

Running Header: Improving Science Learning for Indigenous Students

Science Education. DOI 10.1002/sce.20392

Published online 1 March 2010 in Wiley Online Library (wileyonlinelibrary.com).

Title: Cultural Processes in Science Education:
Supporting the Navigation of Multiple Epistemologies¹

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Abstract. Although there has been considerable focus on the under-representation of minorities in STEM disciplines and the need for science instruction that fosters diversity, much of the associated effort has focused on the goal of diversity and has both neglected learning and tended to assume that science and science learning are acultural. We describe a conceptual framework employed in our work with both urban and rural Native-American communities that focuses on culturally-based epistemological orientations and their relation to the cultural practices associated with science instruction. We summarize evidence on the efficacy of community-based science education to support the proposition for a shift in orientation towards science education from aiming to have students adopt specific epistemologies to supporting students' navigation of multiple epistemologies.

The “places” of learners and practitioners of science from non-dominant groups are increasingly a focus in analyses of science learning and education in the US. Typically these places are defined through the discourse of equity that focuses on (under) representation and the goal of creating learning environments that will allow students of color to perform as well as their white peers. More recently this dialogue has shifted from performance to knowledge of STEM content and the ability to think critically about this content. It has also included attention to learning environments such as museums and other out-of-school learning environments.

Although representation and ability to think critically about STEM content remain necessary lenses for understanding the challenges facing science and science education, by themselves, they are incomplete, because they tend to focus on the goal and not the nature of learning itself. Consequently, they lend themselves to deficit orientations and prescriptions in the form of thinly disguised (or even overt) efforts to get children and parents of color to adopt white middle class practices and orientations (Nisbett, 2009). These same prescriptions treat learning as acultural.

In order to improve teaching and learning for children and adults throughout the life course – from both dominant and non-dominant backgrounds – we must delve more deeply into understanding learning and development as fundamentally cultural processes (Cole, 1996; Lee, Spencer and Harpalani, 2003; Nasir and Hand, 2006; Rogoff, 2003). We believe that *central to the future of science and science education is to understand, support, and leverage the ways in which diversity – of people, practices, languages, meaning, knowing, epistemologies, goals, values, and the like.... in learning environments and professional practice are an asset and expand the possibilities for human knowing and meaning* (Gutierrez et al. 2000; Warren, Ballenger, Ogonowski, Rosebery, and Hudicourt-Barnes, 2001).

Our work has taken up this stance specifically in Indigenous communities. We have conducted close study through a variety of methodologies on the STEM related knowledge, learning and practices embedded in Indigenous communities. We argue these intellectual resources must be mobilized and engaged in meaningful and rigorous ways both to promote learning and engagement in STEM related domains (Moll and Gonzalez, 2004) and to support the vitality of Indigenous people. This is a critical departure from a

deficit lens which views community derived knowledge as an impediment to learning academic STEM content. Further, we believe that this stance towards STEM learning in the early years opens new possibilities for participation in STEM issues across the life span, because it creates new forms of participation for adults -- parents, experts, community members – in the design and implementation of learning environments.

Although there is a chronic under-representation of Indigenous people in STEM-related fields and although increasing achievement is a goal of our work, we are not aiming to usher Indigenous people away from their community-based understandings into western modern scientific understandings. Instead, we have been engaged in the design and implementation of learning environments that have the explicit goal of mobilizing the intellectual resources students develop in their everyday lives (Warren and Rosebery, 2004) primarily to deepen students' community-based ways of knowing and secondarily to support learning of western modern scientific understandings. In the present paper we focus on one important component of this overall effort---epistemological orientations. As we shall see, the term “epistemology” has quite varied definitions and uses. We are specifically concerned with epistemological orientations that bear on relationships among historical and culture identities, relationships with nature, and their links to practices associated with science and science education.

These goals continually highlight the need for understanding and supporting student's navigation in and through multiple ways of knowing. Central to this navigation, in our experience, are issues of epistemologies and their impacts on cognition and sense-making. Although other researchers have demonstrated that learning involves more than cognitive processes – identity and affect are intertwined – (and we agree), this paper aims to further develop the ways in which we understand issues of epistemologies and resultant impacts on engagement and cognition as components of cultural processes (Nasir and Hand, 2006). In doing so we are concurring with the spirit of the NRC report (Bell et. al., 2009) on informal science learning in stressing that seeing science as a body of knowledge derived from (acultural) practices is a very impoverished view that leads science educators to focus on methods and facts rather than motivation, fascination and personal relevance.

The remainder of this paper is organized as follows. First, we introduce the overall

context of our work from which this paper emerges including the broader context STEM school achievement with a focus on under-representation of Native scholars in science as a motivation to examine meanings and orientations to understanding culture in education research more broadly. Next we explore the ways in which epistemology is understood and constructed in the field of science education. We offer some critical analyses of constructs as well as some additional dimensions for understanding epistemology that build from both the science education literature and Indigenous education literature more specifically. In doing so we will briefly summarize some preliminary results from our community-based science education programs. Finally, we discuss the ways in which the focus on epistemology opens new spaces in the design and implementation of learning environments from new configurations of power and meaning that transform the schooling opportunities for Indigenous students but which may represent best practices for all students regardless of community affiliations.

COMMUNITY AND PROJECT CONTEXTS

We begin with a brief description of the overall community contexts of our projects.

Rural Menominee Wisconsin community. The Menominee are the oldest continuous residents of Wisconsin. Historically, their lands covered much of Wisconsin but were reduced, treaty by treaty, until the present 95,000 hectares was reached in 1854. There are 4-5000 Menominee living on tribal lands. Over 60% of Menominee adults have at least a high school education and 15% have had some college. The present boundaries of the Menominee nation were forested then and continue presently - there are currently about 88,000 hectares of forest. Reflected in their on-going forestry practices among many others, sustainable coexistence with nature is a strong value of the Menominee Nation (Hall and Pecore, 1995). For many Menominee community members hunting and fishing are important activities and children are familiar with both by age 12. The Menominee children in the study attend a tribal school. The majority of the teachers and staff and all of the children are Native-American. Although exposing children to the Menominee language is an important focus of the tribal school, science instruction and everyday discourse is in English. For comparative studies, majority-culture children and

adults are recruited from an adjacent county which also has numerous lakes, streams and forest plots.

Rural European-American populations. In some cases it was useful to make cross-community comparisons and for this purpose we relied on samples from rural European-American communities (Shawano County, Pulaski County) located near the Menominee reservation in Wisconsin. These communities share a focus on outdoor recreation, including hunting and fishing.

Urban Indian population. Most previous research on Indian education has not focused on or considered urban Indians. There are approximately 40,000 Indian people in Cook county, many of whom were relocated to the area during the 1950s and 60s during the federal relocation era. The Chicago community is a very diverse intertribal community with individuals representing more than 100 Native Nations across the country. Native-American children are scattered across a number of schools in the district and are almost always the only Native child in the classroom and sometimes the school. Our learning environments are implemented at the American Indian Center (AIC). The AIC is the oldest urban Indian center in the country and serves as the social and cultural center of the Chicago Indian community. Menominee and other Wisconsin tribes are well-represented at the Indian Center. The AIC faces many of the same problems that other inner city communities face, such as high rates of poverty, lack of access to quality healthcare, poor schooling options, low employment rates, issues surrounding drugs and alcohol and high rates of violence. This paper will refer to the community members from the Chicago community as the urban Indian community. Readers should note that this unfortunately collapses significant cultural and historicized experiences of the larger multi-tribal community. This could potentially have a homogenizing affect and is something that we continue to struggle with across multiple dimensions; however it would be inaccurate to suggest that there are not shared practices, values, challenges and strengths that are fundamentally defined by being a part of the Chicago Indian community. As we hope the reader will see, this paper is aimed at a grainsize that neither intends to minimize the vast difference between tribal nations nor claims results that require it.

Methodology and Ethical Considerations. The design of our methods has been based on an understanding of appropriate research methods for working with American Indian communities. There is a long history of research in American Indian communities that has often not been in their best interest, a legacy that has made many Native communities suspect of research. Over the years Indigenous researchers themselves have worked to develop appropriate research methods and criteria (see Battiste and Henderson, 2000; Guyette, 1983; Hermes, 1999, Mihesuah, 1998; Tuhiwai Smith, 1999). There are some general lessons that have emerged. First, the consensus that the community-based participatory action research (PAR) is the best framework of inquiry. PAR has generally been defined as an integrated approach that relies on the participation of community members to investigate the issues at hand while increasing autonomy through a process of praxis (Hermes, 1999). PAR includes the following criteria: elder input, use of traditional language, community participation in research agenda, staff selection, and budget, community payoff, respect of cultural value, and informed consent (Hermes, 1999; Hudson and Taylor-Henley, 2001). Additionally, when conducting research with reservation communities, investigators must go through the tribal ethical review process; Institutional Review Board approval from a mainstream institution is not sufficient (Lomawaima, 2000). Although less has been written about working with urban populations, and the benefit of tribal approval of the research is not possible in an inter-tribal community like Chicago where more than 100 Nations are represented, only one of which has a local branch office, forming a local advisory committee within the community and seeking institutional support of local organizations is a good idea. Our projects attained both tribal government and community approval.

Project history and structure. This paper emerges from a much larger “community-based design research” project aimed at creating community based science curricula in the Chicago inter-tribal Indian community and the Menominee reservation community. Our project is a collaborative effort involving Northwestern University, TERC, the American Indian Center of Chicago (AIC), and various institutions on the Menominee reservation in Wisconsin, including the Menominee tribal school and the Menominee Language and Culture Commission. There are many, many people involved

in this work and we humbly apologize for the gloss but this paper is not intended to tell the full story of that project as it has in part been told in other places (see, Bang et. al, 2009) and it is still unfolding. However, having a basic glimpse into the communities and work we are embarking on as context for our argument in this paper is important.

While there are many important theoretical connections and implications of our project, two critical problems in Indigenous education motivated the work. First, there is simultaneously great need for Indigenous STEM professionals in our Nations and significant under-representation of Indigenous people in STEM fields. This under-representation is linked with historically low student achievement and a paucity of research focused on science education with Native learners, particularly at the K-12 level. Over the past ten years, Native people have represented an average 0.63% of the total number of bachelors degrees and an average of 0.48% of the doctorates awarded in Science and Engineering (NSF, 2007), The 2000 census found that about 1.5% of the US population identified themselves as American Indian or Alaskan Native. Thus, these figures indicate that Native people are about 60% under-represented at the college level and 67% under-represented at the doctoral level (even without taking into account the age distribution of Native-Americans).

The lack of degreed expertise within communities contributes to, and perpetuates, struggles with education and educational achievement, adequate economic development, the enhancement of community health, and community-based governance of resource management. In short, Native people both on and off reservations, continue to struggle. To improve the circumstances that affect Indigenous communities in ways that are likely to have a sustained impact requires that we improve the educational experience and attainment of Native people, especially within STEM education.

Second, we believe that we are at a new stage in reclaiming, uncovering, and discovering best practices in education in the era of self-determination as it pertains to education in Indigenous communities. We would be remiss not to contextualize this project within the larger socio-historic experience of Indigenous communities with formal education. Formal education in American Indian communities has systematically undermined the sovereignty and the cultural and intellectual vitality of Indigenous peoples. Formal education has been wielded on Indigenous communities as a tool for

assimilation. Control over the education of Indigenous children and even the parenting of Indigenous children was systematically and intentionally manipulated as a way to “solve the Indian problem” (Brookings Institution, 1928). Although the most pernicious aspects of the boarding school era have been confronted and displaced, they have been replaced by more subtle, but ultimately equally damaging, power structures that organize learning in terms of the values and practices of the dominant culture. The everyday practices of teaching and learning have not been in the control of or in many cases even implemented by Indian people. For many community members, memories of school are devastating. Although they wish for their own children to have better experiences, it is hard for them not to conceptualize schools as a “necessary evil” let alone as a resource for community values.

While there are important exceptions, the great successes and progress since the 1970s in communities has been at the administrative level, not at the classroom level. The majority of Indian children both on and off reservations have non-Indian teachers, especially in the sciences. The design of this research project recognized this and intentionally proposed engaging teachers and community members in the design of a learning environment integrating levels of classroom, content and pedagogy. The intent was to begin to create a space where community members engaged in reclaiming the classroom level of teaching and learning for Indigenous children (Tuhiwai Smith, 1999). We believe that there is serious work and opportunity at the level of design and moment-to-moment classroom interactions that have yet to receive the close study they demand.

Authors' backgrounds. From the authors' experiences, this project grows out of two primary groups of activities. First, Medin has been conducting a variety of cognitive research with the Menominee community since the mid 1990s. This work has been especially focused on conceptions of the natural world. As part of this work Dr. Medin has been deeply engaged with Menominees who are hunters and fisherman and he has worked closely with various pre-K-8 educational institutions. He has taught at the College of the Menominee Nation as well as Native American Educational Services College. He has formed many relationships with elders, adults and youth over these years, participated in many community events, and has participated in supporting and

working on community issues outside of our research projects. Since these projects began Medin has established a similar relationship with the Chicago inter-tribal community. In part the inclusion of the urban inter-tribal Chicago community evolved because Bang attended graduate school and Medin served as one of her advisors.

The second strand of activities combines the personal, educational, and professional experiences of Bang. Bang is of Ojibwe and Italian decent. Her family has been “off-reservation” for several generations. Bang began her professional career teaching across various grade levels and contexts including museums and after-school programs. She is currently the Director of Education at the American Indian Center of Chicago, is a member of and has been working in the Chicago Indian community for more than twelve years. She taught GED at the Institute for Native American Development, followed by founding a tutor/mentor program called Positive Paths at the AIC and served on the title XII Indian education program of the Chicago public schools for more than 5 years. These three professional experiences motivated her to return to graduate school where she met Medin. While Bang had previous personal relationship with various members of the Menominee Nation prior to graduate school, as a graduate student she became professionally involved with Menominee Nation through Dr. Medin and has now been working with the Menominee community for the past seven.

While science learning and achievement has remained the central focus of the project, we are just beginning to unpack the ripple effects that have emerged. This is in part because of two other crucially important goals we began with: 1. to strengthen the capacity of Native communities to improve student learning and achievement and 2. to increase Native undergraduate and graduate student participation in research. There are a number of ways this has happened including: building the organizational infrastructure of community organizations to conduct research and manage large federal grants, build the professional skills and accreditation (degrees, classes, professional certifications) of community members, increasing tools and resources within community, building institution to institution agreements between the larger research institutions and Native institutions, involving community members at all levels of research, and forming direct relationships with funders. Rather than having Northwestern University control all research funds or having Northwestern as the primary institution issuing subcontracts to

tribal entities, whenever possible we have sought to submit grants with a single project description and three independent budgets, independently administered and benefiting each institution. While the reader might think these are details irrelevant, for us they reflect best practices in conducting research with Indigenous communities because it reflects the entire research process and its infrastructure.

SITUATING THE PROJECT IN (SCIENCE) EDUCATION RESEARCH

Meanings of culture, race, diversity, and equity. Understanding the widespread lack of achievement in STEM education and developing possible solutions poses critical challenges, especially in light of previous cognitive science research, as well as community-based research, suggesting that the problems with achievement are more complicated than simply knowing or not knowing “science content” (see Demmert and Towner, 2003, for a review). Indeed there is a growing body of educational research that is demonstrating the need to understand the complexities that diverse ways of knowing create for teaching and learning environments, particularly if we are to improve achievement for those groups of students who have historically been placed at risk (Gutierrez, 2006; Gutierrez and Rogoff, 2003; Warren and Rosebery, 2007). Fundamentally this work argues that the current state of knowledge about human learning and motivation has yet to adequately understand the ways in which culture is integral to learning (Nasir et. al, 2008; Nasir and Hand, 2006).

The definition and use of the concept of “culture” is deeply controversial (see, for example, Brumann, 1999 and related commentaries) and numerous scholars have suggested getting rid of the term altogether. There is a growing body of work taking up issues of “culture” that have in common the rejection of a “box” model of culture, where boundaries are sharp and categorical and where culture is defined solely in terms of shared characteristics or behaviors (i.e. Rogoff and Angelillo, 2002). For example, one alternative perspective is the epidemiological approach to culture (e.g. Atran, Author and Ross, 2005; Sperber, 1985) where culture is conceptualized as a causally distributed set of ideas, their public expressions, and the practices and behaviors of individuals and groups in particular ecological contexts. From this framework, within-group variation is

an object of study rather than treated as measurement error or random variability.

An increasingly influential framework (Gutierrez and Rogoff, 2003, Moll and Gonzalez, 2004; Nasir and Cobb, 2005) proposes that, although the construct of culture is problematic, people nonetheless “live culturally.” From this perspective a key object of study is the wide-repertoire of sense-making practices that people participate in, particularly in everyday contexts. Lee (1993, 1995, 2001) has used this approach for the design of learning environments that leverage knowledge associated with everyday experiences to support subject matter learning (in her case literacy practices). From this framework, cultural practices can also be seen as providing alternative “perspectives” or epistemologies. This understanding of culture implies that there is no cultureless or “neutral” perspective any more than a photograph or painting could be without perspective. In this sense, everything is cultured (Rogoff, 2003), including the ways schools are organized and education is implemented (Lipka, 1998; Warren, et al., 2001), layout of museums (Bitgood, 1993; Duensing, 2006), scientific practices and the practices associated with teaching science in school (Warren and Rosebery, 2004). Sometimes these perspectives are explicit but they are often implicit in practices and symbols (Unsworth, 2008).

Developing culturally-based science curricula is far from straightforward. One of the key aspects of our work has been the evolution of our understanding of what culturally-based science programming means and the ways in which to design and study the programs. “Culture” and “Science” are two concepts that are strongly subject to stereotyping and simplistic definitions. For example, it may be easy for some people to think of science as a body of knowledge and to imagine scientists as (white) men wearing white lab coats and using beakers and test tubes. Similarly it is easy to think of culture as a set of ideas about what people think or customs rather than as affecting how people think. If these stereotypes and reductionist approaches remain unchallenged, then it is natural to take some pre-existing science curriculum and build in a cultural connection by “adding culture to it.” Indeed this is an approach that has been widely advocated and used but has failed to have the desired impacts (Hermes, 1999; Yazzie-Mintz, 2007). In part, we think this is because it has not addressed the core problems of culture in science and science education nor has it recognized the embeddings of culture in everyday practices.

We think that cultural practices and their connections with Native ways of knowing must be the foundation of a community-based science curriculum. There is a strong body of Indigenous scholarship exploring the philosophies and methods of Indigenous ways of knowing (or “Native Science”) the natural world and corresponding relationships and tensions with western modern science (i.e. Cajete, 1997; Deloria, 1979; Deloria and Wildcat, 2001; Kawagley, 1995). A key aspect of developing our framework has been to resist placing western modern science and Native science in an oppositional dichotomy because it has the effect of inappropriately simplifying both ideas of western modern science and Native science (Maryboy, Begay, and Nichol, 2006).

Our approach works to remove the implicit valuing of western modern scientific some ways of knowing over all others. Native science is not simply folk wisdom accumulated over time that may or may not be “validated” by modern science; instead, Native science embodies values and epistemological orientations for approaching and understanding the natural world that have integrity in the contemporary practice of science (Cajete, 1999a). Recognizing the significance of Native epistemologies may remove some of the problems with student navigation of ethnic and academic identities that is documented in the literature (i.e. Nasir & Saxe, 2003) and put students in the position of successful “border crossing” (Aikenhead 2006; Guitierrez, 2006). Our project has evolved in a way that makes a practice view of culture and the perspective of children moving in, between and through multiple ways of knowing central to our curriculum design, implementation and evaluation.

Epistemologies as cultural processes. There is growing evidence that issues related to epistemology are central to improving the quality of STEM learning and knowing (see, AAAS, 2007). Noticeably missing from the literature on epistemology and science education, all of which has been conducted outside of Indigenous communities, is the consideration of epistemology as an aspect of cultural processes.

In education most epistemology research makes the assumption that the epistemologies that students come to classrooms with are inferior, or less productive, compared with the one(s) that researchers and educators (for our purposes, science education) are trying to assist students in learning. Some researchers have claimed that

successful science education will require students to learn or replace the personal epistemologies they bring with them with an epistemology that is aligned with a western scientific epistemology (King and Kitchener, 1995; Strike and Posner, 1985).

Within science education more specifically, Hammer and Elby suggest framing student epistemologies as “*epistemological resources*.” This reframing can be thought of as analogous to the reframing in conceptual change work that argues that students’ prior knowledge is better characterized as “knowledge in pieces” that can be built upon rather than stable, robust, concepts that need to be replaced or overcome (diSessa, 2006).

Hammer & Elby (2003) define epistemological resources as students’ epistemologies developed in students’ everyday lives and that are appropriately employed in various contexts. The resources are not part of a robust, stable, or context-independent theory or belief about knowledge and learning; rather they vary across contexts and domains, depending upon the appropriateness of fit. They give several examples such as “knowledge as propagated stuff, knowledge as free creation, and knowledge as fabricated stuff.” They nicely demonstrate how even young children are able to draw on these resources given the appropriate context. Hammer & Elby (2003) suggest that recognizing students’ epistemological resources and facilitating students’ proper employment of these resources is a better pedagogical approach in teaching science.

Is it surprising that notably absent from any of this work is any concern about cultural differences. Is there cultural variation in the fundamental epistemological resources different individuals bring to bear in learning? Are similar epistemological resources accessed and used in comparatively the same contexts by diverse learners? To answer these questions, further work to understand the ways in which epistemologies are learned, used, and instantiated as well as the ways in which epistemological issues are connected to identity, knowledge form and content, sense-making and context is critical.

Indigenous science/science education and epistemology. Issues of epistemology are a rich area of scholarship for Indigenous people working within a variety of disciplines and from a variety of perspectives (e.g. Waters, 2003). A body of scholarly work has described and analyzed the plethora of ways in which ethnocentrism plays out, especially in regards to epistemology, Indigenous traditions, Western-European traditions

and those that have emerged from them (See Barnhardt & Kawagley, 2005; Cajete, 1999a; Deloria, 1998; Hermes, 2000; Kawagley, 1995; Meyer, 2001; Deloria and Wildcat, 2001).

Within the context of science and science education specifically, there has been less work, although the work that has been done is extremely important (e.g. Cajete, 1999b; Kawagley, 1995). Scholars such as Cajete (1999a) see Native science in terms of epistemological stances and values, not simply as part of tradition but rather are alive and relevant today. Our own work has documented some of these cultural differences in epistemologies and associated values and we have incorporated them into our community-based science education programs.

Meyer (1998) frames the importance of epistemology in relation to education nicely. She says:

Epistemology, the study of knowledge, is the starting point for any discussion of indigenous education. It is also a discussion of the priorities and need for identity. Understanding what Native peoples believe about their knowledge origins, priorities, context, and exchange teaches us more about its continuity. Knowing something, then, is a cultural experience that strengthens or fractures culture. (p. 22)

Understanding how “knowing something can strengthen or fracture culture” is extraordinarily “multi-leveled and layered because even the smallest of things that we know” can have consequential impact (see Cajete, 1999a). Clearly understanding the impact of having children participate in multiple contexts with sometimes conflicting and sometimes aligning epistemologies becomes critical if we are to design effective learning environments that assist children in learning, distinguishing, and navigating epistemological resources and their applications.

EPISTEMOLOGIES IN PRACTICE

In our view, day-to-day practices are the sites at which epistemologies and epistemological stances are implicitly brought to life, learned and infused with meaning (Bang, 2006). For our purposes in this paper, we are concerned with the dimensions of

epistemology that are focused on the source, scope and validity of knowledge. Ultimately we find that students' understand and engage with the specifics of these dimensions in context specific ways. In the next few paragraphs we describe research that illuminates the multi-dimensional nature of epistemologies in our work.

Multiple epistemologies. There are multiple levels at which we can conceptualize and demonstrate alternative understandings of nature emerging from various studies and methodologies, as well as the ways in which they may play out in learning contexts. We have used a variety of methods and measures to establish supporting examples. In a simple standard sorting task we conducted with urban Indian children we found that the core biological concept of 'alive' shifted depending upon context. We gave urban Indian middle- school students a series of 16 pictures (i.e. animals, plants, water, sun, rocks, artifacts) and asked what a science teacher would say is alive and what an elder would say is alive. Generally, the students answered differently for each context, saying, for example, that an elder but not a science teacher would say that rocks and water are alive. Among other things, this observation reveals that Indian students recognize differences in orientation and raises issues concerning how different orientations are coordinated or negotiated.

Practices and values. In one line of work (Bang, 2006; Bang, Medin and Atran, 2007) we have examined community (urban Indian, rural Menominee, rural European-American) practices as reflecting and revealing implicit epistemological stances. The European-American children and adults in the study were much more likely than the other two groups to engage in activities where nature was the background or setting rather than the focus of attention. The European-American descriptions of practices (e.g. fishing) tended to be goal-oriented and provide little by way of context. The Native-American (both rural Menominee and urban community members) descriptions are broader, focus more on relations and include relevant context. There are also community differences in the goals parents have for children with respect to learning about nature. Native parents said that they want their children to realize that they are a part of nature. In contrast, European-American parents described nature as an externality to be taken care of and respected. Native-American parents were also more likely to mention spiritual practices and the idea that no creature is more important than or "above" any other

creature (Bang, et al, 2007). This work demonstrated that the everyday practices and forms of participation taken up by the Native communities in this study engaged Native children in learning deep science content knowledge as part of their day-to-day lives.

Epistemologies in culturally-based hunter education. The state of Wisconsin mandates that anyone seeking a hunting license must be certified as passing a hunter education course. The same curriculum is used in every Wisconsin county, including Menominee County. We videotaped a hunter education course offered on the Menominee reservation and one populated by European-American instructors and participants in nearby Pulaski County. The data indicated that Menominee instructors are more likely to tell personal experience narratives, more likely to mention non-human animals and when they do so are much more likely to take the animal's perspective when gesturing than are European-American instructors. Follow up studies with Menominee and European-American adults also showed that Menominee adults are more likely to take an animal's perspective in gesture than are European-American adults (Unsworth, 2008).

We believe that these differences in epistemological orientations foster greater attention to ecological relations in Native communities and a greater tendency to see humans as an integral part of ecosystems. In support of this idea, research by Medin et al. (2006), Medin, Ross, Cox and Atran (2007) and Ross, Medin, Coley and Atran (2007) with European-American and Menominee hunters and fishermen indicated that Menominees were more likely to organize their knowledge in terms of ecological relations and more likely to categorize on the basis of habitat than were European-Americans. Related developmental work using an inductive inference task provides evidence that Menominee children are precocious with respect to engaging in ecological reasoning (Ross, Medin, Coley, and Atran, 2003).

Given that science instruction is seldom recognized as a set of cultural practices, many Native students may aptly be perceiving a sharp divide between everyday practices and what takes place in school. The lack of recognition of science and science education as being a set of cultural practices may implicitly or explicitly teach Native students that their own orientations and practices are not recognized or appreciated in school contexts or relevant to professional science. Consequently, it may be hard for Native students (as well as others) to resist the view that science is indeed a practice peculiar to white males

and that science learning consists of the “received wisdom” of the dominant culture. That’s not a prescription for engagement with science. We have attempted to address this and related issues in our community-based science programs.

MOVING TO DESIGNED SPACES

We believe that mobilizing the intellectual resources of learners – in our case Indigenous learners – in the design and implementation of learning environments fosters more effective and sustainable learning environments and engagement with STEM over the life course. One major step in this effort consists of recognizing and honoring Indigenous epistemological practices and orientations as relevant to science and science learning. For us this meant reflecting with community on at least three things: understanding science as a set of practices in which to study and make sense of the world, seeing these practices as socio-historically defined and evolving, and considering the implications of practices embedded within value-systems.

From this process emerged the second important step: recognition that science and science instruction is not acultural but rather reflects (often Western) values and orientations but redesigning learning environments with this perspective could lead to new kinds of science learning. This recognition has vast implications for the practice of science education for all learners especially at classroom level and in teacher preparation. In our experience, these two steps are associated with communities being empowered in science related activities both educational and professionally and students recognizing science as a more inclusive set of practices and orientations that have spaces for Native identities. Only then does it become relevant to focus on navigating alternative perspectives.

To test our hypotheses, we have developed and implemented community-based summer science programs that are designed to support students’ navigation among multiple ways of knowing, including their community-based ways of knowing. The involvement of community members in the program and the explicit use of Native epistemological orientations in science-related practices serve as a strong signal that science is not just for other people. It also helps in creating learning environments that

include the implicit epistemologies of children's everyday lives because the adults that engage in those practices are also engaging in the learning environments. We have also used small-scale studies and classroom observations to identify conceptual points of interest that may contribute to problems with school achievement and to develop strategies for building on the cultural knowledge and values that Native-American children bring to the classroom. We turn now to a brief summary and description of our efforts.

Development and implementation of the curriculum. A significant focus of our project was the creation of curricular units developed by the Chicago and Menominee community-based design teams. The design process is a paper on its own (see Bang, et al, in process) and included participation by a range of community members including: elders, parents, teachers, community content experts, youth, and other community members interested in the project. The overall process included a series of community forums and meetings over a year and half to conceptualize the overall research project, articulate learning goals and objectives, identify and nominate community design leaders and teachers. From these larger discussions the nominated leaders and teachers met weekly or bi-weekly to develop specific activities and lesson plans. These materials were shared, edited, and revised with the larger group in an iterative process. This process was mirrored in the other aspects of the research process as well. For example, our data collection for this project employed participant observations of design process and implementation of learning environments, standard cognitive tasks, semi-structured interviews, and surveys. Community members were involved in developing, refining, and collecting all sources of data.

The curricula developed in both communities were relationally-driven, place-based and problem-based, involving locally meaningful interventions focused on ecosystems. They were organized around the global idea that we (humans, other animals, plants) are all related (See Cajete, 1999a, 1999b; Kawagley, 2000, Chinn, 2007). On a more specific level the students were often invited to take the perspective of an animal (e.g. "put on your deer ears"). The curricula included a range of content concerning plant and aquatic life through a series of hands-on experiences (e.g. cutting down invasive

buckthorn from forest), guest speakers (e.g. elders and professionals working in relevant fields), and “labs” (e.g testing pH levels of water samples). At the American Indian Center (AIC) we used the medicinal garden surrounding the building as an anchor and then branched out to various local neighborhoods to identify and experience urban ecosystems, local forest preserves and lakefront restoration sites. On the Menominee reservation our focus was on the forest and waters but the program included activities like visiting the Menominee water treatment plant which maintains its own laboratory for water quality testing and conducting inquiries into maple sugaring. Another specific element of the curriculum was the inclusion of culturally-based stories that convey some knowledge about nature, primarily stories about plants and animals.

The following is a brief vignette that exemplifies the kind of activities that were designed and implemented. Although there are some particulars to this activity, generally our designers followed a similar structure and logic for all of the activities.

The Chicago program was based on plant ecology and organized around the big idea that everything is related. Students “recognized their relatives” by engaging in close study with one medicinal plant species that was in the medicinal garden surrounding the AIC. Students “remade a relative” by interacting with the same plant daily in a variety of ways including: daily visits and offerings, growth observations, plant anatomy, soil observations and testing, and plant health (for example, was there evidence of insects or animals interested in their plant). These practices were integrated into other activities. For example, part of the summer program involved learning about invasive species. One activity was centered around understanding buckthorn’s (an invasive species) impact on local forest ecosystems. We went to a local forest preserve, accompanied by forest preserve staff (practicing scientists) where buckthorn is damaging the health of oak trees (and thus the forest canopy) and ultimately the entire health of the forest ecosystem.

Upon arriving at the forest preserve students were first introduced to the history of the preserve and Native peoples’ relationships with the forest before European contact and how that changed over the course of US-Indian history.

Through this history students were introduced to their community responsibilities to the forest and to the respectful protocol for entering into special places. They were also asked to locate their plant relative in the forest and to make a series of observations about the plants focused on their habitat, anatomy, proximity to other plants, and of their state of health. After each student located their plant we gathered together to learn about buckthorn from the plant's perspective (including its history in the area) in order to strategically clear (cut) some of the buckthorn. The idea of invasive species was reframed as distant relatives who had lost their relationship with people. We wanted our students to have continuity in orientation towards plant life even if the plants were not part of traditional Native communities. Students learned appropriate community-based protocols for cutting down these plants, safe and proper use of tools, as well as species identification strategies at various stages in a plant's life cycle.

During this time we were visited by a doe and fawn walking through the preserve. The elder on our trip interpreted this as the doe and her fawn welcoming us and thanking us for the good work we were doing. Students, teachers and other community members then cut buckthorn for a couple of hours. During that time there were a series of mini lessons that took place about other local plants, plant identification and plant anatomy. We were also fortunate to observe several other animals during the visit including: a possum and possum baby sleeping in the trunk of a tree, a snake, mice, and squirrels.

Navigating multiple epistemologies. In this vignette there are multiple points in which multiple epistemological orientations are being supported. We'd like to make several clear. To begin, the naming of learning about plant ecology as "*Remaking Relatives*" places the foundation of student learning in a community based epistemology in which plants are relatives. This decision was layered in community epistemologies because students were in a medicinal garden that incorporated plants that tribes have used for various purposes for millennia. The garden includes medicines that are for physical and ceremonial purposes. Students were asked to "visit" with their relative plant daily and would learn about these dimensions of the plant. As mentioned in the vignette these

visits included making observations of their plants through a variety of means and senses. In addition some standard science data collection practices were integrated – i.e. measuring plant growth, soil pH levels. Importantly, however, students were never asked to collect specimens from their relative plants during this process as a way of making visible boundaries on appropriate types of data collection from a community based perspective. Teachers and students discussed the value of not collecting parts of a plant unless it was necessary. Students did harvest plants when making medicines and distributing those medicines to community. This discussion also opened students' thinking about appropriate methods and forms of data for particular questions or tasks – a goal in many science classroom learning environments.

As the students were engaged in a new place, the forest preserve in this vignette, they were first taught about the history of the place and their ancestors' relationship to it over time. Knowing place over ancestral time is a critical component of community based ways of knowing (Cajete, 1999a; Kawagley, 1995). This was an important aspect of connecting urban Indian youth in this project to place because it opened the space for them to see Chicago as Native lands, a place where their ancestors had been before. In addition, designers articulated that it was important for students to understand how different orientations toward land led to different uses.

The final point of support we'd like to highlight is the framing of invasive species in forest preserves. Extending the frame of plant relatives and human relationships with plants to invasive species served two important functions: 1) it demonstrated to our youth that community epistemologies can be expansive and not just to our medicinal plants, and 2) it extended understanding human impacts and interactions with ecosystems.

Student learning & nature of science. Although our goals included acquiring a body of knowledge concerning the natural world, our focus here is less on this form of learning and more on students' perception of science and their relation to it. Central to our design was the premise that Native students will be more engaged in school science if they see it as relevant and useful to their communities (e.g. Aikenhead, 2006). Further, we hypothesized that students would take ownership and engage as expectant apprentices if they understand science as a set of practices closely associated with or used by tribes

currently and historically rather than something alien (i.e something done only by white men in lab coats).

Based in part on previous research (e.g. Lederman, Abd-El-Khalick, Bell, and Schwarz, 2002) we designed program interviews that explored content knowledge, conceptions of the nature of science and associated motivation for and identification with science. We conducted pre-and post-interviews over two summers that included scale questions. There are several notable findings from our pre- and post- interviews that bear on these orientations. From the scale questions, children show a reliable increase in their willingness to endorse the statement, “My tribe has been doing science for a long time.” This is supporting evidence that students shifted their stance toward science as something done by Native people but it also reflects an epistemological shift in where sources of science knowledge come from and that science is about a practice or “doing” science rather than a set of facts to memorize.

The shift in sources of knowledge was also evident in student pre/post semi-structured interviews. Pre and post-interviews were coded for all sources of knowledge Paired-sample t-tests were conducted to compare types of sources of knowledge between pre and post-interviews. Students show a reliable shift from saying that they learn science in school and from books and their teachers to expanding their sources of knowledge and contexts in which the learn science. Students’ post-interviews included community as a context for learning science and including people in community (elders, parents, and ancestors) as sources of science knowledge (community $t=3.606$ $p<.01$, community people $t=2.280$, $p<.05$). The following is an example from Sarah’s, a sixth grade Choctaw student who was born and raised in Chicago, pre-interview.

1. Interviewer: How do you learn about science?
2. Sarah: Well, I learn science by my textbook about how different chemicals can change from liquid to solid and how earthquakes how they began how it shifts and then it cracks open and cut the earth in half and how hurricanes and twisters become and how the twisters become to the tornado how hot air and cold air blend together.

3. Interviewer: Who teaches you about science?
4. Sarah: My teacher, her name is Mrs. Smith.
5. Interviewer: I have a friend who says you can learn about science by watching television. Is this right?
6. Sarah: You can learn some stuff from television but not all you can learn from a textbook. At school they provide us with science videos to watch and it teaches us a lot about how twisters and hurricanes and liquids.

Sarah squarely locates science and science learning as a school based activity. There is no hint of practice-based orientation towards knowing science in her answer. Interestingly, she qualifies whether television can serve as a source of knowledge by also locating the viewing within a school context. Sarah's answers have shifted in her post-interview.

1. Interviewer: How do you learn about science?
2. Sarah: By my elders and my mom and teachers.
3. Interviewer: What sorts of things do they teach you?
4. Sarah: They teach me about how a long time ago my ancestors how they used to like plant and if there's weeds how they would get it out. They burn...when plants use to take over they would burn all of them down in one spot.
5. Interviewer: I have a friend who says you can learn about science by watching television. is this right?

6. Sarah: You can learn a little from it but not as much as you would learn through your ancestors or your teachers or books or your mom.

In her post interview Sarah identifies (line 1) her elders and her own mother as well as her teachers as sources of science knowledge reflecting a shift in her viewing science as squarely a school based activity. In addition, Sarah begins to reflect a historicized view of science knowledge by including her ancestors as sources of science knowledge (line 6). In another example, Rachel, a seventh grade Lakota student says:

“Sometimes my school, sometimes my parents, sometimes I just discover things on my own....pretty much just go for a stroll. You can learn about science by just looking around and seeing what is happening. Watching ants grow or working actually watching it - - that would take months, but.”

From our perspective the inclusion of school, home, and community life as well as themselves as sources of science knowledge is perhaps the most empowering orientation our students could take up.

This shift in source of knowledge was mirrored in students' conceptions of the nature of scientific knowledge. When students were asked how they would explain what science is to someone with no exposure to it, students show a reliable shift from talking about science as facts or a body of knowledge and done by non-Native people to talking about science as a set of knowledge-making activities done in school and community by Native people (Native people $t=2.280$, $p<.05$, practices in community $t=2.482$, $p<.03$). This is also reflected in Rachel's comment above in her suggestion that she can learn science on her own by observing what is happening in the world around her.

The final result we'd like to mention is the change in the form of knowledge students demonstrated in pre-post interviews. When asked what constitutes a forest in pre- interviews, students tended to give lists of kinds (i.e. trees, plants, animals, dirt, water). In the post-interviews students named specific organisms with marked increase in specificity and in articulating a property or behavior of the kind (e.g. poison ivy, oak trees, milk weed, arrow root). For example, in a typical post-interview, a student might

list a plant like poison ivy and note that deer eat it or mention that there are certain specific plants that grow by a bog because of the soil and water that they need is nearby (Paired sample t-test of focusing on a property or behavior of a kind listed $t=2.280$, $p<.05$). In addition there was an increase in the form of students explanations from single actors to causal chains (Paired sample t-test of causal chains $t=2.121$, $p<.05$). The following example is from a section of the postinterview reasoning scenario based on forest ecology of Seth, a sixth grade student who is Ojibwe, Navajo, and Lakota. In a section of this reasoning task students were asked how they would know if there were an overpopulation of deer in a forest. In his pre-interview Seth says that he didn't think anything would really happen to a forest if there were too many deer. Post implementation Seth says:

“Well there would be less plants because deer are herbivores and there would - - and I would be seeing a lot more deer and a lot more - - the other animals wouldn't be around as much because there is too many deer and there is not enough plants to feed them all.”

Summary. These results are examples of the change in learning and epistemic orientations we saw in students after participating in learning environments that attempted to support students' navigation of multiple epistemologies. While there is an extraordinary amount of work to do in improving what such environments may look like, we contend there is much promise in this orientation, especially given we saw such striking results after three weeks of summer camp. What would be the impact of these reorientation over the life of K-12 education?

DISCUSSION AND CONCLUSION

While our project may have unique aspects specific to Indigenous communities, taking seriously the larger socio-historic context of schooling – learning of content in schools has traditionally been raced and cultured in oppressive ways – for those groups

who have historically underachieved is absolutely essential to truly transforming learning opportunities. Other scholars have demonstrated the ways in which learning mathematics was racialized for a group of African Americans and makes the argument that mathematics learning is a racialized experience for all learners (Martin, 2004; Nasir, 2000). Some scholars have argued that there is an education debt, which is comprised of historical, economic, socio-political and moral components – that must be addressed for schooling to improve for students of color (Ladson-Billings, 2006).

Taking seriously this context for science education in Indigenous communities meant reframing what the design of learning environments could mean. The foundation of *community-based design* (CBD) rests on the comprehensive participation of community members, including teachers, elders, parents, community experts, researchers, and youth in all aspects of the research, including conceptions of the problems, project design and implementation, data collection, analysis, and dissemination. The project uses the design process for learning environments as opportunities for professional learning both for the teachers and designers of the project. Finally, this approach to the design of learning environments supports the analysis of historically raced and cultured meanings with science and science education as a path to sovereignty in these fields for Indigenous people.

Engaging learners across the life course. The reframing of the design of learning environments, focused on authentic problems, placed-based issues and the integral inclusion of parents, elders, and other community members opens new spaces for adults in Indigenous communities to engage both with science and with science education. Although our project is barely three years old, we have also seen striking changes in the professional goals of people working on the project. This includes three project personnel enrolling in graduate school, and four either returning to or enrolling in college (one after completing her GED). Several other Native scholars holding Master's degrees have indicated their intention return to school to complete their PhDs in the near future. Virtually all of these community members say that working on the project was a key factor in their decision-making. It is also striking to see the evolution of generalized community support into various forms of empowerment in which self-determination and

claiming ownership of science is a part of and concrete understandings of how community knowledge and values are relevant to students and teachers alike. Ultimately, self-determination through community engagement with and ownership of science and science education may be the most important outcome.

References

Aikenhead, G.S., (2006). *Science Education for Everyday Life: Evidence-Based Practice*. New York: Teachers College Press.

Atran, S., Author, & Ross, N. (2005). The Cultural Mind: Environmental Decision Making and Cultural Modeling Within and Across Populations. *Psychological Review*, 112(4), 744-776.

Ballenger, C., & Rosebery, A.S. (2003). *What Counts as Teacher Research? Investigating the Scientific and Mathematical Ideas of Children from Culturally Diverse Backgrounds*. Blackwell Publishing Ltd.

Bang, M. (2006). *Understanding Students' Epistemologies: Examining Practice and Meaning in Community Contexts*. Doctoral Dissertation, Northwestern University.

Bang, M., Medin, D., & Atran, S. (2007). Cultural Mosaics and Mental Models of Nature. *Proceedings of the National Academy of Sciences*. 104, 13868-13874.

Bang, M., Medin, D., Washinawatok, K., and Chapman, S. (in press). Innovations in Culturally-based Science Education through Partnerships and Community. In M. Khine & I. Saleh (Eds.) *New Science of Learning: Cognition, Computers and Collaboration in Education*. New York: Springer.

Barnhardt, R., & Kawagley, A. O. (2005). Indigenous knowledge systems and Alaska native ways of knowing. *Anthropology & Education Quarterly*, 36(1), 8–23.

Battiste, M., & Henderson, J.Y. (2000). *Protecting Indigenous Knowledge and Heritage*.

- Saskatoon, Saskatchewan, Canada: Purich.
- Belenky, M. (1986) *Women's Ways of Knowing: The Development of Self, Voice, and Mind*. New York, NY: Basic Books.
- Bell, P. (in press). On the theoretical breadth of design-based research in education. *Educational Psychologist*.
- Bitgood, S. (1993). Social Influences on the Visitor Museum Experience, *Visitor Behavior*, 8 (3), 4-5.
- Brookings Institution. (1928). *The Problem of Indian Administration: Report of a Survey made at the request of Honorable Hubert Work, Secretary of the Interior, and submitted to him, February 21, 1928*. Baltimore, MD: The Johns Hopkins Press.
- Brumann, C. (1999). Why a Successful Concept Should Not Be Discarded. *Current Anthropology* (Special Issue), 40, S1-S14.
- Cajete, Gregory A. (1997). *Look to the mountain: An ecology of indigenous education*. Skyland, NC: Kivaki Press.
- Cajete, Gregory A. (1999a) *Native Science. Natural Laws of Interdependence*. Santa Fe, NM: Clear Light Publishers.
- Cajete, Gregory. A. (1999b) *Igniting the Sparkle: An Indigenous Science Education Model*. Skyland, NC: Kivaki Press.
- Cajete, G. A. (2000) Indigenous Knowledge: The Pueblo Metaphor of Indigenous Education. in M. Battiste (Ed.) *Reclaiming Indigenous Voice and Vision*. Seattle, WA: University of Washington Press.
- Chinn, P.W.U. (2007). *Decolonizing Methodologies and Indigenous Knowledge: The Role of Culture, Place and Personal Experience in Professional Development*.

- Journal of Research in Science Teaching*, 44, 1247-1268.
- Cobb, P., Confrey, J., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design Experiments in Educational Research. *Educational Researcher*, 32(1), 9-13.
- Cole, M. (1996). *Cultural Psychology: A Once and Future Discipline*. Cambridge, MA: Belknap Harvard.
- Deloria, V., (1979). *The Metaphysics of Modern Existence*. San Francisco, CA.: Harper & Row.
- Deloria, V. (1998). *For this land: Writings on religion in America*. (Treat, J.) New York, NY: Routledge.
- Deloria, V. & Wildcat, D. (2001). *Power and Place. Indian Education in America*. Golden, CO: Fulcrum Publishing.
- Demmert, W., & Towner, J. C. (2003). *A Review of the Research Literature on the Influences of Culturally Based Education on the Academic Performance of Native American Students*. Portland, OR: Northwest Regional Educational Library.
- diSessa, A. A. (2006). A history of conceptual change research: Threads and fault lines. In K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 265 – 282). Cambridge, England: Cambridge University Press.
- Duensing, S. (2006). Culture Matters: Science Centers and Cultural Contexts in Z. Bekerman, N. Burbules & D. Silberman-Keller (Eds.) *Learning in Places: the Informal Education Reader*. Peter Lang Publisher.
- Gutiérrez, K. (2006). *Culture Matters: Rethinking Educational Equity*. New York: Carnegie Foundation.
- Gutiérrez, K. D., & Rogoff, B., (2003). Cultural Ways of Learning: Individual Traits or

- Repertoires of Practice. *Educational Researcher*, 32 (5), 19 -25.
- Gutierrez, K.D., Baquedano-López, P. Tejeda, C. (1999). Rethinking Diversity: Hybridity and Hybrid Language Practices in the Third Space. *Mind, Culture, and Activity*, 6(4), 286-303.
- Guyette, S. (1983). *Community Based Research: A Handbook for Native Americans*. Los Angeles: University of California.
- Hall, P., & Pecore, M. (1995). *Case Study: Menominee Tribal Enterprises*. Madison, WI: Institute for Environmental Studies and the Lane Tenure Center, University of Wisconsin-Madison.
- Hammer, D. and Elby, A. (2003). Tapping Epistemological Resources for Learning Physics. *Journal of the Learning Sciences*, 12, 53-90.
- Hermes, M. (1999) Research Methods as a Situated Response: Toward a First Nations' Methodology. In Parker, L., Deyhle, D., & Villenas, S., (Eds.) *Race is...Race Isn't: Critical Race Theory and Qualitative Studies in Education*. Boulder, CO: Westview Press. 4. 83-100
- Hermes, M. (2000). The scientific method, Nintendo, and eagle feathers: Rethinking culture-based curriculum at an Ojibwe tribal school) *International Journal of Qualitative Studies in Education*, Special Issue 13 (4) 155-168.
- Hofer, B. K. (2000). Dimensionality and disciplinary differences in personal epistemology. *Contemporary Educational Psychology*, 25, 378-405.
- Hofer, B. K. & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research*, 67, 88-140.

- Hudicourt-Barnes, J. (2004). Argumentation in Haitian Creole classrooms. *Harvard Educational Review*.
- Hudson, P., & Taylor-Henley, S. (2001). Beyond the Rhetoric: Implementing Culturally Appropriate Research Projects in First Nations Communities. *American Indian Culture and Research Journal*, 25, 93–105.
- Kawagley, O. (1995). *A Yupiaq Worldview*. Prospect Heights, IL: Waveland Press.
- Kawagley, O. (2000). Identity-creating Camps. *Sharing Our Pathways*, 5(2), 4-5.
- King, P.M., and Kitchener, K. S. (1995) *Developing Reflective Judgment*. San Francisco, CA: Jossey-Bass Publishers.
- Ladson-Billings, G.J. (2006). *From the Achievement Gap to the Education Debt: Understanding Achievement in U.S. Schools*. Presidential address at the American Educational Research Association Annual Meeting, San Francisco, CA.
- Leach, J., Millar, R., Ryder, J. & Séré, M.-G. (1999). An investigation of high school and university science majors' epistemological reasoning in the context of empirical investigations. Presented at the *Annual Meeting of the American Educational Research Association*, Montréal.
- Lederman, N, Abd-El-Khalick, F., Bell, R., & Schwarz, R. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, 39:6, 497-521.
- Lee, C. D. (1993). *Signifying as a Scaffold for Literary Interpretation*. Urbana, IL: National Council of Teachers of English.
- Lee, C.D. (1995). A Culturally Based Cognitive Apprenticeship: Teaching African

- American High School Students Skills in Literary Interpretation. *Reading Research Quarterly*: 30(4), 608-631.
- Lee, C. (2001). Is October Brown Chinese? A Cultural Modeling Activity System for Underachieving Students. *American Educational Research Journal*, 38(1), 97-141.
- Lee, C., Spencer, M. B., Harpalani, V. (2003). "Every Shut Eye Ain't Sleep": Studying How People Live Culturally. *Educational Researcher*, 32(5), 6-13.
- Lipka, J. (1998). Expanding Curricular and Pedagogical Possibilities: Yup'ik- Based Mathematics, Science, and Literacy, In Lipka, J., Mohatt, G.V., & the Ciulistet Group, (Eds) *Transforming the Culture of Schools: Yup'ik Eskimo examples*. Mahwah, New Jersey: Lawrence Erlbaum.
- Lomawaima, K. T. (2000). Tribal Sovereigns: Reframing Research in American Indian Education. *Harvard Educational Review*, 70(1).
- Martin, D. (2004). Mathematics Learning and Participation as Racialized Forms of Experience: African American Parents Speak on the Struggle for Mathematics Literacy. *Mathematical Thinking and Learning*, 8(3), 197-229.
- Maryboy, N.C., Begay, D.H. & Nichol, L., (2006). Paradox and Transformation. *World Indigenous Nations Higher Education Consortium, Vol. 2*.
- Medin, D., Ross, N., Atran, S., Cox, D., Coley, J., Proffitt, J., & Blok, S. (2006). Folkbiology of freshwater fish. *Cognition*, 99(3), 237-273.
- Medin, D., Ross, N., Cox, D & Atran, S. (2007). Why folkbiology matters: Resource conflict despite shared goals and knowledge. *Human Ecology*. 35(3), 315-329.
- Meyer, J-J C., 2001, "Epistemic Logic," in Goble, Lou, ed., *The Blackwell Guide to Philosophical Logic*. Blackwell.

- Mihesuah, D. (1998). *Natives and Academics: Researching and Writing about American Indians*. Lincoln: University of Nebraska.
- Moll, L. C., & González, N. (2004). Engaging life: A funds of knowledge approach to multicultural education. In J. Banks & C. McGee Banks (Eds.), *Handbook of research on multicultural education* (2nd ed., pp. 699-715). New York: Jossey-Bass.
- Moore, W. S. (1994). Student and Faculty Epistemology in the College Classroom: The Perry Scheme of Intellectual and Ethical Development. In K. Pritchard & R. M. Sawyer (Eds.), *Handbook of College Teaching* (pp. 45-67). Westport, CT: Greenwood Press.
- Nasir, N. (2000). "Points ain't everything: Emergent goals and average and percent understandings in the play of basketball among African-American students." *Anthropology and Education Quarterly*; 31(3): 283-305.
- Nasir, N. & Cobb, P. (2005). *Diversity, Equity, and Access to Mathematical Ideas*. Teachers College Press.
- Nasir, N.S. & Hand, V. (2006). Exploring Sociocultural Perspectives on Race, Culture, and Learning. *Review of Educational Research*, vol. 76: 449 - 475.
- Nisbett, R. (2009). *Intelligence and How to Get It: Why Schools and Cultures Count*. New York, NY: Norton & Co.
- National Science Foundation (2007) Women, Minorities, and Persons with Disabilities in Science and Engineering: 2007 (NSF Publication No. 07-315) (NSF 41. Division of Science Resources Statistics, Arlington, VA).
- Nasir, N. & Saxe, G. (2003). *Ethnic and Academic Identities: A Cultural Practice*

- Perspective on Emerging Tensions and Their management in the Lives of Minority Students. *Educational Researcher*, 32 (5), 14-18.
- Ochs, E., Gonzales, P. & Jacoby, S. (1996). When I Come Down I'm in the Domain State: Grammar and Graphic Representation in the Interpretive Activity of Physicists. In Ochs, E., Schegloff, E. & Thompson, S., (Eds.) *Interaction and Grammar*, Cambridge: CUP, 328 – 369.
- Pavel, D. Skinner, R., Cahalan, M., Tippeconic, J. & Stein, W. (1998). American Indians and Alaska Natives in postsecondary education. Washington, DC: National Center for Educational Statistics.
- Perry, W.G. (1970). *Forms of intellectual and ethical development in the college years: the scheme*. New York: Holt, Rinehart and Winston.
- Rogoff, B. (2003). *The Cultural Nature of Human Development*. New York: Oxford University Press.
- Rogoff, B., & Angelillo, C. (2002). Investigating the coordinated functioning of multifaceted cultural practices in human development. *Human Development*, 45, 211-225.
- Rosebery, A., & Hudicourt-Barnes, J., (2006). Using Diversity as a Strength in the Science Classroom: The Benefits of Science Talk. In R. Douglas (Ed.) *Linking Science & Literacy in the K-8 Classroom*. NSTA Press. 305-320.
- Ross, N., Author, Coley, J.D. & Atran, S. (2003). Cultural and Experiential Differences in the Development of Folkbiological Induction. *Cognitive Development*, 18, 25-47.
- Ross, N., Author & Cox, D. (2007). Epistemological models and culture conflict: Menominee and European American hunters in Wisconsin. *Ethos*, 35(4), 478-515.

- Sperber, D. (1985). *Anthropology and Psychology: Towards an Epidemiology of Representations*. *Man*, 20, 73-89.
- Strike, K., & Posner, G. (1985). A conceptual change view of learning and understanding. In L. West & R. Hamilton (Eds.), *Cognitive structure and conceptual change* (pp. 211-232). London: Academic Press.
- Tuhiwai Smith, L. (1999). *Decolonizing methodologies: Research and indigenous peoples*. New York: Zed Books.
- Unsworth, S. J. (2008). *The influence of culturally varying discourse practices on cognitive orientations toward nature. *Doctoral dissertation. Northwestern University, Evanston, IL.
- Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A.S. & Hudicourt-Barnes, J. (2001). Rethinking Diversity in Learning Science: The Logic of Everyday Sense-Making. *Journal of Research in Science Teaching*, 38(5), 529-552.
- Warren, B. & Rosebery, A.S. (2004). What do you Think Keenan Means?: Exploring Possible Meanings of Explicitness in the Science Classroom. Speaker Series: *Center for the Scholarship of Teaching*. College of Education: Michigan State University.
- Warren, B. and Rosebery, A. (2007). *Teaching Science to English Language Learners*. NSTA Press.
- Waters, A. (2003). *American Indian Thought: Philosophical Essays*. Malden, MA: Blackwell Publishers.
- Wolpert, L., & Richards, A. (1997). *Passionate Minds: The Inner World of Scientists*. Oxford University Press.

Yazzie-Mintz, E. (2007). *Voices of Students on Engagement: A Report on the 2006 High School Survey of Student Engagement*. Bloomington, Indiana: Center for Evaluation and Education Policy.

¹ The research described in this paper was supported by NSF ROLE grant #0529650 and NSF REESE grant #081522. Correspondence concerning this paper can be directed to Megan Bang (megan_bang@terc.edu) or Douglas Medin (medin@northwestern.edu).