Playing Games or Learning Science? An Inquiry into Navajo Children's Science Learning

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Consideration of the subtleties in a group of Navajo children's science learning activities provides us with some useful ways of viewing those activities. It also more clearly establishes the elements to consider in valuing or not valuing the use of these kinds of activities that I am calling "games" and other possible kinds of student inquiry during science lessons. These views allow us to go beyond generalizations such as "the students were actively engaged" or "the students cooperated well" or "the activity was hands-on" in describing students' activities and in making judgments about their value. While many educators undoubtedly already consider such perspectives in an intuitive way, articulating these constructs explicitly can help researchers, teachers, and curriculum designers use the perspectives more effectively in their research, planning and teaching. Understanding the differences inherent in how children learn science opens up questions of the responsibilities of teachers and of a dominant society in valuing other demonstrations of learning. It also causes us to reflect on larger policy issues. This reflection leads us to questions of whether or not the pathways to a science, which has traditionally been a white male enterprise, might not remain closed to those who are not schooled in the dominant society manner.

Inventing The Ice Cube Game

Three girls and two boys, on the second day of science camp, are happily leaning in toward the center of the cloud-making activity table. They are smiling and laughing while their attention is focused on the large jar in the center of the table. There is water in the jar and an aluminum pan with ice cubes on it is on top of the jar. One student is heard to remark, "The steam is trying to come out." One by one the students reach into the large jar testing the temperature of the water. "Hey cool, it cooled down," says Darren. This testing of the temperature of the water goes around the table as one after another the students "test" the water and comment on the temperature they find. Then, again, one by one the students taste the ice cubes on the pan. Each student takes a turn picking up an ice cube, putting it in his/her mouth and then returning it to the pan. The turn then passes to the next student in a clockwise fashion.

Then the students begin to time how long it takes an ice cube to melt. They pass the ice cube from student to student, again clockwise, occasionally glancing at the large clock hanging on the wall. After a time there is a change in the passing of the ice cube. One student, Darren, takes the ice cube from Savanna, holds it for a second, and then passes it back to Savanna. She turns and gives it back to the student who gave it to her. The result being that the cube is now being passed in a counterclockwise fashion. This continues for several rounds. Then Jade slips the ice cube, not to the person next to her, but to the person next to the person next to her. That person also skips a person in the passing, the result being that the ice cube is passed around among the five students in a star pattern. The star pattern gives way to a standard clockwise pattern when Jerry passes the cube to the person on his immediate left. After a few more rounds of the clockwise pattern Nicki initiates a counterclockwise star pattern. The game ends after seven minutes when the ice cube has melted.

The teachers in the classroom confer at the end of the day: Was this science? Were the children engaged in a valuable activity? Should they have derailed this particular activity and directed the students into something more obviously “science”? These are important questions without easy answers. The piece that follows is an attempt to describe and analyze, using a constructivist learning theory framework, some aspects of the science learning of these young Navajo students who were attending summer school at a reservation elementary school that summer. It is an investigation into and a discussion of the ways these children worked with science phenomena, an investigation into the behaviors that emerged in a natural fashion when the students were engaged in a classroom that had been organized into several science-related activity centers. This research arises from a research program that focuses on supporting learning in science through understanding that learning from the standpoint of the student.

This paper grows out of a large body of work about children learning science that I have compiled from years spent in science classes and hours of viewing videotapes of children enrolled in various kinds of science programs in the Midwest and on the Navajo Reservation. In this paper I will discuss a kind of activity I am calling “games,” that I witnessed with some regularity at the Navajo school. After providing my theoretical and methodological perspective, I will describe another of these games and discuss what using these games to learn science might or might not contribute to the understanding of science learning for the individuals involved. I will also begin a discussion of the ramifications of valuing different kinds of science learning for the classroom and for society.

My goal is not a search for a general learning principle that purportedly works for everyone, nor an exercise in saying that one way of learning is better or more preferable than another, but to work on the development of ideas, concepts, constructs, and explanations about the different ways in which children learn and relate to science phenomena with the hope of ultimately improving science schooling and opening doors for advanced science schooling for all children.

Theoretical Perspective

From a constructivist perspective, learning science is an active process of inquiry working towards a coherent, conceptual understanding of natural phenomena--a conceptual understanding that must be woven from existing conceptions, not "swallowed whole" from an authority nor unproblematically induced from experience. Such a constructivist perspective is increasingly viewed as an important starting point in research on science learning and teaching, but it is only a starting point and must be elaborated by research into a fuller understanding of the nature of students' sense-making in different contexts.

In my work I investigate how children learn science and how they relate to scientific phenomena specifically looking for their spontaneous responses to and engagements with various kinds of phenomena. In the social constructivist tradition I look at how individual differences contribute to the group dynamic and the learning that results from these interactions, believing that "cognitive change must be regarded as both a social and an individual process..." (Newman, et al., 1993, p. 1). I video and audio record children because repeated viewings of the recordings can make an analysis of the children's interactions richer and more complete.

Observing in Classrooms

My first summer in the classroom on the Navajo Nation, I noticed a kind of group activity, but unknowingly paid little attention to it at the time. Later that summer I observed in a classroom where a Navajo teacher was teaching the class. This teacher had the children designing games in order to help them learn math facts. Two students asked me to play their game with them. The game was a bit confusing to me, which was met with delight and great efforts on the part of the children to explain it to me. It soon became obvious to me that the way I understand "rules" and how games are played was not the same as it was for these two Navajo students. This led me to re-think some of the "activities" I had observed earlier and to search for them on the videotapes. I found several examples of activities similar to the game in which I had participated with the students. In the following sections I will discuss the example described above as well as one other "game" from the corpus of materials I collected.

Methodology

I am an ethnographer with the added advantage of having portions of my fieldwork videotaped. Specifically, what I do is termed *microethnography* or a concentrated in -depth analysis of specific events, episodes or happenings. In this work I focus on actual instances of everyday happenings in the classroom. This method is similar to that of Erickson and Mohatt (1982) and others, who work in the same tradition using videotaping, direct observation, and interviews in their work. The analysis of videotapes seems to be a particularly valuable way of providing for in-depth analysis of what children are doing in the classroom; and, indeed, work in the use of videotapes in research is becoming more common (see

Beck, 1998; Frazier, 1996; Brown, et al., 1996; Brown, Beck, & Frazier, 1997; Jordan & Henderson, 1995; Rath & Brown, 1996;). My approach, which I call interpretive microanalysis, is operationally very similar to the process called interaction analysis by Jordan and Henderson (1995). Jordan and Henderson define interaction analysis as "an interdisciplinary method for the empirical investigation of the interaction of human beings with each other and with the environment" (p. 39). Their method begins with the idea that "...knowledge and action are fundamentally social in origin, organization, and use, and are situated in particular social and material ecologies" (p. 41). They believe in the importance of studying communities of practice, as well as communities *in* practice and then using the various "tools at hand" to study these ecologies. This includes multiple levels of verbal and nonverbal analysis--language, actions, and behaviors, physical objects, and temporal and spatial manifestations.

The setting for data collection was an elementary school on the Navajo Nation in New Mexico. The classroom was comprised of 15 second, third and fourth graders--eight females and seven males. Although the students all attended this school during the school year, because of the broad age-range several of them were not familiar with each other or knew each other in a peripheral way only.
The summer school was held in late June and early July. The sessions were held in the mornings from 8:30 A.M. until 12:30 P.M. in the classrooms at the school. The students who attended the camp appeared to be "just regular kids" in all senses of the word. They were participating in summer school for a variety of reasons such as: "My friend was going to be attending," "My parents made me," or "It sounded like fun."

During the instructional time students were engaged in all sorts of traditional as well as nontraditional science activities--mixing and experimenting with kitchen chemicals, among them baking soda and vinegar; constructing and swirling tornado tubes; studying living creatures; having stories read to them; and filling out work sheets. At 11:30 A.M. we all went to lunch together, sitting and eating together, and then returned to the school for a brief recess and a classroom closing time.

Each morning I set up two video cameras in the classroom. I had received permission to do this prior to the start of camp. Each camera was focused on a table where a group of 4 or 5 children sat. The groups were determined randomly each day; the teacher assigned children to tables as they entered the room. Usually the groups were mixed gender groups. Small external microphones were taped to the edges of the "camera-ed" tables. Cameras and microphones were located so as to lessen obtrusiveness and to capture the best quality transmissions possible. I functioned as a participant/observer at the site remaining physically removed from the students' immediate vicinity most of the time. In other words, I did not intrude in the groups. Through a microphone in my ear I listened to children talking, arguing, laughing, asking questions, filling out work sheets, and negotiating activities, projects, and roles. I watched children respond to directions and instructions, become puzzled, search for answers, become frustrated, and become deeply involved in projects.

Later I watched the videotapes, wrote transcripts of the children's words, and reviewed my field notes. I used frame-by-frame viewing, slow motion viewing and stop action viewing to perform a close microanalysis of the videotapes. I searched through the videotapes looking at body language, gestures, eye movements, sequencing, organizing and other things in context. I then read the transcripts while viewing the tapes exploring whether the students participated in a shared rhythm through noting pauses, intonations, grammar, non-verbal and any other cues. I analyzed how groups negotiated who spoke when, who held the floor, and who got listened to. I also noted whether or when questions were asked and whether they were responded to with or without words.

Inventing the Go Fish Game

Five students, four girls and a boy have seated themselves around the "ecology center" table. The teacher has placed a large stack of photographs in the center of the table. The photographs are of her trip to Alaska and contain pictures of clouds, mountains, airplanes, forests, trees, lakes, and various animals. One of the female students picks up the pile, looks at the top picture, and passes it to her right. She repeats the action rapidly with all of the photographs. Each student at the table does likewise--glances at the photograph and passes it to the right--until all of the photographs have been passed around the table. Then another round of photograph passing begins. On this round, the students begin to pull out and hold cards that seemingly appeal to them. These cards do not get passed. During this time the dialog--and there is very little of it-- consists of one-word statements: airplanes, lakes, deer, and mountains. Then the students begin to take several cards from their "hands" and pass them to each other. "Take all those. Give me all those," one or another remarks. The cards no one wants--the rejects--are placed in a large pile in the center of the table.

Meanwhile Lara keeps passing the reject-cards to the right. In fact, Lara initiates the entire reject card shuffling and passing. Then Lara begins to pass the reject cards alternating one to the right and one to the left very rapidly. The other students pass them on. When all of those cards have been passed out, the students stop passing, and start laughing. All of the cards are in piles in front of the five students. Lara starts to look through each pile taking cards here and there and putting them in the center. Others she gives to one or another of the students. Then the students start saying, "I'll take four." "Who wants this one?" as they draw cards from the center and either hold on to them or pass them to someone else. "Hey, who wants this one?" asks Lara. "No one," answers Ryan. "Hey, you took my picture," cries Faye. "Do you want the water?" asks Jerod. "Here are two. That makes three," says Tara.

At the end of the game, which comes with the cessation of the passing, negotiating, and shuffling, Lara gathers all of the cards and piles them in the center and sits back looking very pleased with herself. All of the other students, sit back, smile, and look pleased.

Observing Other Games

I have offered the extended rendition of the above ice cube and go fish scenes to reveal the seeming complexity of these "games." Yet, these are only two illustrations. They are offered as exemplars of the kinds of things that students might do and the kinds of questions that might be asked concerning those actions or others like them. These exemplars are offered as a way of enlarging the perspectives or lens that might be used when observing children.

There were similar instances that occurred over the course of the two weeks of the camp. For example, I observed students playing a game comparable to the "photograph go fish game" when they were given various kinds of leaves. They also devised a "singing" kind of game when they were making bubbles, and they routinely organized cleanup time into a round of activities and actions sequentially performed by everyone. At the "tornado tube center" participants arranged the activity so that everyone's tube emptied at the same time. This meant that each person had to start at a different time depending on whether s/he had a fast tube or a slow tube. Those with the fastest tubes had to start after the others.

Each of these "games" had some things in common: The "games" continued for several minutes, were not negotiated beforehand, and seemed to have no winners or losers. There was little conversation, but all of the activities and behaviors were coordinated and executed flawlessly. The rules of the "games" seemed to be understood and accepted by all and were not discussed before, during, or shortly after the playing. Although Tharp and Gallimore (1988) report that Jordan found that Navajo children do not work well together in different sex groups, I cannot confirm that claim. During these activities all of the students at the table, male and female, were part of the "game." These "games" involved the materials of the projects or sometimes the finished projects.

Valuing the Actions and Learning Inherent in the Games

Helping students develop awarenesses of phenomena is a reasonable goal for elementary school science classes and a goal providing a skill that will serve students well in later science study. Considering these games, it then becomes reasonable to ask how the children are investigating or relating to the object of study or science phenomena under investigation while they are enmeshed in a gaming context. In other words, does the gaming context conflict with learning? Particularly in this instance the question becomes, "If the phenomena under investigation is thought of as a part of a game, is an awareness of the material itself possible?" Brown, et al (1996) ask a similar question when two young students "invent" a pretend strawberry milk shake machine while supposedly studying siphoning. The researchers query if students pretend that water is softened vanilla ice cream, is a real awareness of water then possible. In another study where a student is reading a story aloud to a frog, Frazier (1996) wonders whether the student can be developing any awareness of the genuine qualities of frogs while pretending that the frog is a pet or perhaps a younger student.

If the phenomenon is being understood or investigated as a pretend thing, then it seems unlikely that the children would appreciate or enjoy the actual properties or develop awarenesses of the genuine properties of the phenomena. In order to counter this claim we need to ask if there is any evidence that the materials of these "games" were being encountered as more than mere parts of the game. An examination of the "go fish" game reveals that the students developed an awareness of the objects in the Alaska pictures enough to be able to classify them. The activities of looking at and making determinations of whether to hold the photographs or pass them on, called for the students to notice things in the photographs, categorize what they were noticing, and make connections between objects in one and objects in another. In order to do this they had to have been relating what they were seeing in the photographs to other experiences and making discriminations about similarities and differences. Noting similarities and difference requires that students make judgments about salient points and synthesize quantities of information.

In the ice cube game the students were more obviously engaged with the phenomena in a way, which would familiarize them with the properties of the substance. They were gathering sensory awarenesses--wetness, coldness, and slipperiness--in a kinesthetic fashion. They were becoming familiar with the activity of melting, including the length of time it took the cube to melt. In addition they were developing a concept of patterning, building concepts of ways to order actions and activities by passing the ice cube among themselves in a varying but systematic procedure.

It is my contention that these games were a way for these children to make sense out of the phenomena. The games represent the way the Navajo children were putting the parts of the phenomena into some kind of order, a way of understanding the place of the parts in their world. They were investigating and becoming familiar with the kinds of effects the parts could have on them and that they could have on the parts. In addition to giving a sense of efficacy, this kind of activity could help them build relationships between objects, action, thoughts and concepts. It is part of the Navajo belief system that "one cannot attain higher levels of knowledge without coming to a clear and definite understanding of prerequisite knowledge, thereby properly preparing oneself for further learning. Without basic understandings at each level, higher knowledge is unattainable because the learner simply is not prepared to understand or effectively use it" (McCarty, et al., 1991, p. 51). I think that these children were working toward "coming to a clear and definite understanding" of the properties of ice cubes and the principles behind organizing disparate photographed objects.

This led me to question if there was something about the materials themselves that "invite" children to do certain kinds of things with them. Brown, et al, (1997) claim that certain phenomena "invite children" to do things with them or to them. Perhaps then, water is for sticking fingers into, ice cubes are for tasting, cards with pictures on them and various kinds of leaves are for sorting into categories. If the phenomena "invite," this would explain the seeming concurrence of the group about what to do with the items lying on each table. Most of the time the students sat and waited until one student or another started something and then the rest followed. There was not one student who always started everything--a class leader, so to speak--whom everyone watched. Various students at various times seemed to accept the "invitations" of the phenomena. The idea that phenomena "invite" is a compelling one and warrants further investigation particularly regarding the concurrence of "invitation" for genders, cultures and even grade levels.

The Navajo tradition presupposes "an active, interactive learning process--one in which children build increasingly sophisticated and realistic understandings incrementally, by ordering and extending their own observations" (McCarthy, et al., 1991, p. 51).

> Considered a personal possession, knowledge is more prized than material possessions, since it can be endlessly expanded and it neither diminishes, nor can it be taken away. Because of its value, knowledge is meant to be both shared and protected. It cannot be given to another or passively received. To learn something of value requires that individuals actively seek that knowledge. In doing this they not only take control over their learning, they also assume ownership over what is learned.

In both cases, the go fish game and the ice cube game, the students took control and assumed ownership over what was learned. The activities the children were engaged in required thinking, planning, and organizing even though there was little verbal interaction. Also implied in the patterned iterations and the structured organization of each game is a sense of each student as part of a functioning unit--of a large system that encompassed the whole group. In addition to the personal knowledge of the ordering and extending individual observations, each student was a necessary part of the whole. While each was individually making knowledge his/her own, each was also sharing collectively in the knowledge building of the others.

One possible way to understand these games is to see them as a manifestation of a particular "learning style." However, I do not want to call these games "learning styles." Even under the best of circumstances ideas about learning styles can be used to further marginalize non-dominant groups and subject them to inferior education (McCarthy, et al., 1991; Swisher & Deyhle, 1989). In my work I prefer to think of what the children do as situation/contextual "dispositions" or inclinations and investigate how these dispositions might allow the children to construct knowledge. What these games are is a classroom behavior that can be analyzed for its ability to enhance or detract from science learning. If looked at closely much of value is revealed in these games the children invented. In these games the children participated in cooperative learning, rehearsed motor skills, built a sense of efficacy, synthesized information, and were personally involved in a functioning unit. In addition, they were developing awarenesses in the phenomena involved in many and varied ways.

Learning Science

In many ways the behaviors I observed in the summer school classrooms are congruent with those found by other researchers. The cooperative learning techniques I witnessed during the games were comparable with the non-competitiveness in classroom situations others have observed when working with Navajo students. Swisher and Deyhle (1992) synthesizing the research done by Phillips and Dumont report that “some Indian children are more apt to participate actively and verbally in group projects and in situations where they volunteer participation” and that they are “predisposed to participate more readily in group or team situations” (p. 88-89) than they are to perform individually. The students I observed while playing the go fish and ice cube game, were not trying to “beat each other” or “best each other,” and were not declaring one or the other to be a winner. They were voluntarily participating in a non-competitive team situation. However, teachers sometimes see students exhibiting reluctance to perform and a non-competitive attitude as unmotivated. Being thought unmotivated puts many students at a decided disadvantage.

Misinformation about behaviors or “learning styles” attributed to American Indians in general and Navajos in particular, have led teachers and some researchers to misconceptions about the capabilities of the children. Many studies seem to present evidence that Navajo children are visual learners (Cazden & John, 1971) but there is evidence that they are *not* incapable of verbal learning (McCarty, et al., 1991). In both the go fish and ice cube games, the children were watching each other, picking up cues about what to do next and how to read the activity. This certainly demonstrates visual acuity. However, there was also a patterning and sequencing to their actions and activities giving evidence for an ability to understand the linearity that is essential in verbal learning.

Walker, et al. (1989) discuss pattern-symbol learning and the attributes of those who prefer to learn in this way. Pattern symbol learners exhibit well-organized, cooperative, engaged classroom behaviors, and prefer to personalize information rather that produce a product, again attributes exhibited by the players of the games. Indeed, the students playing the ice cube game were more engaged with the materials of the activity than they were with producing the product of the activity center--the cloud. But, because of a lack of motivation to produce a product, pattern-symbol learners can be thought “lazy” by some teachers.

Macias (1989) found that the American Indians she studied had difficulties with science courses in graduate school because the courses seemed too impersonal and analytic. In addition, the vocabulary was too extensive and the ways of testing did not fit the cognitive abilities of the students. However, Macias’ studies revealed that the American Indian students used various learning strategies to overcome the problems. These strategies included integrating varied stimuli into a meaningful whole, and simultaneously processing and synthesizing quantities of information--the same strategies displayed by the students engaged in the go fish game as they categorized and sorted their photographs.

The literature is replete with examples of classroom behaviors or "learning styles" of Navajos not being valued or being misinterpreted. Teachers look for specific kinds of evidence that children are participating in an activity the way they are "supposed to" and this "supposed to" is derived from an Anglo/dominant cultural perspective. Being "not valued," deviations from the expected are frequently stopped or sidetracked into another form of the activity in this culture as well as in others (Beck, 1998; Brown, et al., 1997; Brown, et al., 1996).

With education and significant effort, this non-valuing could be remedied. Knowledge of various cultural and behavioral patterns and varying dispositions toward learning strategies would enable teachers to make classrooms more "learner friendly." Teachers could allow children to observe before performing and acting (Swisher & Deyhle, 1989), allow more time for mental practice before performing (Werner & Begishe, 1968) and could design evaluation methods that match the students' strengths--essay tests or oral exams instead of multiple-choice tests, for example. They could also allow opportunities for creative integration and synthesizing and for the subjective analysis of information during inquiry activities. They could employ cooperative groups and assessment techniques that do not require that students produce a certain product. They could be educated to look for the positives, the development of phenomenological awarenesses and conceptual understanding, not evaluate on rote memorization and regurgitation or strict adherence to a structured script.

What needs to be considered at this point is whether or not encouraging teachers to go beyond the "dominant culture expected" or the "supposed to" in evaluating Navajo students' science learning is really serving those students well. While obviously advantageous to those students in the classrooms where it occurs, there is the broader question of the necessity of enculturing Navajo students into the kinds of learning experiences and assessment situations they will encounter in the "real world" of traditional Anglo science. If what the Navajo children are doing and being supported for doing in their classrooms, however pedagogically sound it may be, is not consistent with that found in Anglo classrooms, if it will not enable the Navajo children to perform well on Anglo constructed standardized tests, if it will not make it possible for them to eventually compete with the Anglo students for jobs or positions in colleges and universities, then Navajo learner friendly classrooms will not be serving the Navajo students well.

As I watched the tapes of these young Navajo students "doing science," I had to ask myself these questions: Can, or should, we engender the values of Anglo science into Navajo children? Would a more inclusive Navajo student-friendly method of teaching, which did not prepare Navajos to enter the competitive world of Anglo science, be advantageous to them in the long run? For a Navajo to succeed in the Anglo world of science how much of his/her Navajo-ness would he/she need to dissolve? Admission to most advanced programs in science is highly competitive, based on a strong academic performance and objective modes of testing. Would changing school practices even while allowing those children to succeed in their classrooms, further disadvantage already marginalized Navajo children in getting accepted into science programs in competitive high schools and colleges?

Children make assumptions about what they are to do with science phenomena, assumptions based on their own cultures, experiences, and traditions about what counts as knowledge. Thus, there is often a disjuncture between the students' lives and the construction of science knowledge and initiation into the ideas and practices of the scientific community. In any science learning there is a real tension between valuing the students' constructions on one hand and enculturing or connecting the students to a discourse tradition or heritage on the other. Although this is true in the dominant culture, it is particularly pertinent when the scientific tradition being "taught" is being taught to those of another culture. Learning in science is an active process of inquiry working toward a coherent, conceptual understanding of natural phenomena--a conceptual understanding that must be woven from existing conceptions, not "swallowed whole" from an authority nor unproblematically induced from experience. Lived experiences, which are the avenues used for conceptual construction, can be so different for those from another culture that learning the science of the dominant culture becomes especially difficult. Because the experiences are different, the perspectives different, the ways of holding knowledge and the value to that knowledge are different; the conceptual understanding constructed will be different.

Thus, it is clear that there can be a conflict between much of Navajo culture and the values and practices of Anglo schools and science. Based on what I have observed in classrooms and what I know of teaching, learning, and schooling, I do not believe that the children's Navajo-ness holds them back from academic success, but that it is educators' and society's view of what to value in science classrooms that holds children back from success. We find the deficit, not in Navajo-ness, but in the vision and the practices of the educational system; an educational system which at its core is not cooperative, but competitive, not supportive of all, but designed to weed out and rank order all. My concern is that a supportive early grades structure--a more user-friendly science--while encouraging and valuing what the Navajo children do with science phenomena will in the end ill-prepare them for the way science is presented and what is valued later. "The dominant conceptual schemes of the natural and social sciences fit the experience that the Western men of the elite classes and races have of themselves and of the world around them" (Harding, 1991, p. 48). Teachers can be educated to value what children--all children--naturally do when encountering natural phenomena in classrooms, but before an acceptance of different ways of being in the classroom will serve students well in the long run, we have to change the way science is taught system wide and that could be a problem.

I do not have any ready answers to this conundrum. Promising though it is, we cannot take for granted that changing what is done in non-dominant population schools will be serving students well and, certainly not if it only creates more obstacles for those from non-dominant groups wishing to pursue further science study. Ovando (1992) claims that we need to have more American Indians in science so that they can understand the effect it has on their lives. But there is more to it than that. More American Indian/Alaska Native scientists are needed not just so they can understand how science affects their lives, but also so that their lives can affect science and the ideas and practices of the educational and scientific communities. This would serve then to make those communities more accessible to Navajos and others from non-dominant groups and traditions.

Conclusion

Although virtually all science educators would agree that a responsible science education involves students in inquiry activities, the complexities of the interactions in these kinds of activities are poorly understood. What exactly are children doing when they are engaged in open-ended science inquiry? And, how do we value what we finally determine they are doing, if indeed we do. Too many children and too many teachers, even those in the dominant culture, are "turned off" to science, claiming, "I'm just not (or never was) any good at it. I just don't understand science." The problem is exacerbated for those from another culture because their ways of understanding the world, their frames of reference, and the contexts they bring to science may differ from those of the dominant culture leaving their learning and understandings undetected. Close analysis of elementary students exploring natural phenomena in classroom settings has provided the data to analyze more holistic contexts of science sense-making--the emotional, intellectual, social, and purposive agendas that constrain, shape, and energize science sense-making processes. These analyses give researchers, teacher practitioners and others concepts, constructs, perspectives and new lenses for understanding what is happening when children engage science phenomena.

There is, however, a dilemma. Science has traditionally been a white male enterprise and science learning is still assessed in largely traditional ways. It is possible that if we begin to appreciate and celebrate other ways of learning science in the lower grades we will be doing a disservice to those hoping to continue in science who then find themselves later constrained by the more traditional ways of doing science. The answer of course is to broaden the contexts of education and the pursuit of advanced learning in scientific areas at all levels. Broadening our understandings of what it means to do science, of what it means to be engaged with natural phenomena, could benefit all children but particularly those in non-dominant groups where the representation in advanced science studies is so minuscule.

In the classrooms described above, the Navajo students were involved in valuable ways with the phenomena under study. Researchers can investigate and analyze what children are doing. Teachers can be educated to find and value demonstrations of other ways of learning and knowing and to build on the conceptual knowledge held by individual children. But, how can we influence other institutions and society to accept a move away from the traditional ways of teaching and valuing science learning? This is a question that remains and there is work to be done to figure out how to make this happen. Starting to build on the knowledge and skills demonstrated with Navajo children's organized science games is to begin to appreciate other ways of coming to know, other ways of holding knowledge and that is a beginning that in the long run can only benefit us all.

Author's Note

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