Chapter 8
Drawing on Place and Culture for Climate Change Education in Native Communities

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Connection to place is a critical cornerstone of a Native sense of identity, and a necessity for preservation and restoration of land and Tribal sovereignty. The land and environment hold particular significance for Native peoples and communities. Changes in the environment due to a rapidly changing climate have a profound impact on the livelihood of Native people (Davis 2010). Daniel Wildcat (2009) suggests climate change can be thought of as the "fourth removal" for Native communities. For example, effects of climate change are a cause for the movement or

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elimination of local food sources, such as buffalo and fish resulting in the relocation of a local community to search for other sources of food. With this fourth removal, unlike the others where the focus was to "civilize" the American Indian through "geographical, social, and psycho-cultural" (p. 3), the impacts of climate change reach far beyond Native communities, impacting all life on the planet.

Science Education and Native American Culture

The United States education system has failed American Indian youth (Baker 2003; McKinley 2007). Western models of education fail to incorporate knowledge fundamental to American Indian being and understanding (Cajete 1994, 1999). These models are particularly problematic when considering the science and mathematics taught in public schools where there is a often conflict between Native cultures and values and national goals and standards, thereby creating a science curriculum that is generally irrelevant to students' lives (Allen 1997; Matthews and Smith 1994; Ogbu 1992). In some instances the Indigenous Knowledge passed down through elders' stories are in direct conflict with western scientific knowledge. For example, some Native cultures understand there is a systematic relationship between everything in the natural world. By contrast, in much of western science, particularly as represented in the school curriculum, the tendency is to treat the natural world as isolated units and interactions between single variables (Szasz 1999). Deloria and Wildcat (2001) suggest the goal is for Native students to be *bicultural*, constructing knowledge in both the dominant and their home cultures, so that they are both academically prepared and actively connected to their tribal communities. In other words, it is critical to connect science directly to Native students' lives empowering them to pursue careers as scientists and engineers that allow them to become leaders in their own communities, with a purpose to maintain community sovereignty such that American Indian people as scientists and informed citizens are actively involved in policy-making in their communities related to climate change and other environmental issues. In this chapter, we present a theoretical framework for engaging teachers and students in Native communities in the critical issue of climate change education, including specific applications of the framework illustrated through two teacher professional development programs working with Native communities in Minnesota and Idaho. While our examples are from two specific locations, the framework is applicable within any Native community.

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Climate Change Education Teacher Professional Development

Our work through two separate NASA Innovations in Climate Education teacher professional development programs is designed to promote the teaching and learning of climate change education in American Indian communities: Teachers Discovering Climate Change from a Native Perspective (CYCLES) and the Intermountain Climate Education Network (ICE-Net). CYCLES and ICE-Net are three-year professional development programs that integrate Native and western scientific explanations of the natural world, specifically climate change, as interconnected, cyclical processes. CYCLES provides professional development in Northern Minnesota in collaboration with the following Ojibwe reservation communities, Fond du Lac, Leech Lake, Red Lake, and White Earth ICE-Net provides professional development in several tribal communities across a 600-mile stretch of the Intermountain west (Idaho and Northeast Washington), including the Shoshone-Bannock, Nez Perce, Coeur d'Alene, and Spokane reservations.

The CYCLES and ICE-Net professional development programs was developed specifically for teachers in our partner communities. Teachers working in schools on or in close proximity to the reservation were invited to participate. Our participants were primarily non-Native, which reflected the teacher demographics at our school sites. The professional development included a series of multiday summer workshops and school year follow-up activities. Both programs offer 4–8 day resident summer workshops engaging teachers in understanding climate concepts as articulated by the *Climate Literacy: The Essential Principles of Climate Science* (National Oceanic and Atmospheric Administration [NOAA] 2009). During, the workshops teachers explore climate change science within the local environment, using culturally relevant teaching and pedagogies. Follow-up activities are carried out differently by the two programs: CYCLES implements 5 day-long Saturday experiences throughout the school year and ICE-Net offers monthly 90-min "check-in" meetings for program teachers to touch base, ask for ideas from fellow teachers, and assistance from program scientists and experts. Both programs purpose is to engage teachers in learning and reflecting on ways to provide their American Indian students culturally relevant ways to learn about climate change, encouraging them to draw on the local community and environment around them.

In developing and implementing our professional development curriculum, we draw on our framework for climate change education in Native Communities. As stated in our opening paragraph, the effects of climate change will impact everyone, however in American Indian communities these have deep implications for both societal and environmental concerns. The framework draws on the elements of Ecojustice where culture, community, and environment are considered as both content and context. In the following section, we describe the framework and provide examples of activities and lessons that highlight the various features.

A Climate Change Education Framework in Native Communities

The culturally-relevant framework for Climate Change Education in Native communities (Roehrig et al. 2012) used to inform our professional development programs integrates three approaches to science teaching and learning that are aligned to native epistemologies: (1) Place-based approaches to link learning with local understanding and motivation (2) Interdisciplinary approaches to learning science, and (3) Inquiry-based approaches (Fig. 8.1). We recognize that there many Native epistemologies and the approaches and examples used within this chapter are specific to our partner communities.

It is important to recognize that *place* holds a significant and holistic meaning for American Indians. For example among the Coeur d'Alene people *place* provides rich meaning in terms of history, culture, and environment; historically, as the location for being, culturally, as a sense of identity, and environmentally as a place of stewardship and guardianship (Woodworth-Ney 2004). As a result *place* has the potential to offer a familiar context in which to learn about and understand the effects of climate change.

The goal is to design climate change curricular activities for cultural relevance that integrate all three approaches from the framework. In the following section, we describe the three approaches embedded in the framework and examples of activities and lessons from our professional development programs. Each example activity incorporates multiple approaches from the framework; however, for each example we highlight a specific aspect of the framework.

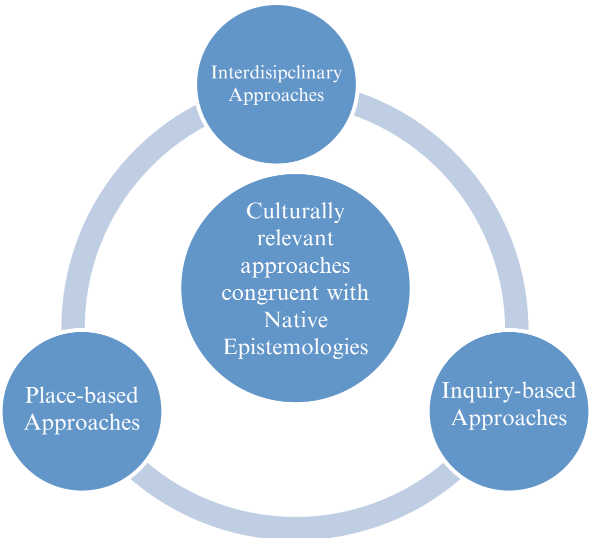

Fig. 8.1 Framework for climate change education in native communities

Place-Based Approaches

Place-based approaches to education are grounded in the notion that the students' local environment and community are a primary resource for learning, which is rooted in the unique history, culture, and environment of a particular place. Gruenewald (2003) suggests, that placed-based approaches to teaching are grounded in the notion that geographical places are rich in social, cultural, and historical significance, yet become devoid of life "when we fail to consider places as products of human decisions" (Gruenewald 2003, p. 627). Semken and Freeman (2008) note, "in the natural sciences, place-based pedagogy is advocated as a way to improve engagement and retention of students, particularly members of indigenous or historically inhabited communities" (p. 1044). Davidson-Hunt and O'Flaherty (2007) add "the goals of a place-based learning community are to support people in responding to their own needs, developing a capacity to generate their own research projects, creating supportive relationships with other actors through the building of dynamic processes for the coproduction of locally relevant knowledge" (p. 295).

While the purpose of a place-based approach to climate change education for American Indian students helps to maintain a sense of identity and cultural connections to the land, it is also important for students to be able to make connections between local and global climate concerns as climate change effects the entire planet With the anchor of their own local issues, students are encouraged to investigate how climate change issues in their community are similar or dissimilar to other places and how the local can contribute to an understanding of *global* climate change and the development of the big ideas in climate science (NOAA 2009; NSF 2009).

Program Highlight: Place-Based Approaches

Place-based approaches provide a context and opportunity to elicit prior knowledge. It is essential to become familiar with the community and community resources. Thus, one of the first activities that ICE-Net teachers complete is a *Community Resources Inventory* of their local community. The Community Resources Inventory allows teachers to identify local climate change resources and environmental agencies. These resources include agencies such as local departments of natural resources, non-profit environmental groups, and Tribal committees. These organizations can provide a wealth of resources that teachers can draw on to engage the community. The use of local resources provides an opportunity for community communication and relationship building. The building of community membership is instrumental in engaging American Indian teachers, and by extension their students, in more than developing STEM knowledge; it provides opportunities for civic engagement where students give back to their tribal communities or other places in the region. Civic engagement, in various forms, can familiarize teachers with local needs and builds skills in interacting with members of the community.

The CYCLES program focuses on unique and local research projects that bring together place-based climate issues, culture and climate change science throughout the summer and follow-up workshops. Many local plant or animal species are used for exploring impacts of climate on ecology and agriculture but the wild rice provides a context for enacting culturally-relevant, place-based education. Wild rice grows abundantly in shallow lake and marshy habitats of northern Minnesota. This sacred plant plays a crucial role in the economic and ceremonial life of many tribes, including the Ojibwe. Wild rice is extremely sensitive to environmental factors and cannot withstand extreme changes in water levels. Flooding and deep water in early spring lead to delayed seed germination on the bottoms of lakes and rivers, while low water levels in the late summer causes the wild rice stalks to break under the weight of the fruit head. Over time, extended drought conditions could encourage greater natural competition from more shallow water species (Hoene 2010).

CYCLES use of the context of wild rice also illustrates interdisciplinary and inquiry-based approaches to learning that draws on multiple forms of data to understand the effects of climate and other human impacts on wild rice harvests. Wild rice lakes are interacting systems of chemistry, biology, physics, and geology, and sediment cores integrate the records of these systems over time. Sediment core transects from shallow to deep water (i.e., from the edge to the center of the lake) provide tangible evidence of differences in sedimentation (coarse to fine grained) and biota. Three follow-up workshops focus on cultural and place-based issues surrounding the growth of wild rice. In September, teachers learn the traditional processes for harvesting wild rice, working side by side with elders to harvest at a local lake (see Fig. 8.2). Elders stress the differences between paddy rice (produced by farming)

Fig. 8.2 CYCLES teachers using traditional techniques to harvest wild rice

Fig. 8.3 Teachers collecting lake core samples at Lake Itasca

and naturally grown wild rice and changes in yields over time related to climate change. Personal recollections of elders and community members and the oral histories passed down through generations provide important data depicting variability in wild rice population abundance and distribution.

During January and February, CYCLES teachers collect and analyze lake sediment cores from Lake Itasca in northern Minnesota. At the January workshop, teachers work with research scientists from the University of Minnesota Limnology Research Center, LacCore, to complete a transect of the east arm of the lake, collecting five core samples (see Fig. 8.3). The five different locations are chosen because of the lake's unique topology to understand geological and biological interactions and events that have happened during the last 10,000 years. In February, CYCLES teachers analyze their core samples at the LaCore research facility, exploring the long ecological history of the lake and human impacts on water chemistry and plant life (including wild rice) over time. Through the application of the framework, teachers (and students from teachers classes that complete follow-up activities at their school sites) are provided with an opportunity to connect historical information shared by elders to scientific findings from the lakes on their reservation.

During the first ICE-Net summer workshop, teachers are introduced to the tradition of storytelling in the local community (see Fig. 8.4). Western society references the past using specific chronological dates with years, months etc. Many American Indian communities more often relate stories and references to past events. Tribal Elders and community leaders use stories, not only as entertainment, but also to document their history. Elders may talk about weather in terms of seasons or harvests comparing the present to the past, such as "remember the past buffalo hunts, when the buffalo were trapped in the valley due to heavy snowfall on the prairie" (Finley, personal communication). Time is marked by natural phenomena such as moon phases, rather than western calendar months. For example, in some regions, Native stories tell of the "full wolf moon" during the cold and deep snows when wolf packs could be heard to howl hungrily outside the village. The "full worm moon" denotes spring as the ground thaws causing earthworms to appear out of the ground.

Fig. 8.4 Community leader sharing oral histories of place through stories

An understanding that some stories are very old and may contain vestiges of historic weather patterns when decoded can help teachers and their Native students make a connection to the enduring effects of climate change. Famed Blackfeet poet and songwriter, Jack Gladstone has taken some older stories and turned them into songs. For example, “The Bear That Stole the Chinook” (Gladstone 1992), a popular story among the Blackfeet, Montana community, tells of a time when there was no warming wind in the wintertime, when the wind blew cold and bitter and remained that way for a very long time. While these oral stories are typically unfamiliar to our non-Native teachers, they are usually highly regarded by Tribal youth, and have the potential to provide a bridge to the data and knowledge of climate change science (i.e. *Climate Change Standards/Principles"#4.A-Climate is determined by the long-term pattern of temperature and precipitation averages and extremes at a location. Climate descriptions can refer to areas that are local, regional, or global in extent. Climate can be described for different time intervals, such as decades, years, seasons, months, or specific dates of the year*) to the celebration and history of Native lore.

The snow came early and lay on deep
The cold blown bitter made the women weep
Our men tracked hard but could find no game
In our children's bellies were cryin' pains
Our elders gathered in the eve and dawn
They prayed and waited and looked
But, little did they know that way up high
The Bear Had Stole the Chinook.

A ragged orphan boy living alone
Called to the animals in his home
Owl and Magpie flew on in
With Coyote and Weasel, there were four of them

As their council met, the Magpie "cawed"
As our heroes shivered and shook
He said, "my relatives told me so",
He said, "The Bear Has Stole the Chinook."

Our heroes' journey to release the wind
Turned west to the mountain bear's den
Four days they teamed and traveled along
Together they did ascend…
Up to the den that held the Chinook.

The Grizzly snored and snarled in his sleep
Owl crept close, into his lodge peeped
Bear punched Owl's eyes with a stick
So they sent in a brother who was lightning quick.
The weasel slithered easy through the hole,
And found the elk skin bag of the crook
The bear, enraged roared, "Go Away!" (and said)
"I'm the Bear Who Stole the Chinook!"

Then our friends made medicine smoke appear
And blew it in the Grizzly Bear's den
The big ol' Griz fell fast asleep
As Coyote crept on in.

He found the bag where the wind was kept
And pulled it to the light of day
There a Prairie Chicken picked the stitches out
Then the Chinook blew on its way
The Chinook blew on its way.

The Bear burst suddenly from his sleep **Grrrrr!**
Our friends all fled, their job complete
The Bear, in vain, pursued the wind
But, the warm wind never was again his friend.
Now Bear sleeps underground the winter long
In his lodge he grumbles and looks
Back to the days of the winter warmth
To the Bear Who Stole the Chinook
To the Bear Who Stole the Chinook
I'm the Bear Who Stole the Chinook!

I'm the Bear Who Stole the Chinook!
Grrrrr! Grrrrr! (Gladstone 1992)

Interdisciplinary Approaches

Interdisciplinary curricular approaches to science teaching are an important consideration when working with teachers of Native students, as an integrated approach is aligned with Indigenous worldviews. An Indigenous worldview is interconnected and holistic (Deloria 1992), taking into account the myriad of interconnections between living and natural entities (Brayboy and Castagno 2008). Unfortunately, schools have traditionally taught the subjects, including the sub-disciplines of science, in isolation without drawing upon the organic connections between them (Czerniak et al. 1999; Katehi et al. 2009; Sanders 2009). This compartmentalization of school subjects can be an impediment to American Indian students' ability to learn and engage with science (Barnhardt and Kawagley 2004).

Climate change represents one of the most pressing global and multidisciplinary problems facing humans and is identified as one of the big ideas in Earth Science essential to developing K-12 scientific literacy in the new *Next Generation Science Standards* (NRC 2012). Understanding the evidence for climate change and proposed solutions requires a significant understanding of geologic time, hydrology, geomorphology, ecology, and atmospheric processes. However, both educators and scientists stress the necessity of studying the earth as an integrated system in order to explain complex phenomena (Johnson et al. 1997). Students need to develop understandings of the interactions between the atmosphere, hydrosphere, lithosphere, biosphere, and heliosphere. For example, the Earth Science Literacy Initiative (ESLI) (National Science Foundation [NSF] 2009) states that Earth is a complex system of interacting rock, water, air, and life, which requires an integrated approach to science teaching. Climate literacy cannot be achieved if Earth science continues to be taught as independent and isolated sub-disciplines (Libarkin et al. 2005). National initiatives in the Earth sciences, such as the ESLI (NSF 2009), focus on the fundamental concepts (big ideas) in Earth science through an Earth System approach and provide a framework for teaching climate change that aligns both with the ways in which scientists conceptualize their work and the holistic view of the earth embodied in many Native cultures.

Program Highlight: Interdisciplinary Approaches

To provide greater relevance and immediacy for climate change education CYCLES builds upon cutting-edge research being conducted in northern Minnesota relevant to the teacher participants in the program. While impacts commonly associated with climate change, such as sea-level rise, are unfamiliar phenomena for Minnesotans, their landscape is experiencing many climate related changes, such as earlier "ice-out" dates on lakes and shifting biomes. Thus, the first 5-day summer workshop is held at Cedar Creek Ecosystem Science Reserve (http://www.cedarcreek.umn.edu/). The Cedar Creek Ecosystem Science Reserve is a 5,400-acre ecological research site in central Minnesota with natural habitats that represent the entire state. This allows access for teachers to explore the three prevalent Minnesota biomes: prairie, deciduous and boreal forests.

Cedar Creek is home to many large-scale interdisciplinary, scientific experiments; David Tilman and Peter Reich, two eminent ecologists, conduct their primary research at Cedar Creek. BioCON (Biodiversity, CO2, and Nitrogen) is a long-term experiment that explores the ways in which plant communities will

Fig. 8.5 Three sisters garden

respond to three environmental changes that are known to be occurring on a global scale: increasing nitrogen deposition, increasing atmospheric CO_2, and decreasing biodiversity. Projects such as BioCON provide clear examples for teachers that are both place-based and reflect the interdisciplinary nature of understanding climate change. Data from BioCON shows that elevated CO_2 levels do not have the hoped-for effect of greatly increasing plant growth and thus to decrease atmospheric levels of CO_2. This research also demonstrates that nitrogen limitation constrains ecosystem responses to elevated CO_2, illustrating the fact that climate is regulated by complex interactions among the components of Earth System (Essential Climate Literacy Principle 2 [NOAA] 2009).

Principles of biodiversity are not new to Native cultures; for centuries, tribes including the Ojibwa, plant Three Sisters gardens to supplement traditional hunting and gathering. The Three Sisters are corn, beans and squash planted close together in a mound. The corn is planted in the center of the mound and the cornstalk then serves as a pole for the beans (see Fig. 8.5). The beans provide nitrogen to the soil, while the squash provides coverage and shade both preventing weeds and creating a microclimate to retain moisture in the soil. Teachers learn about the Three Sisters gardening approach and how this native knowledge relates to the biodiversity lessons of BigBio and BioCON and the interactions of biodiversity and nitrogen levels under a climate change scenario.

Inquiry-Based Approaches

Research on how Native American students learn supports the use of hands-on learning (Freeman and Fox 2005). The Bureau of Indian Affairs (BIA) developed education standards to assist educators in integrating Native content and perspectives into the K-12 curriculum (Bureau of Indian Affairs [BIA] 2000). The Science as Inquiry standards state that students should "develop an understanding about science inquiry as a specific process/framework for investigating natural phenomena" and how inquiry is "used by different American Indian peoples in the past to investigate and explain natural phenomena" (BIA 2000). Thus, when considering climate change, it is critical that both teachers and students understand how scientists work and the forms of evidence used by both scientists and Native peoples. For example, ESLI's Big Idea #1 is that Earth scientists use repeatable observations and testable ideas to understand and explain our planet suggesting that students should be engaged in scientific explorations related to climate change.

Care must be taken however that an exclusive approach that privileges western science (repeatable, testable observations) is not assumed. In fact, the American Association for the Advancement of Science has begun to recognize the potential contributions of Indigenous people to our understanding of the world (Lambert 2003), leading to an increasing realization that typically marginalized groups are a valuable source of climate change information (Salick and Byg 2007). Indigenous people have traditionally engaged in science. *Traditional Ecological Knowledge* (TEK) includes narratives and observations that provide data and explanations for various kinds of natural resource phenomena (Alexander et al. 2011). TEK is "a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (Berkes 1999, p. 8) and provides important evidence for changing climate.

Program Highlight: Inquiry Approaches

To demonstrate ways to embed common science inquiry activities within a cultural context, ICE-Net teachers engage in the *Climate Change-Greenhouse Gases* activity. The core scientific understanding developed in this lesson is that some greenhouse gases retain heat longer than others, with the implication being that as heat retention increases over time overall warming becomes significant on a global scale. This activity is a small-scale chemistry investigation that involves measuring the heat retention of various greenhouse gases, such as CO_2, CH_4, and water vapor.

In this activity, a "simulated ecosystem" is created in a petri dish where teachers can observe the heat retention rates of CO_2, CH_4, and water vapor that are pumped into the individual simulated ecosystems (see Fig. 8.6). Additional equipment includes heat lamps-to raise the initial temperature of the ecosystems, and microencapsulated liquid crystal thermal paper (thermo-strips)-used to observe the rate of heat retention in the separate "simulated ecosystems" (petri dishes). The thermo-strips change color as the ambient temperature varies in the "ecosystem;" thus the rate of heat retention can be measure by observing the rate of temperature decrease over time. The petri dish with the carbon dioxide holds heat longer, and thus decreases in temperature slower than the one without the added CO_2.

Fig. 8.6 Teachers compare the heat retention of different greenhouse gases

The Tribal leader working with the ICE-Net project shares stories about historical "weather" patterns and the length of drought during a hunting season. The CC-Greenhouse Gases activity provides an observable model of how greenhouse gases can increase the overall temperature of the environment by retaining heat due to an increase in greenhouse gasses, CO_2 in particular. The relationship of an increasing climate temperature can be related to the cultural rituals of Tribes of Western Montana and Northern Idaho who have adjusted harvesting times and celebrations to welcome the blooming season of traditional plants such as bitterroot and camas to accommodate the earlier (about 3 weeks) budding and blooms. Records of spring budding celebrations can be compared to the increasing spring temperature records.

Another example of a culturally relevant inquiry activity is the *Tree Rings and Climate Change* activity used in the CYCLES program. The *Tree Ring* activity includes two sets of inquiry activities: examining the relationship between local tree ring growth and local weather data for a short-term analysis (30–50 years) and for a long-term analysis (150–200 years) (see Fig. 8.7). During the first activity teachers collect local oak tree cores from the Cedar Creek site and analyze tree rings using skeleton plots and microscopes. Prior to collecting the tree cores, a tribal elder gives a traditional tobacco blessing. Teachers explore the relationship between the observed tree ring growth patterns and local weather data, such as precipitation records. The second activity involves finding patterns between long-term dendrochronology data (tree ring growth data) and historic weather data, specifically precipitation data. Through the inquiry activity, teachers have opportunities to examine

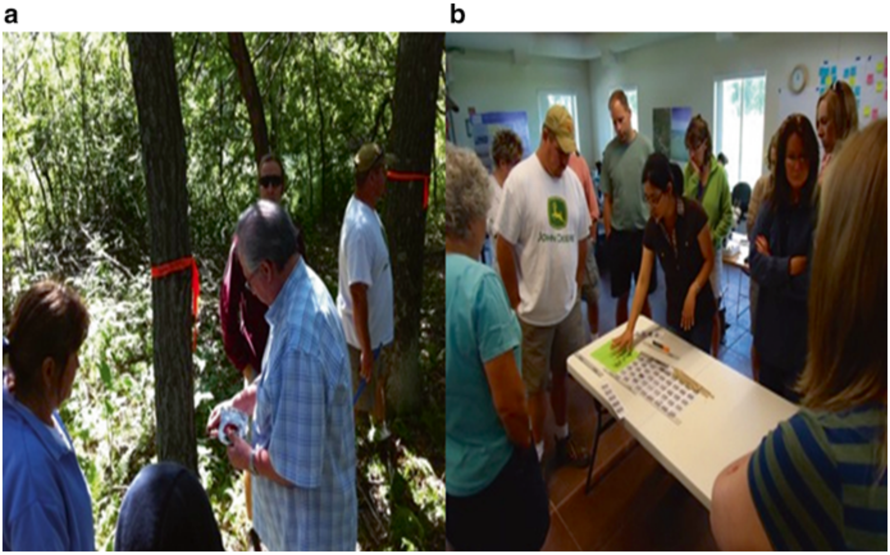

Fig. 8.7 (**a**) Tribal elder performs a tobacco blessing before tree cores are taken and (**b**) teachers analyze and collate their tree core samples comparing with ground and satellite data records

local proxy data and develop understandings of how it is used to reconstruct climate throughout earth history.

Phenological events, such as the flowering, migration, and breeding of specific species are becoming known as a 'globally coherent fingerprint' of climate change impacts on plants and animals (Parmesan 2007). Currently, phenology holds one of the most sensitive biological responses to environmental variation. The *ICE-Net* teachers are introduced to the network of citizen science phenology recorders though *USA National Phenology Network* (www.usanpn.org). The *Lilac Bloom Activity* links climate to growth patterns of the lilac (*red rothomagensis)*, a cloned, perennial, deciduous shrub that is grown as an ornamental shrub that produces reddish-purple flowers, growing 12–16 feet tall (see Fig. 8.8). Cloned lilac plants are readily available and a low cost species to purchase as a climate indicator species in a school garden. While the lilac is not a traditional or native plant, the connections to growth behavior and tracking of first bloom have been occurring in Native communities for centuries. As described above, harvest patterns and budding ceremonies of native plants have been a recognized part of culture and place in these communities. Tribal records and archives can reveal the recording of these "phenological" records through celebration and harvest accounts and chronicles.

In the *Lilac Bloom* activity, teachers and their students track the variability of bud growth in the spring and loss leaf growth in the fall. Through recording the timing of those "plant life" events, the impact of climate variability and climate change becomes apparent over time. Students can monitor these events and the change in plants over a growing season with a 'Plant Cam', an automated camera, and post their recordings to a national network of lilac bloom observers across the country.

Fig. 8.8 Full bloom lilac (red rothermagenesis)

These "online" resources where students record their data are part of an authentic database of lilac bloom data provided by citizen scientists across the country (see *USA National Phenology Network*).

Relationships With and Within Native Communities

The reverence and significance of *place* provides an opportunity for teachers to build connections to the everyday life of American Indian youth. Our framework provides an innovative and promising approach for teaching not only climate change, but other scientific topics, with American Indian students. The blending of integrated, place-based and inquiry-based approaches allows us to address the needs of students and teachers in American Indian communities in a manner that is respectful of Native ways of knowing and cultural values and knowledge held sacred within the community (Cleary and Peacock 1998; Deloria and Wildcat 2001). It is critical to note that application of the framework requires developing relationships and collaborations with and within Native communities.

As we move forward, it is essential to acknowledge Tribal communities as distinct sovereign governments that are engaged in protecting and exercising their sovereignty to assure the basic welfare of their community and need to shape a future of hope and prosperity for their generations yet to be born. As such, building leadership and protecting tribal sovereignty are central endeavors for tribes. A key charge for educators of American Indians students is to support and assist them in learning how to maintain the place in which they live.

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References

Alexander, C., Bynum, N., Johnson, E., King, U., Mustonen, T., Neofotis, P., Oettlé, N., Rosenzweig, C., Sakakibara, C., Shadrin, V., Vicarelli, M., Waterhouse, J., & Weeks, B. (2011). Linking indigenous and scientific knowledge of CC. *BioScience, 61*, 477–484.

Allen, N. J. (1997). *Indigenous models for science-and-culture curriculum development*. Paper presented at the annual meeting of the national association for research in science teaching, Oak Brook, IL, 21–24 March 1997. Retrieved on January 7, 2013, from http://www.eric.ed.gov/PDFS/ED407222.pdf

Baker, D. R. (2003). Equity issues in science education. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 869–895). Dordrecht: Kluwer Academic Publishers.

Barnhardt, R., & Kawagley, A. O. (2004). Culture, chaos and complexity: Catalysts for change in indigenous education. *Cultural Survival Quarterly, 27*, 59–64.

Berkes, F. (1999). *Sacred ecology: Traditional ecological knowledge and resource management*. Philadelphia: Taylor and Francis.

Brayboy, B. M. J., & Castagno, A. E. (2008). How might Native science inform "informal science learning?". *Cultural Studies of Science Education, 3*, 731–750.

Bureau of Indian Affairs. (2000). *American Indian content standards by subject* (Center for Educational Technology in Indian America). Retrieved on January 7, 2013, from http://web.archive.org/web/20030502224845/http://www.ldoe.org/cetia/science.htm#912

Cajete, G. A. (1994). *Look to the mountain: An ecology of indigenous education*. Skyland: Kivaki Press.

Cajete, G. A. (1999). *Igniting the sparkle: An indigenous science education model*. Skyland: Kivaki Press.

Cleary, L. M., & Peacock, T. D. (1998). *Collected wisdom: American Indian education*. Needham Heights: Allyn & Bacon.

Czerniak, C. M., Weber, W. B., Sandmann, A., Jr., & Ahern, J. (1999). Literature review of science and mathematics integration. *School Science and Mathematics, 99*, 421–430.

Davidson-Hunt, I., & O'Flaherty, M. (2007). Researchers, indigenous peoples, and place-based learning communities. *Society & Natural Resources, 20*, 291–301.

Davis, S. H. (2010). Indigenous peoples and climate change. *The International Indigenous Policy Journal, 1*, 1–17.

Deloria, V., Jr. (1992, Autumn). Relativity, relatedness, and reality. *Winds of Change, 7*(4), 34–40.

Deloria, V., Jr., & Wildcat, D. R. (2001). *Power and place: Indian education in America*. Golden: Fulcrum Resources.

Freeman, C., & Fox, M. (2005). *Status and trends in the education of American Indians and Alaska Natives* (NCES 2005–108). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Gladstone, J. (1992). The bear that stole the Chinook. *Buckskin Poets Society.* Retrieved on November 1, 2012, from http://www.jackgladstone.com/Lyrics__Buckskin_Poet_Society.html

Gruenewald, D. A. (2003). A multidisciplinary framework for place-conscious education. *American Educational Research Journal, 40*, 619–654.

Hoene, N. (2010, March). Climate change, an Ojibwe prespective. Minnesota Sea Grant Newsletter. Retrieved from http://www.seagrant.umn.edu/newsletter/2010/03/climate_change_an_ojibwe_perspective.html

Johnson, D. R., Ruzek, M., & Kalb, M. (1997). What is earth system science? Paper presented at *Remote Sensing-A Scientific Vision for Sustainable Development. 1997 IEEE International, 2,* 688–691.
Katehi, L., Pearson, G., & Feder, M. (Eds.). (2009). *Engineering in K-12 education: Understanding the status and improving the prospects*. Washington, DC: National Academies Press.
Lambert, L. (2003). From "savages" to scientists: Mainstream science moves toward recognizing traditional knowledge. *Tribal College Journal, 15*, 11–12.
Libarkin, J. C., Anderson, S. W., & Dahl, J. (2005). Qualitative analysis of college students' ideas about the earth: Interviews and open-ended questionnaires. *Journal of Geoscience Education, 53*, 17–26.
Matthews, C. E., & Smith, W. S. (1994). Native American related materials in elementary science instruction. *Journal of Research in Science Teaching, 31*, 363–380.
McKinley, E. (2007). Postcolonialism, indigenous students, and science education. In S. Abell & N. Lederman (Eds.), *Handbook of research on science education* (pp. 199–226). Mahwah: Lawrence Erlbaum.
National Oceanic and Atmospheric Administration. (2009). *Climate literacy: The essential principles of climate science.* http://www.climate.noaa.gov/education/pdfs/ClimateLiteracy-8.5x11-March09FinalHR.pdf
National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academy Press.
National Science Foundation. (2009). *The earth science literacy initiative*. Retrieved on January 7, 2013, from http://www.earthscienceliteracy.org
Ogbu, J. U. (1992). Understanding cultural diversity and learning. *Educational Researcher, 21*, 5–14.
Parmesan, C. (2007). Influences of species, latitudes and methodologies on estimates of phonological response to global warming. *Global Change Biology, 13*, 1860–1872.
Roehrig, G. H., Campbell, K. M., Dalbotten, D., & Varma, K. (2012). CYCLES: A culturally-relevant approach to climate change education in native communities. *Journal of Curriculum and Instruction, 6*, 73–89.
Salick, J., & Byg, A. (2007). *Indigenous peoples and CC*. Oxford: Tyndall Centre for CC Research.
Sanders, M. (2009, January). STEM education, STEMmania. *The Technology Teacher, 68*, 20–26.
Semken, S., & Freeman, C. (2008). Sense of place in the practice and assessment of place-based science teaching. *Science Education, 92*, 1042–1057.
Szasz, M. C. (1999). *Education and the American Indian: The road to self-determination science 1928*. Albuquerque: University of New Mexico Press.
USA National Phenology Network. (2011, April). *Phenology as an indicator of environmental variation and climate change impacts.* www.usanpn.org
Wildcat, D. (2009). *Red alert! Saving the planet with indigenous knowledge*. Golden: Fulcrum.
Woodworth-Ney, L. (2004). *Mapping identity: The creation of the Coeur d'Alene Indian Reservation, 1805–1902*. Boulder: The University Press of Colorado.

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