, and Feder 2009). Matching program values to people values, engaging the community, ensuring that culture is foundational, using traditional ways of teaching, creating space for knowledge to be shared and respected, seeking out collaborations and resources, and encouraging policy change in formal educational institutions are all methods that will move ISE programs towards incorporating Native ways of knowing into the education of Indigenous children. These methods were developed based on the committee's review of relevant published literature related to recommendations for culturally relevant ISE programs, the interviews conducted by the researchers with science educators and theorists, and the Consensus Advisory Committee's experiences.

Community Specific Values: It is important that the ISE programs teach values that are specific to the values of the community. There is no one 'pan-Indian' culture. Although many tribes share similar values, they also have unique cultures that should be reflected in the educational program (James 2006). Every individual interviewed spoke of the traditional values of their community that they incorporated into the program. One way to ensure this is to collaborate with community members and utilize the resources that exist within the tribe and community. Often the communities these programs serve are low-income with limited teaching resources. In many cases a wide range of organizations, educational institutions and tribal programs have to share their resources to make these programs possible. In order to be sustainable, a program must advance existing resources, create resource networks, and have community investment. The benefits of these collaborations are two-fold; community values are incorporated into the education curriculum, and educational institutions and organizations share resources making them stronger and more sustainable.

Engaging Community Members: Next, engaging people from the community who can share cultural and scientific knowledge that is related to the community is a necessary step towards effective practice of education grounded in Native ways of knowing. Wood and Lethwaite note that engaging the *whanau* (family and community) in education demarcated the most successful Maori *kura* from the less successful; educators in the schools consistently claim that close community involvement in students' everyday experiences "is critically important at ensuring science education aspirations become reality" (Wood and

Lethwaite 2008, p. 650). Engaging the community in ISE programs will help teachers and students alike to respect and value elders, fluent speakers, and traditional knowledge holders, just as they would a Western trained scientist. One salient point that was brought up in interviews is that it is very important for educators to learn the culturally appropriate way of inviting community members to come and share knowledge. Several program directors credited their success primarily to finding the right people from within the community to share knowledge from both Native and Western perspectives.

Viewing Culture as Foundational: Another recommendation focused on realizing effective practice is to ensure that culture is foundational to the program. Most programs interviewed stated that they would first use culture and Native knowledge to engage students—then move to the science application. This often made the science lesson much more relevant. Bryan Brayboy and Angelina Castagno (2008) agree with this method, recommending that educators equally emphasize science and Native ways of knowing, comparing and contrasting them while teaching the legitimacy of both. As Aikenhead (2001) discusses, an ideal teacher would be a "culture broker," who would help students move between their Indigenous culture and the culture of contemporary science, and would help them deal with conflicts that might arise. Gregory Cajete also agrees (1999) that good bicultural teaching first utilizes objects that are familiar within the context and culture of the student to introduce basic scientific skills and processes such as observing and classifying. By applying these basic skills to the local environment, students can discover and discuss the differences and similarities between Western science ideas and Native ways of knowing. This knowledge transfer can go both ways. In one example, a First Nations member who interned with an environmental organization led the organization to reorient its activities based on traditional knowledge that he shared about native plants and his people's historical use of the local area. The organization began to focus more on traditional uses of marine ecosystems and native plants, based on the knowledge that the intern shared. The intern, realizing that his traditional knowledge was appreciated, decided to pursue an academic science education in hopes of becoming an ethnobiologist or native plant nursery owner (van Eijck and Roth, 2009); thus, this informal science education program was mutually beneficial.

Cultural Relevancy and Context: It should be noted that culture and science are not two separate entities. Science is embedded within Native cultures. Often when the intersection of culture and education is examined, culture can become trivialized or superficially incorporated in a way that does not benefit the student. Frank Dukepoo (1993) provides an excellent example of a teacher who incorporated culture by having students count and categorize beads, buckskins and bolo ties. Although this did integrate 'culture' it did little to engage the students in mathematics. Dukepoo further points out that culturally relevant lessons must be firmly rooted in the value system of the culture as well as the personal needs of the students in order to be effective. Nancy Maryboy, David Begay, and Lee Nichol (2006) further this point by explaining that when Western cultures focus only on the specific applied Indigenous knowledge and remove it from the context of the rest of Native ways of knowing they are breaking the natural holistic order and turning it upside down. Wood and Lethwaite (2008) discuss a more successful example of integrating science education and culture in a Kura Kaupapa Maori school (a school with a charter created by the Maori community and where the Maori language is the principle language of instruction). In a science lesson, students built a *hangi*, a traditional Maori earth oven, with the guidance of *kaumatua* (Maori elders). The project melded traditional Maori knowledge regarding *hangi* and volcanic rocks with Western scientific beliefs such as geologic classification and heat capacity (Wood and Lethwaite 2008). This lesson is an excellent

example of integrating Indigenous knowledge and Western science without removing it from the context of Native cultures.

Using Traditional Ways of Teaching: How students are taught and the pedagogy that is used must be traditional and defined by the community. Every tribe has unique ways in which knowledge is passed down. Programs found success in incorporating these ways of sharing knowledge. For example, one program leader that was interviewed described how the curriculum in Western educational systems is based on the student grade level, which is usually directly related to their age. Conversely, in the educator's traditional ways students have to show readiness and maturity before they can be taught certain topics. They are not entitled to learn material just because they had reached a certain age. Utilizing this teaching method helps to integrate Native ways of knowing into the program while respecting the teaching traditions and practices that many children have experienced at home.

Creating Space for Knowledge to be Shared and Respected: Many educators in this study report that their students learn a tremendous amount of knowledge from their families and the community that is very relevant to lessons being taught. For example, one educator told a story of teaching plant identification to a group of Native students only to discover several students in the group had already learned from their families the Native language names of the plants and there traditional uses. It was very important that ISE instructors recognized this knowledge as sacred, and create a space for it to be respectfully shared. Much of the Native knowledge about the environment is related to ceremonies and rituals and it should be shared in that context and in ways appropriate to the culture. Approaching knowledge sacredly also includes the idea that the natural world should not be subjected to harm for the sake of learning science. For example, in many Native communities, it is deemed unnecessary to take samples of Native plants unless they are needed for medicinal purposes. Additionally, Western education systems often view the teacher as the holder of the knowledge and the students purely as receivers of knowledge. In many Native cultures, the students and teacher are viewed equally as knowledge holders and everyone is equally involved in the exchange of knowledge.

The current education system struggles in many Native communities to interest and retain their students and even to garner parental support. The ISE programs that incorporate Native ways of knowing can model successful ways to educate Indigenous students. First, following the recommendations discussed above such as utilizing the community, focusing on traditional pedagogy, and incorporating local cultural values into the curriculum, can model successful processes for educating Native students that can be adapted by formal education. Another thing that ISE programs can do to model good practice is to incorporate research that is community oriented, initiated, and overseen into their curriculum. In the past, outside researchers have exploited and misused Indigenous knowledge. Exceptional ISE programs incorporate research; however, that research must be done in an appropriate manner that benefits the local community.

## Important considerations in Native informal science education programs

In addition to the suggested effective practices and recommendation, a few important additional reflections and observations were made by the interviewees and Consensus Advisory Committee. These additional considerations are not specific practices that increased success; instead they are common reflections of the individuals running these programs. The Consensus Advisory Committee found these relevant to their own

experiences, and agree that they are salient points for educators to consider. For example, some instructors who were used to formal classroom settings noticed their role as an educator shifted when they began ISE programs in tribal communities. They were no longer teaching science as a subject; their role now included mentoring, guiding, and teaching values. This role shift is explained in this excerpt from an interviewed educator:

> When the reservation said we want our students to learn about generosity and belonging and connection to generations, for those of us from the university with a science background it was a little hard for us to grasp what that actually meant and how you design a program with those types of values in place.

Almost every Native ISE program included in this project incorporates community values. These values model those of the community and include: respect, care, generosity, giving back, importance of intergenerational work, teamwork, sense of belonging, wisdom, work ethic, honesty, humility, truth, bravery, sharing, helping each other, courage, patience, sustainability, tradition, history, integrity, self respect, the idea of all being related, language, and hope.

Informal science educators observe their work affecting the community in many ways. Often it brings the community together across generational lines and increases parent and family involvement. Community members get excited about what is happening and want to get involved. "*We've had a lot of feedback that parents and grandparents want to participate next year both in the activities and in the fundraising*," said one program leader. Another pointed out that the program, "*…provides situations for dialogue…you know that exchange between the generations and just pure fun*."

A few programs have even seen an increase in math and science scores. Several programs noted that the reputation of the reservation and other entities associated with the program became more positive. It gave the community something to be proud of. Other programs observed an increased interest in cultural knowledge. One leader described the programs giving people a sense of pride and value for their knowledge and "*really empowering people to speak up…and to get more involved in culture, to get more involved in tradition."* One educator stated, "[the program] *gives them a respect and a better understanding of how their ancestors survived on the land. I think it excites what I call their historical imagination.*"

Having the right resources is very important to starting an informal science program. When individuals were asked what resources had been most helpful in their work, human resources was the most frequent response. This includes having the right people for the job, being able to tap into a network of people doing similar work, having access to traditional knowledge holders in the community, feeling like you have support and people who will listen to you, and having people in main stream academia recognize the value in this work. This is shown in the following interview quote, "*Just knowing the right people who can help you, who can support you, that's my most powerful resource right now, the people who can support us right now whether its coming to the meetings, voicing anything and just saying that they're willing to help*." Other helpful resources include finances and community organizations. In low resourced communities, collaborations are very important because few organizations have the means to organize programs like this on their own. Organizations such as museums, tribal colleges, extension offices, USDA, state departments, fish and game, wildlife management, education departments, recreation departments, and Boys and Girls Clubs have important sources of information and infrastructure that ISE programs can utilize.

Just like all other important work, running informal science programs comes with its fair share of challenges. Most of these programs are in very rural reservation settings which bring challenges such as a lack of infrastructure, systemic issues that exist in the community, remote locations, and sometimes a limited access to electricity, phone, and internet. Another big challenge is funding. Sometimes funds are very inconsistent and many programs are dependent on short term grants that are not sustainable over a long period of time causing the program to end when the grant end. Many of these programs have a very broad holistic mission, which can make it difficult to fit into a grant category or to articulate the program to a foundation. Several programs also commented that it is challenging to get the community to invest and to earn the communities' trust. The concept of a nonprofit organization is still very new in many reservation communities. It may take some community members a while to warm up to these programs. Much of this work is dependent on the people running the programs and it can be challenging to find the right people. Since this work is often very new to local people, there can be a steep learning curve for those involved. It can be especially challenging to find the right people who can communicate both science and culture, but with consistent and continued invitations to help with community and cultural events, people will begin to learn the value of these educational programs that will teach their youth Native values and ways of knowing.

## Conclusion

There is no culturally neutral science (Bell, Lewenstein, Shouse, and Feder 2009). Nevertheless, both formal and informal science instruction and scientific discourse often cater to the scientific practices of the dominant middle class, and fail to focus on scientific practices of minority groups (Fenichel and Schweingruber 2010). This is reflected in low standardized test scores for minority groups and a low percentage of minorities in science and technology professions. A first step towards culturally inclusive education is to recognize this (Fenichel and Schweingruber 2010). Indigenous youth benefit when ISE programs are grounded in Native ways of knowing (Fenichel and Schweingruber 2010). Educators and administrators are beginning to acknowledge this and design curriculum and instruction techniques to reflect this research. For example, the director of the Blackfeet Native Science Field Center, Helen Augare, states, "We're trying to do more than just teach biology and ecology, and even more than just teach culture or history. We're trying to show kids the spiritual element—how to take that in and make it a part of their worldview" (Fenichel and Schweingruber 2010, p. 133) In addition, culturally sensitive assessment strategies that have been developed reiterate the importance of cultural values and the Native language within the community (Solano-Flores and Nelson-Barber 2001).

Formal classroom settings often lack the flexibility to create programs that successfully integrate Native ways of knowing. This is why integrative science programs are often more successful in informal settings. The effective practices and recommendations developed in this study will help educators build effective, transformative ISE programs that are grounded in Native ways of knowing. Utilizing a review of the current research, interviews with both individuals working on the ground on relevant projects and scholarly experts in the field, and the experiences of the Consensus Advisory Committee, the following effective practices and recommendations were agreed upon:

- Create hands on, inquiry based lessons that reflect the people in their aboriginal homeland.
- Use the community as an integral resource in developing curriculum and instruction.
- Use Native language to facilitate instruction and to promote the Native worldview
- Match the values of the program to the values of the people.
- Seek out and engage people from the community and beyond who can share cultural and scientific knowledge related to the community.
- Ensure that culture is foundational to the program.
- Use traditional ways of teaching and pedagogy.
- Create space for all knowledge and experience to be shared and respected.
- Approach things sacredly.
- Seek out creative collaborations to utilize resources within the tribe and community.
- Encourage policy change by modeling processes and educating stakeholders.
- Incorporate research on Native ways of knowing and Western science that is community initiated and overseen.

These effective practices and recommended methods are intended as guidelines for integrating Native ways of knowing into informal science education programs. Every community is unique and ISE programs should be tailored to fit the distinct goals of the community it serves. However, these practices have shown to be effective and are designed to help communities start new ISE programs and strengthen current programs that are already in existence.

**Acknowledgments** Within each of us there is potential to do great things for our community and for future generations. When a person recognizes the limitless strength of the spirit, and reaches beyond themselves to form a living bridge between the knowledge of our ancestors and the future health of our grandchildren, they give a gift to our community that lasts far beyond their lifetime. Angayuqaq Oscar Kawagley embodied this vision in his work and the wisdom that he shared. We are honored to have worked with him on this effective practices research study and article. We are enormously grateful for his leadership and his many contributions towards forging a new path in this field. In an earlier tribute to his life, this journal recognized that "Oscar's gift and love of teaching has seen him empower students to become leaders in their communities, teachers to become better at their practice, and stand at the forefront of many innovations in his field with an influence far beyond his own community (Archibald et al. 2007)." We recognize the legacy of his life and hope to carry these gifts far into the future for the generations to come. This material is based upon work supported by the National Science Foundation (Native Science Field Centers grant #0610270) and the Bush Foundation.

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