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CYCLES: A Culturally-Relevant Approach to Climate Change Education in Native Communities

Gillian Roehrig
Karen Campbell
Diana Dalbotten
Keisha Varma
University of Minnesota

Abstract

This perspective article presents the CYCLES approach to climate change education for American Indian students. Our framework blends integrative science, technology, engineering, and mathematics (STEM) approaches to teaching and learning, place-based education, and inquiry-based strategies to provide cultural relevance to science learning that will empower American Indian students. Our integrative approach to STEM is aligned with the holistic, Indigenous world view that takes into account the myriad of interconnections between living and natural entities. Our place-based approach respects the close and sacred connections between Native peoples and the Earth. Our inquiry-based approach is designed to allow students to understand and value both scientific and Native ways of knowing about the world.

> *[O]ur duty as indigenous peoples to Mother Earth impels us to demand that we be provided adequate opportunity to participate fully and actively at all levels of local, national, regional and international decision-making processes and mechanisms on climate change…[And that w]e, Indigenous Peoples, live in sensitive zones where effects of climate change are most devastating. Traditional ways of life are disproportionately affected by climate change particularly in polar and arid zones, forests, wetlands, rivers and coastal areas. (United Nations, 2002, p.1)*

In spite of the prominent role of science, technology, engineering, and mathematics (STEM) in K-12 education and the investment of millions of dollars in various STEM initiatives (Kuenzi, Matthews, & Mangan, 2006; National Academies, 2006; National Governors Association, 2007; Sanders, 2009), there remain sizable inequities in science and mathematics achievement of K-12 students (Lynch, 2000, 2001) that disadvantage students' career choices and economic futures. Students in Native communities are among those who are most underserved and underrepresented by traditional curriculum materials and instructional approaches. American Indian students experience higher percentages of high school dropout and special education placements than any other minority group and are the most underrepresented group in higher education (Allen, 1997; Bowman, 2003; Monhardt, 2003). As educators, we need to do more to address the education of American Indian students through promoting

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respect for Native ways of knowing and exploring educational models that better align with Native culture. In this perspective article, we describe the discrepancy between Native American culture and the current education system and present an interdisciplinary, place-based approach to science education designed to make science more meaningful and relevant to the American Indian students.

Theoretical Framework

Science Education and Native American Culture

The education system experienced by American Indian youth is derived from a western model (Baker, 2003; McKinley, 2007) that has failed to incorporate knowledge fundamental to American Indian being and understanding (Cajete, 1994, 1999). Particularly when considering science and mathematics, there is a cultural conflict between Native American culture and values and national goals and education standards based on a western view of science and mathematics, thus creating a science curriculum that is generally irrelevant to students' lives (Allen, 1997; Matthews & Smith, 1994; Ogbu, 1992). Cleary and Peacock (1998) call for the inclusion of American Indian students' belief systems and cultural values in their schooling, or the *indigenization* of the current K-12 educational paradigm as it relates to American Indian students (Deloria & Wildcat, 2001). These scholars clarify that the goal for Native students is to become *bicultural*, knowledgeable in both the dominant and their home cultures, so they are both academically prepared and actively connected to their tribal communities. In other words, the goal is to connect science directly to Native students' lives promoting their scientific literacy and critical thinking skills. This can increase the possibility that they will seek a future in science and empower them to act within their own communities.

Native Americans have a special connection to and respect for Mother Earth and Father Sky. The Indigenous worldview accepts that survival depends on cooperation and coexistence with nature, a holistic view, rather than the Western view that attempts to harness and control nature through the isolation of variables within a controlled environment, a reductionist view (Hewitt, 2000). However, some scientific disciplines share common tenets with Native science and afford science educators topics that allow for the development of curriculum and pedagogical approaches that respect and embrace Native ways of knowing. For example, ecology and environmental science have been identified by Native scholars as scientific disciplines that while grounded in Western science are more holistic in nature and provide more culturally compatible approaches to understanding the world (Cajete, 2000). In this article, we consider the science of global climate change, which includes important scientific concepts from the fields of ecology and environmental science, to illustrate how our framework for science education in Native communities can provide more meaningful and relevant learning opportunities for American Indian students.

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Global Climate Change and Native American Communities

Challenges related to global climate change are faced by all Americans. Native American communities are especially concerned about these challenges since changes in climate present serious concerns to land and water management, adversely affecting Native communities whose ties to the land are both economic and cultural. Daniel Wildcat (2009) in his book, *Red Alert! Saving the Planet with Indigenous Knowledge,* refers to the western world's inaction as the fourth removal. He argues that in spite of the three historic removals (geographic, social, and psycho-cultural) of many American Indians and Alaskan Natives from their lands, much of tribal identity and culture has remained. This fourth removal is not the result of governmental policy but the destruction of the land itself through the effects of climate change.

There is an urgent need to develop and support the climate science literacy of teachers, students, and community members in Native communities. Doing so ensures that American Indian people as scientists and informed citizens are actively involved in policy-making related to climate change in their communities. Salick and Byg (2007) argue that "Indigenous Peoples must exercise self-determination and be empowered to deal with climate change which threatens their livelihoods, indeed their very existence" (p. 25). In this perspective article, we present an innovative approach to engaging American Indian youth in science through the application of the urgency of climate change concerns in Native communities to teacher professional development and K-12 curriculum.

The CYCLES Approach

CYCLES: Teachers Discovering Climate Change from a Native Perspective is a NASA Innovations in Climate Education project designed to improve educational outcomes in science for American Indian students. CYCLES is a partnership between science educators, scientists, and Ojibwe communities in northern Minnesota (NEX, 2010). Twenty middle and high school teachers from five reservations in northern Minnesota are participating in a three-year teacher professional development program to develop and implement culturally-relevant approaches to teaching climate change science with their American Indian students. CYCLES reflects the similarities between Native American and scientific explanations of the natural world as interconnected processes that are cyclical. In Native culture, the medicine wheel symbolizes the interconnectedness of the earth, air, water, and fire (see Figure 1).

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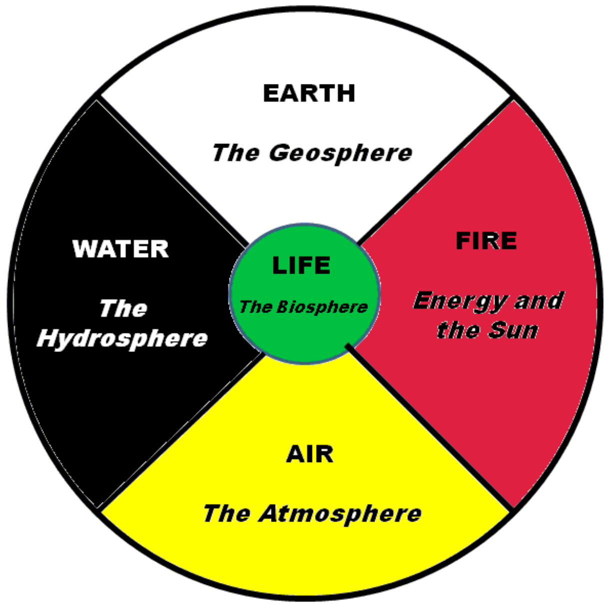

Figure 1. Medicine Wheel connected to earth's spheres.

Mutual dependency is recognized in science through an Earth Systems approach based on the interconnectedness of the geosphere, atmosphere, hydrosphere, and biosphere, with the energy flow of these systems derived from the "fire" of the Sun and the interior of the Earth. The medicine wheel components represent the central concepts (or earth spheres) needed to understand climate change. These central concepts are explored through a culturally-relevant framework that blends three approaches to teaching and learning that are aligned to Native epistemologies: (a) interdisciplinary approaches to learning big ideas in science (integrating content across earth-fire-water-air-life), (b) place-based approaches to develop local understanding and motivation, and (c) inquiry-based approaches to learning. Figure 2 graphically illustrates this framework which we describe in more detail throughout the rest of the article.

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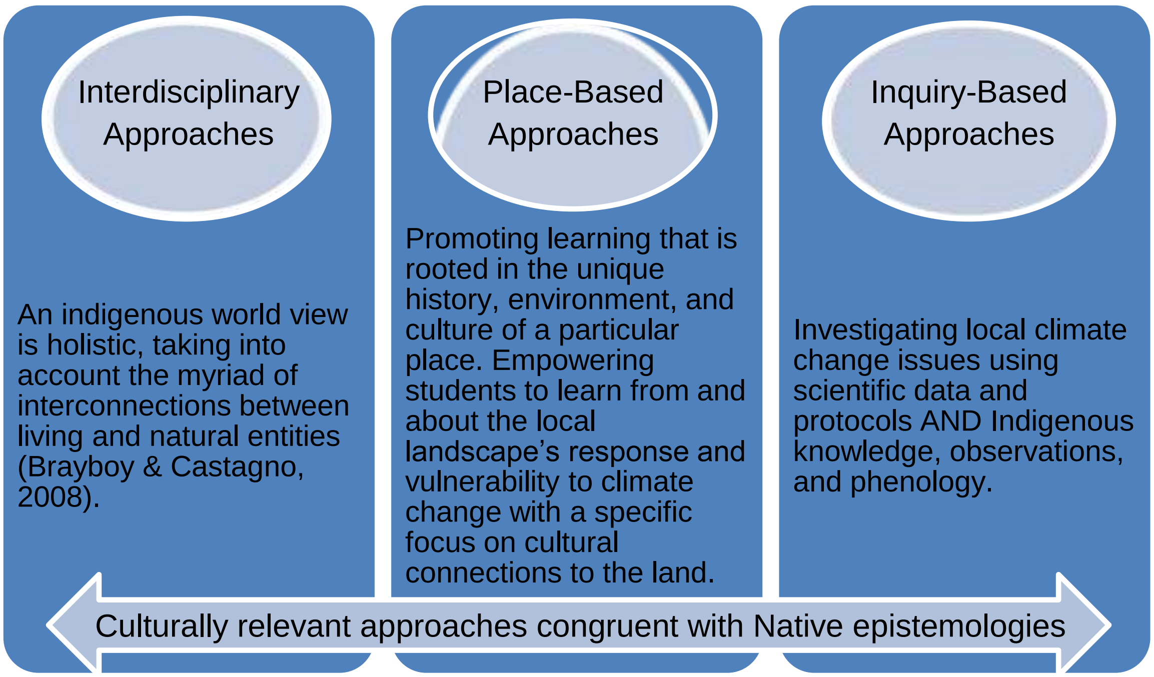

Figure 2. The CYCLES framework for teaching climate change to American Indian students.

Interdisciplinary Approaches

The problems that we face in our ever-changing, increasingly global society are multidisciplinary in nature. Professional societies, such as the American Society for Engineering Education (ASEE) and National Academy of Engineering (NAE), call for new educational approaches that focus on the interdisciplinary approaches to STEM teaching (Brophy, Klein, Portsmore, & Rogers, 2008). In part, this call is to address STEM workforce needs in the rapidly evolving technological 21st century, but also to develop technological, or STEM, literacy for all students. Hurd (1998) indicated that current ways of teaching and learning "need to be reinvented to harmonize with changes in the practice of science/technology, an information age, and the quality of life," (p. 411) because science today is "holistic in nature" (p. 409). Hurd emphasized teaching science around real-world issues that naturally integrate traditional subject areas. Unfortunately, the current structure of schools does not allow for these connections to be easily made. Schools have traditionally "siloed" topical areas and taught the STEM subjects in isolation without drawing upon the organic connections between them (Czerniak, Weber, Sandmann, & Ahern, 1999; Katehi, Pearson, & Feder, 2009; Sanders, 2009).

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Rather than the traditional siloed approach to science education, we draw on an interdisciplinary or curriculum integration approach (Beane, 1995). Beane described the interdisciplinary and integrated nature of this approach:

> In curriculum integration, knowledge from the disciplines is repositioned into the context of the theme, questions, and activities at hand. Even when teaching and learning move into what looks like discipline-based instruction, the theme continues to provide the context and the motivation. It is here that knowledge comes to life, has meaning, and is more likely to be "learned." Particular knowledge is not abstracted or fragmented, as is the case when its identity and purpose are tied only to its place within a discipline or school subject area. (p. 620)

Climate change represents one of the most pressing global and multidisciplinary problems facing humans. Understanding the evidence for climate change and proposed solutions requires a significant understanding of geologic time, Earth-surface dynamics (hydrology, geomorphology, and ecology), as well as atmospheric processes and the interrelationship between local and global processes in all the "spheres" of the Earth system (see Figure 1). Over the last two decades, scientists have recognized the necessity of studying the Earth as an integrated system in order to explain complex and unpredictable natural phenomena. Consequently, the knowledge of the physical Earth system generated by the traditional Earth science disciplines was integrated to form the concept of the Earth as a set of systems for the new discipline of Earth System Science (ESS; Johnson, Ruzek, & Kalb, 1997). However, there has been increasing concern about K-12 Earth science teaching and teachers' understandings of Earth as system. While the national standard documents (American Association for the Advancement of Science, 1993) address "system" as one of the important themes in understanding science concepts, the standards (national as well as the state standards) do not directly present how to use a system-based approach to teach Earth science. A recently published survey of Earth science standards across the U.S. was less than positive about the state standards of K-12 Earth science education (Hoffman & Barstow, 2007) as Earth science continues to be taught as independent and isolated sub-disciplines (Libarkin, Anderson, & Dahl, 2005).

From an Indigenous epistemological perspective there are very compelling connections to be made between an integrated or interdisciplinary curricular approach to science teaching and the Indigenous world view. Epistemologically, an Indigenous world view is holistic, taking into account the myriad of interconnections between living and natural entities (Brayboy & Costagno, 2008); Indigenous knowledge is grounded in the idea that everything is interconnected (Deloria, 1992). This holistic approach to knowing is derived from intimate interactions with the world for the purposes of survival (Cajete, 1994, 1999).The compartmentalization of school subjects is an impediment to American Indian students' ability to engage given a holistic epistemology and valuing learning from direct experiences (Barnhardt & Kawagley, 2004).

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Recent national documents (National Research Council, 2012) concerning science education have focused on an Earth System approach as advocated by scholars such as Hoffman and Barstow (2007) and focus on the fundamental concepts and big ideas in Earth science and climate change, for example, the Earth Science Literacy Initiative (ESLI; National Science Foundation, 2009) and Climate Literacy: The Essential Principles of Climate Science (National Oceanic and Atmospheric Association, 2009). While these documents connect their big ideas directly to national and state science standards, they also provide a framework for presenting content that aligns both with how scientists now conceptualize their work and Native ways of knowing that is more appropriate not only for American Indian students but all students. For example, Big Idea 3 (National Science Foundation, 2009) states that Earth is a complex system of interacting rock, water, air, and life which requires an integrated approach to science teaching – not a separate class or unit on geology, hydrology, atmospheric science, and ecology. These big ideas embody the ways in which scientists conceptualize their work and the holistic view of the earth embodied in Native cultures.

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. Place-based education promotes learning that is rooted in the unique history, environment, and culture of a particular place. Recent research has shown the value of place-based education in engaging youth in science that affects their community and lives (Semken, 2005, 2008; Riggs, 2005). Semken and Freeman (2008) noted, “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). From a science education perspective, a place-based education approach carefully considers characteristics associated with a unique location geographically, the inherent interdisciplinary nature of a place, and the engagement of entities outside of the school setting (Semken & Freeman, 2008).

To provide greater relevance and immediacy for climate change education, CYCLES builds upon current cutting-edge research being conducted in our geographical region, northern Minnesota. While impacts commonly associated with climate change, such as sea-level rise, are unfamiliar phenomena to Ojibwe youth, their local landscape is experiencing many climate related changes, such as earlier “ice-out” dates on lakes and shifting biomes. By promoting a place-based approach to Climate Change Education, CYCLES empowers American Indian students to learn from and about the local landscape’s response and vulnerability to climate change with a specific focus on cultural connections to the land.

The purpose of a place-based approach to climate change education for American Indian students is for them to maintain their sense of place and cultural connections to the land, it is also important for students to connect between local and

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global climate concerns. With the anchor of local issues in place, students are encouraged to investigate how climate change issues in their community are similar or dissimilar to other places and how these local issues contribute to our understanding of global climate change and the development of the big ideas or fundamental concepts in climate science (National Oceanic and Atmospheric Association, 2009; National Science Foundation, 2009).

Inquiry-Based Approaches

To understand climate change and engage in the public debate about the reality of climate change, it is important to understand how scientists work and the forms of evidence used by scientists. Indeed, ESLI's Big Idea #1 is that Earth scientists use repeatable observations and testable ideas to understand and explain our planet. Throughout CYCLES we model inquiry-based approaches to teaching science using the five essential features of inquiry (National Research Council, 2000):

1. Learners are engaged by scientifically oriented questions.
2. Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
3. Learners formulate explanations from evidence to address scientifically oriented questions.
4. Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
5. Learners communicate and justify their proposed explanations.

To provide a stronger connection to placed-based approaches to learning, we employ a science-technology-society (STS) approach to inquiry (Yager, 1993). In an STS approach, students identify problems with local interest and impact and use local information and data in problem resolution, thus creating a placed-based focus on the first two essential features of inquiry.

Indigenous people have also traditionally engaged in science. For example, they have studied and know a great deal about the flora and fauna, and they have their own classification systems and versions of meteorology. This *Traditional Ecological Knowledge* (TEK) is a subset of Indigenous knowledge that can be understood as "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). TEK includes narratives or observations by Indigenous people that can provide intergenerational observations of various kinds of natural resource phenomena (Alexander et al., 2011).

As a matter of survival, Indigenous communities have long sought to understand the regularities in the world around them and the unseen patterns within nature. Climate scientists tend to rely primarily on information from peer-reviewed scientific studies and

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have largely excluded traditional indigenous knowledge as a source of information (Alexander et al., 2011). 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), and in recent years, there has been an increasing realization that indigenous groups are a valuable source of climate change information (Salick & Byg, 2007). In an effort to link Indigenous and western scientific knowledge of climate change, Alexander et al. (2011) state:

> Indigenous knowledge can provide complementary information that has particular value in determining patterns of climate change for regions in which there are limited instrumental records. It can provide a broader picture of the impacts of climate change by putting scientific changes in the context of a human landscape. (p. 477)

When working with teachers and students in the CYCLES program, we deliberately place equal emphasis on Indigenous knowledge of climate to empower American Indian students. For example, changes in seasons and phenology indicate climatic change through generational tracking of phonological markers that signal the change of the seasons, such as changes in the time to tap the maple syrup or to harvest wild rice. Other Indigenous knowledge relates to changes in snow cover, ice, rivers, and lakes; for example, scientists and tribal elders have noted an increase in ice-free days in Minnesota lakes (Dadaser-Celik & Stefan, 2008). Other climatic factors noted by Indigenous people include changes in biodiversity with the decline of some species and the arrival of other "invasive species."

Implementing the CYCLES Framework

CYCLES draws on unique and local research projects to explore the impacts of climate change on vital and culturally important community resources—such as wild rice and forests. We illustrate the framework components in action through the example of wild rice, one of the contexts used in our teacher professional development with reservation teachers.

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 cause the wild rice stalks to break under the weight of the fruithead. Overtime, extended drought conditions could encourage greater natural competition from more shallow water species (Hoene, 2010).

CYCLES specifically utilizes research from the NSF-funded *manoomin* (wild rice) project - a community-based collaboration between university and reservation natural

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resource scientists intended to better understand wild rice production on the Fond du Lac Reservation. Many plant or animal species could be used as the context for exploring impacts of climate on ecology and agriculture but the context of wild rice promotes the strategy of place-based education. Also, because of the unique history and cultural relevance of wild rice, this topic focuses learning not only for Ojibwe students and teachers, but also for parents and community members.

CYCLES explores the role of wild rice within a holistic system. The Ojibwe understand the importance of wild rice to the biodiversity of local lakes and rivers; wild rice acts as both a food source and habitat for many other species. Wild rice is also important in stabilizing water quality, reducing algal blooms, and increasing water clarity. In addition to illustrating these important ecological system concepts, the life cycle and harvesting of wild rice illustrates how ecology is impacted by other Earth cycles such as the water, carbon, nitrogen, and phosphorus cycles. Recorded increases in average global temperature are leading to changes in precipitation. In Minnesota, increased summer temperatures increase the likelihood of drought, while heavy rain and snow events are expected to be more frequent, leading to increased incidences of flash flooding. These impacts on the water cycle can severely impact wild rice harvests through changes in water levels at critical stages in the annual cycle of wild rice growth, as well as increasing pollution from run-off containing increased levels of fertilizers and other chemicals. A wild rice lake is one part of the environment; it affects and is affected by other parts of the larger environment. An understanding of one's local natural and cultural systems is the first step to approaching much larger systems. Knowledge gained from lake studies can be scaled up and applied to Earth Systems subjects such as global climate change, extinction, and biogeochemical cycling.

CYCLES use of the context of wild rice also illustrates an inquiry-based approach 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. Research on cores spanning time scales of decades to hundreds of years – a human time scale – can be particularly compelling, as it promotes the connection between scientific findings and historical events. While climate change on geological time scales can seem somewhat esoteric to students and to the general public, changes occurring on the scale of generations involve processes and impacts with which most people are familiar, such as agriculture, food resource use (fish, wild rice), land development, recreational use, etc. Personal recollections of elders and community members and the oral histories passed down through generations also depict variability in wild rice population abundance and distribution. Through the application of the CYCLES framework, teachers and students are provided with an opportunity to connect historical information from elders to scientific findings from the lakes on their reservation.

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Conclusion and Implications

We conclude with some considerations for the application of the CYCLES framework in new communities. This approach does not usually result in a written curriculum or set of activities that is directly transportable to other communities; wild rice provides a meaningful context for northern tribes in Minnesota and Wisconsin but not all northern tribes in the United States. For example, in Idaho, the water potato provides an appropriate local, cultural, and environmental context for investigating climate change on the Coeur d'Alene reservation. Appropriate local and cultural contexts for applying the CYCLES framework should be developed in collaboration between scientists, educators, and members of the reservation community. Native stories, perspectives, and traditions need to come from the community rather than being co-opted for educational purposes by well-intentioned non-native educators. Non-native educators should be prepared to listen and understand the issues and possible controversies that can arise. In the case of wild rice, commercial farming began approximately fifty years ago and western science has worked toward the development of new strains of cultivated wild rice to provided larger harvests; however, many Ojibwe people see the wild rice as a spiritual gift not a commodity, viewing western research as the theft of something sacred. We emphasize the care and time needed in conversation with Native schools and communities that are required to utilize the CYCLES framework to its fullest potential.

Used appropriately, the CYCLES framework provides an innovative perspective through its culturally-relevant and integrated approach to teaching science with American Indian students. Our use of integrated, place-based, and inquiry-based approaches allows us to address the needs of students and teachers in Native American communities in a manner that is respectful of Native ways of knowing and includes American Indian students' belief systems and cultural values in their schooling (Cleary & Peacock, 1998; Deloria & Wildcat, 2001). A new perspective on education, and science education in particular, is warranted to address the achievement gap for American Indian students and provide avenues to STEM careers for these students. Each component of the CYCLES framework provides increasing alignment between providing a strong academic preparation for American Indian students and Native ways of knowing.

Finally, we note that new approaches to science teaching and learning are necessary to promote the kinds of skills and critical thinking needed to engage in the increasingly global and multidisciplinary problems facing our planet. We argue that our perspective on transforming the teaching and learning of science is in fact beneficial for all students. Providing a real-world context or theme provides motivation for learning and situates disciplinary knowledge in a meaningful local context as opposed to abstract concepts in a textbook. Solutions to real-world problems are not found within the pages of a chemistry curriculum or the answer key in the back of the algebra textbook. Real-

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world problems require inter-disciplinary thinking that applies concepts and methods from many relevant disciplines. The CYCLES framework provides such an approach for motivating and engaging students in meaningful problems within their communities.

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About the Authors

Gillian Roehrig, Ph.D., is Co-Director of the STEM Education Center and an associate professor of science education in the Department of Curriculum and Instruction at the University of Minnesota. Her research interests are in teacher preparation and professional development, STEM Integration, and climate change education. E-mail: roehr013@umn.edu

Karen Campbell, M.S., is the Education Director for the National Center for Earth-surface Dynamics, a National Science Foundation sponsored Science and Technology Center. She divides her time between the NCED headquarters on the Mississippi River at the St. Anthony Falls Laboratory, and the Science Museum of Minnesota. She is also an adjunct instructor in Education and Information Management at the College of St. Catherine. E-mail: mkmc@umn.edu

Diana Dalbotten, Ph.D., is the Diversity Director for the National Center for Earth-surface Dynamics, a National Science Foundation sponsored Science and Technology Center. She coordinates educational programs for Native American middle-school and high-school students and undergraduates including an REU site on Sustainable Land and Water Resources. E-mail: dianad@umn.edu

Keisha Varma, Ph.D., is an assistant professor in the Department of Educational Psychology at the University of Minnesota. Her research explores the cognitive processes that underlie science learning. Her research is at the intersection of educational psychology, cognitive science, and the learning sciences, examining learning and cognition in technology-enhanced classroom settings. E-mail: keisha@umn.edu