American Educational Research Journal
Summer 1999, Vol. 36, No. 2, pp. 187–219

Science Knowledge, World Views, and Information Sources in Social and Cultural Contexts: Making Sense After a Natural Disaster

Okhee Lee
University of Miami

This study examined children's views of the world after they personally experienced a natural disaster—specifically, Hurricane Andrew in South Florida during the summer of 1992. The study addressed three issues: (a) children's knowledge of the hurricane; (b) children's views of the world, especially the causality of the hurricane; and (c) children's sources of information in social and cultural contexts. The study was conducted in the early spring of 1994. It involved 127 fourth and fifth grade students in two elementary schools located in areas that were particularly hard hit by the hurricane. The student sample was representative of various ethnic, socioeconomic, and gender backgrounds. Both quantitative and qualitative research methods were used for data collection and analysis. Results indicate significant differences as well as similarities in children's knowledge, world views, and information sources by ethnicity, socioeconomic status, and gender. Implications for promoting scientific literacy for all students, including socially and culturally diverse students, are discussed.

OKHEE LEE is Associate Professor, Department of Teaching and Learning, School of Education, University of Miami, P.O. Box 248065, Coral Gables, FL 33124. Her specializations are science education, language and culture, and teacher education.

Current reform in science education emphasizes: "*Science is for all students*. This principle is one of equity and excellence" (National Research Council [NRC], 1996, p. 20). The emerging, although limited, body of research in science education indicates various ways of knowing, thinking, and communicating among diverse student groups (Atwater, 1994; Lee & Fradd, 1998). Students bring with them their own ways of looking at the world that are representative of their social and cultural environments as well as personal experiences. Their ways of knowing may or may not be compatible with the nature of science or the way science is generally taught in science class. To achieve the goal of science for all, including socially and culturally diverse students, it is important to consider students' ways of knowing, thinking, and communicating in the science teaching and learning process.

This study examined science knowledge, world views, and information sources of elementary students who personally experienced a natural disaster—Hurricane Andrew, which devastated South Florida in late August 1992. Focusing on similarities and differences among diverse ethnic, socioeconomic, and gender groups, the study investigated the following research questions:

1. What are students' science knowledge and conceptions about the hurricane?
2. What are students' views of the world—specifically, in terms of the causality of the hurricane?
3. What are students' sources of information about the hurricane?
4. How are students' science knowledge, world views, and information sources related in social and cultural contexts?

Theoretical Perspectives

Children construct knowledge and explanations about natural phenomena. They also develop beliefs or views of the natural world. Children's knowledge and world views are products of sociocultural influences as well as individual construction, in light of the fact that every child is exposed to multiple information sources and discourses in social and cultural contexts (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Mitchell & Weiler, 1991; Wertsch, 1991). Science education, because it deals directly with the natural world, plays a major role in shaping children's knowledge and world views. In the science classroom, children's knowledge and world views may sometimes be incompatible with scientific knowledge and the scientific world view.

In this section, children's science knowledge, world views, and information sources across diverse social and cultural contexts are discussed from three theoretical perspectives: (a) cognitive science and conceptual change, (b) sociocultural, and (c) sociolinguistic. After reviewing each perspective, the relationships among the three perspectives are described. Finally, a natural disaster, Hurricane Andrew—as the research setting for the study—is described.

Science Knowledge

National Science Education Standards (NSES) (NRC, 1996), Project 2061 (American Association for the Advancement of Science [AAAS], 1989, 1993), and the conceptual change research in science education consistently define science knowledge in terms of "concepts, principles, theories, and models that are important for all students to know, understand, and use" in the fields or disciplines of science, including physical, life, and earth and space science (NRC, 1996, p. 106).

Conceptual change and *cognitive science* researchers stress the central role of prior knowledge and personal experiences in learning new knowledge (Driver et al., 1994; Posner, Strike, Hewson, & Gertzog, 1982; Reif & Larkin, 1991). Learning science occurs when students successfully integrate new information with their prior experiences in ways that are both scientifically accurate and personally meaningful. Although students' prior knowledge can serve as a bridge to new learning, erroneous ideas can obstruct the learning of science knowledge. Researchers in cognitive science and conceptual change have identified students' common conceptions about natural phenomena for a range of science topics (for a review, see AAAS, 1993; Confrey, 1990; Eylon & Linn, 1988).

The role of prior knowledge is especially important for students from diverse social and cultural backgrounds because their experiences and knowledge may differ from those of mainstream teachers and peers (Atwater, 1994; Barba, 1993; Lee, Fradd, & Sutman, 1995; Rakow & Bermúdez, 1993). In the science classroom, these students often have more difficulty learning science knowledge than their mainstream peers. Large-scale assessment results indicate that Caucasian, higher SES, and male students generally have higher achievement scores in school science than ethnic minority, lower SES, and female students (National Center for Education Statistics, 1992; National Science Foundation, 1994; O'Sullivan, Reese, & Mazzeo, 1997).

World Views

While cognitive science and conceptual change research focuses on individual construction of knowledge, the *sociocultural perspective* posits that a person's knowledge or beliefs are socially and culturally constructed (Cazden, 1988; Vygotsky, 1978). From the sociocultural perspective, learning science involves learning to think, talk, and act as a member of the science community. It also involves developing the values and beliefs shared in the science community (Lemke, 1990; Roth, 1995).

A topic that has received increasing attention in science education is the world view theory (Cobern, 1991, 1996). This attention reflects the awareness among science educators that students' beliefs in the study of science are influenced by the world views commonly held in their sociocultural environments. A world view is defined as "a culturally organized macrothought; those dynamically inter-related basic assumptions of a people that determine much of their behavior and decision making, as well as organizing much of

their body of symbolic creations . . . and ethnophilosophy in general" (Kearney, 1984, p. 1), or as "a person's set of beliefs held consciously or unconsciously about the basic nature of reality and how one comes to know about it" (Proper, Wideen, & Ivany, 1988, p. 547).

Both the NSES (NRC, 1996) and Project 2061 (AAAS, 1989, 1993) stress the scientific world view based on the tradition of Western science, as opposed to alternative views. According to these documents, science is a way of knowing that "distinguishes itself from other ways of knowing and from other bodies of knowledge" (NRC, 1996, p. 201). The NSES (NRC, 1996) states: "Explanations on how the natural world changes based on myths, personal beliefs, religious values, mystical inspiration, superstition, or authority, may be personally useful and socially relevant, but they are not scientific" (p. 201). Although the distinction between the scientific world view and alternative views is made clear in these documents, this distinction is not so clear in the history of science (Kuhn, 1970; Loving, 1997).

Research results indicate a complex interaction of personal beliefs and scientific understanding in children (Carey, 1987; Ross & Shuell, 1993), high school students (Roth & Lucas, 1997), and college students (Cobern, 1993). In addition to the scientific world view, they hold alternative views, such as anthropomorphism, teleology, spiritual forces, animism, or mysticism (Proper et al., 1988; Tamir & Zohar, 1991; Thelen, 1983). Different cultural groups hold diverse, sometimes opposing, views about the natural world (Allen & Crawley, 1998; Hewson, 1988; Lawrenz & Gray, 1995). Even within cultural groups, there are gender differences in students' world views (Jegede & Okebukola, 1992). Generally, compared to their Caucasian peers, students from diverse cultures are more likely to hold alternative views in which supernatural forces, spirits, or myths have significant roles in natural phenomena (Cobern, 1991; Dart, 1972; Dart & Pradhan, 1967; Hewson, 1988). Native Americans, for example, believe in a close, harmonious relationship between humans and nature, rather than humans in control of nature (Allen & Crawley, 1998; Hampton, 1991; Robbins, 1983). Native Americans also view the relationship between humans and nature as spiritual; thus, some explanations for natural phenomena may be supernatural.

Kearney (1984) proposed a logico-structural model of a world view based on interactions of seven categories: self, non-self (society, nature, and supernatural forces), relationship, classification, causality, time, and space. The interactions among self, non-self, and causality are important in science. The notion that there is a discoverable cause for every natural phenomenon is an important assumption in science, whereas alternative views may consider causes as various combinations of self, society, or supernatural forces (Dart, 1972; Maddock, 1981; Thelen, 1983).

Information Sources

Much of the research pertaining to children's knowledge and conceptions of natural phenomena has been conducted by the cognitive science perspective, whereas children's world views have been addressed by the sociocul-

tural perspective. The *sociolinguistic perspective*, on the other hand, considers discourses or voices that children encounter in social and cultural contexts (Gee, 1990, 1991; Green, 1983; Hicks, 1995; Michaels & O'Connor, 1991; Suzuki & Knudtson, 1992). In learning science, children's knowledge and world views have been formed and are continuously forming through the interactions between personal knowledge and new information from various sources, including family, teachers, school, friends, media, and other social institutions (AAAS, 1989; NRC, 1996).

Some of the information sources and discourses in children's social and cultural contexts present them with mainstream Western views, whereas others present alternative views. Children are faced with the complex task of making meaning from various information sources and discourses. The task of reconciling different, and sometimes incompatible, ideas poses challenges for some children, especially those from cultures in which Western science does not play a central role (Cobern, 1991; Maddock, 1981).

Relationships Among Three Theoretical Perspectives

Although the three theoretical perspectives seem to complement one another in explaining the relationships among science knowledge, world views, and information sources, the current research and literature is limited. Conceptual change and cognitive science research, while active in science education, have not considered social and cultural issues. Recently, sociocultural and sociolinguistic perspectives have been applied to science education research. Research on the relationships between or among these three perspectives is only beginning to emerge. For example, topics of debate include the distinctions between conceptual change and world views (Cobern, 1996) and between science knowledge and beliefs (Cobern, 1994; Smith, 1994). This study could contribute to the currently limited literature within each theoretical perspective and across the three perspectives.

A Natural Disaster as a Research Setting

This study examined children's knowledge, world views, and information sources after they personally experienced a major natural disaster—Hurricane Andrew, which devastated South Florida in late August 1992. With the sustaining winds over 150 miles per hour in some areas, this natural disaster was the most costly in the U.S. history, and the recovery took several years.

The natural disaster of Hurricane Andrew provided a unique and rare opportunity for investigation strategically and theoretically. The hurricane was a salient and traumatic experience in the lives of the children. They needed to make sense of this natural event that had such a profound impact on their lives and the larger community. South Florida is a multiethnic community with distinct social, cultural, and language backgrounds. Children from diverse backgrounds would have to make sense of this shared experience that they would remember for the rest of their lives. The children already had certain conceptions and world views about natural phenomena before Hurricane Andrew. Natural events with traumatic consequences

could influence their science knowledge of such events and also reveal their fundamental beliefs or views of the world (Ross & Shuell, 1993). Children also received a barrage of information about the hurricane from a variety of sources. They would have to reconcile multiple views and discourses and develop personal meanings. Eventually, the knowledge and world views with the most significant personal value would prevail.

Method

Research Setting

The study was conducted in Dade County Public Schools (Miami), Florida. The school district had a multi-ethnic student population: 46.5% Hispanic, 33.3% Black, 19% White non-Hispanic (Caucasian),, and 1.2% Asian and American Indian (Dade County Public Schools, 1994). According to the district science curriculum, weather was a required topic at the fourth grade level.

The study was conducted at two elementary schools in the Cutler Ridge and Naranja areas. The ethnic composition of one school was 53% White non-Hispanic, 29.5% Black, 16.6% Hispanic, 0.6% Asian, and 0.2% American Indian. Approximately 50% of the student population was on free or reduced-price lunch programs. The other school was 11% White non-Hispanic, 45% Black, 42% Hispanic, and 2% Asian. Slightly over 85% of the student population was on free or reduced-price lunch programs. Both the Cutler Ridge and Naranja areas were hit particularly hard by Hurricane Andrew during the summer of 1992. Even at the time of this study in the early spring of 1994, approximately 1 1/2 years after the hurricane, the schools and many of the students' homes were not yet completely rebuilt. Signs of damage remained visible in the community.

Research Design and Participants

The study used three-way factorial designs. Three independent variables included 3 (ethnic groups) X 2 (SES groups) X 2 (gender groups). Three dependent variables included science knowledge, world views, and information sources.

Participants were 127 fourth- and fifth-grade students at the two school sites. From a pool of students who personally experienced Hurricane Andrew and whose parents gave written permission for their children to participate, 10 or 11 students were randomly selected from each of 12 groups in terms of ethnicity, SES, and gender. The three ethnic groups included African American, Hispanic of diverse national origins, and White non-Hispanic students. Student ethnicity was taken from official school records, as reported by parents. The status of lunch programs is a variable frequently used by education researchers to identify students by socioeconomic status (SES). The two socioeconomic levels were distinguished by including students on free or reduced-price lunch programs in the lower SES group and those who paid for lunch or brought lunch to school in the higher SES group.

Instruments

An interview protocol was developed to examine students' responses to the three research questions. Each of the three sections in the protocol addressed both students' personal experiences and formal knowledge of the hurricane. The intent was to provide opportunities for students to express both their personal meanings and knowledge of school science. The study used seven color 8 x 10 glossy photographs of Hurricane Andrew, originally prepared by two major newspapers in South Florida (*The Miami Herald* and *The Fort Lauderdale Sun-Sentinel*). Three of them were used to start the interviews with students' personal experiences before moving into their knowledge of the hurricane. The other four were used to examine students' ability to read maps related to the hurricane. The instrument for each research question is described next.

With regard to children's knowledge of the hurricane, the interview protocol consisted of two components. First, the explanations of the hurricane involved: (a) the nature of the hurricane in terms of its shape, size, and parts; (b) the formation and development of the hurricane in terms of its origin, development, movement/path, and wind strength and direction; and (c) the impact of the hurricane on humans and nature in terms of prediction, preparation, and damage. Second, map readings involved the accuracy of explaining the four maps related to the hurricane. These maps included (a) a satellite photograph of the hurricane over the southern part of Florida; (b) a drawing of the hurricane approaching South Florida and the westward movement of the hurricane; (c) a drawing indicating the direction, strength, and movement of wind within the hurricane while it was directly over South Florida; and (d) a drawing showing the extent of damage in different areas of South Florida.

With regard to world views, the study addressed students' beliefs about cause(s) of the hurricane from the perspectives of both self and non-self, the latter including parents or family, people or society, nature, and supernatural forces of God and the devil (Cobern, 1991; Kearney, 1984). Three sets of questions were addressed: (a) student-generated responses to an open-ended question about the cause of the hurricane; (b) forced choice (yes or no) response for each of plausible causes; and (c) student perceptions of a scientist's or a weatherperson's views.

Finally, sources of information and discourses included parents and family, teachers and school, friends, mass media (books, radio, television, newspapers), social and cultural organizations (neighbors, church), and any other sources identified by the students. After asking students to indicate whether they learned about the hurricane from each of these sources, the interviewers probed the content of each source. Finally, the interviewers asked students to identify the three most important sources.

The interview protocol and materials were developed by the researcher, with the assistance of a scientist, a science educator, a communication scholar, a bilingual educator, and an elementary school teacher. In addition, the researcher also consulted with a counseling and student service special-

ist from the school district, as well as the principals and the counselors at the two school sites. Special care was taken to ensure a level of comfort in which students could talk about their experiences of the traumatic natural disaster.

Data Collection

Three trained research assistants conducted interviews with dyads of the same ethnic, SES, and gender backgrounds. The study involved dyads, rather than individuals, to make the interview process less test-like, to reduce potential emotional reactions or anxieties about the hurricane, and to allow students to share their experiences and feelings with one another. In addition, the triad of two students and an interviewer, all from the same ethnic background, was designed to facilitate interactions and to render the interviews culturally congruent. The schools provided the research team with special rooms to interview the students. All interviews were videotaped and audiotaped and later transcribed. Each interview session lasted 40-60 minutes.

In the opening of each interview, the interviewers highlighted two key points: (a) The students could stop participation or decline responses at any point in the interview,[1] and (b) people have different ideas and beliefs about the hurricane, so students' own ideas were encouraged. Using the interview protocol as a general guideline, the interviewers probed and prompted student responses in an open-ended manner. Although there were standard probes to ensure consistency among student dyads and across the groups, the interviewers used semi-structured approaches to respond to the particular needs of the interview situations. To enable data analysis for each student, the interviewers alternated the questions with the two students in each dyad to reduce influences between the students.

Data Analysis

For each of the three research questions, a coding system was developed based on both the literature and careful readings of student responses in the study. The unit of analysis was each student, not the dyad. Overall, students provided their own responses independently from those of their peers in the dyads. Two coders analyzed the entire data set, and any disagreements were resolved through discussion. In addition to statistical analysis, qualitative methods were used to identify major patterns or themes (Erickson, 1986; Miles & Huberman, 1994; Strauss & Corbin, 1990). Employing the categories used for data collection and statistical analysis for each research question, children's responses were coded into relevant categories. Vignettes that were representative of major patterns or themes were obtained. Data analysis procedures for each research question are described next.

First, students' science knowledge was analyzed using a scoring rubric. Depending on the levels of difficulty and complexity, scores for the 13 items ranged from 1–3 points. The maximum score for science knowledge was 28 points, including 16 points for explanations of the hurricane and 12 points

for map readings. Scores were analyzed using three-way analysis of variance (ANOVA) tests for each of two components, explanations of the hurricane and map readings. Because of unequal group sizes, general liner models (GLM) were employed using the SAS statistical program package. The small group size of 10 or 11 subjects in each of the 12 groups should be noted.

Second, children's world views—specifically, their beliefs about the causes of the hurricane—were analyzed in terms of: (a) self, (b) parents or family, (c) people or society, (d) nature, and (e) supernatural forces. Frequencies of student responses and percentages of respondents were obtained for each group and across groups. Tests of statistical significance were not employed because they would have required too many discrete Chi-square tests based on the small group size. Instead, the intent of data analysis was to identify overall patterns based on both descriptive statistics and qualitative results.

Finally, students' reports of information sources were analyzed in terms of family (parents, grandparents, other members), teachers and school, friends, mass media (television, radio, newspapers, books), and social and cultural organizations (neighbors, church). Frequencies of student responses and percentages of respondents were obtained, but statistical tests were not employed (for the same reasons explained for world views above). The content of each information source was also analyzed. For the three most important sources, differential weights were assigned to the most important source (3 points), the second most important source (2 points), and the third most important source (1 point). Total scores for each information source were obtained for each group and across groups.

Results

A year and a half after Hurricane Andrew, many children expressed vivid memories. Some recounted their experiences of the hurricane in detail, losses of material possessions, and losses of lives (family members, neighbors, and pets). Others expressed emotional reactions, including nightmares of the hurricane and anxieties about storms. The severity of their experiences needs to be considered in the interpretation of the results.

The results are presented in terms of both overall results in the entire sample and differences among groups. For each question, statistical results are presented first; then, qualitative results of major patterns or themes are described. These quantitative and qualitative results are used as triangulation of interpretations, as well as complimentary information from different sources. It needs to be emphasized that there are substantial variations among the students within a particular group, as well as commonalties across groups.

Science Knowledge

There were wide variations in science knowledge of the hurricane among the students in the sample. Of the 28 maximum points, students' scores ranged from 5 points to 23 points. Overall, students' science knowledge was

not adequately developed. The means and standard deviations of science scores are presented in Table 1. The total mean score in the sample was 11.9 points (SD = 3.27) out of 28 points maximum (43% correct responses). The total score consists of two components. First, the mean score for explanations of the hurricane was 6.27 points (SD = 2.26) out of 16 points maximum (39% correct responses). Second, the mean score for map readings was 5.66 points (SD = 1.50) out of 12 points maximum (47% correct responses).

Results of statistical tests among ethnic, SES, and gender groups are presented in Table 2. There were significant differences among ethnic, SES, and gender groups, ranging from the highest mean score of 17.00 points (higher SES Caucasian boys) to the lowest mean score of 8.80 (lower SES Hispanic girls). First, an ANOVA by ethnicity showed a significant difference (F = 24.33, $p < .001$). The total mean score was 14.38 (SD = 4.07) for Caucasian students; 11.30 (SD = 2.94) for African-American students; and 10.22 (SD = 2.80) for Hispanic students. Scheffe's post-hoc tests show differences between Caucasian and African-American students (t = 4.08, df = 88, $p < .001$) and between Caucasian and Hispanic students (t = 5.51, df = 86, $p < .001$). Caucasian students had better knowledge of the hurricane than African-American or Hispanic students, but there was no significant difference between African-American and Hispanic students.

Table 1
Science Knowledge: Group Differences (Means and Standard Deviations)

				Explanations of hurricane		Map readings		Total	
Ethnicity	SES	Gender	*n*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Caucasian	Higher	Boys	11	8.84	1.95	8.15	1.95	17.00	3.05
		Girls	11	8.53	2.63	7.23	2.17	15.77	4.02
	Lower	Boys	11	7.45	2.33	5.36	1.12	12.82	3.28
		Girls	10	5.80	2.34	5.10	0.88	10.90	3.11
African-American	Higher	Boys	11	7.63	1.28	6.00	1.54	13.64	2.42
		Girls	10	6.40	2.32	5.30	1.25	11.70	3.33
	Lower	Boys	10	5.00	1.05	5.40	0.51	10.40	1.35
		Girls	12	4.50	2.15	5.08	1.08	9.58	2.78
Hispanic	Higher	Boys	10	6.60	1.07	5.40	1.43	12.00	2.11
		Girls	11	4.91	2.55	5.36	1.43	10.27	3.23
	Lower	Boys	10	4.90	2.37	4.90	1.29	9.80	3.19
		Girls	10	4.40	1.65	4.40	0.52	8.80	1.62
Total			127	6.27	2.26	5.66	1.50	11.9	3.27

Note. Maximum scores for explanations of the hurricane = 16 points; for map readings = 12 points; total = 28 points.

Table 2
Science Knowledge: Group Differences (ANOVA Results)

		Explanations of hurricane		Map readings		Total	
Source	*df*	Mean square	*F*	Mean square	*F*	Mean square	*F*
Ethnicity (A)	2	81.03	18.92***	29.60	15.24***	208.59	24.33***
SES (B)	1	108.09	25.23***	50.85	26.18***	307.22	35.84***
Gender (C)	1	30.75	7.18**	6.56	3.38	65.73	7.67**
A × B	2	4.06	0.95	13.71	7.06**	20.89	2.44
A × C	2	0.18	0.04	0.37	0.19	0.11	0.01
B × C	1	0.15	0.04	0.37	0.19	1.00	0.12
A × B × C	2	5.09	1.19	0.91	0.47	2.53	0.30
Residual	115	4.28		1.94		8.57	
R square		0.39		0.39		0.45	

*$p < .05$, **$p < .01$, ***$p < .001$.

Second, there was a significant difference between the SES groups. The total mean score was 13.62 (SD = 3.87) for the higher SES and 10.40 (SD = 2.88) for the lower SES group. Higher SES students were more knowledgeable about the hurricane than lower SES students (F = 35.84, $p < .001$). Third, there was a significant difference between the gender groups, with the total mean score of 12.83 (SD = 3.57) for boys and 11.32 (SD = 3.86) for girls. Boys had better science knowledge than girls (F = 7.67, $p < .01$). Finally, there was a significant interaction effect between ethnicity and SES for map readings (F = 7.06, $p < .01$). The difference between higher and lower SES groups in the Caucasian group (means 7.69 and 5.24 points, difference of 2.45 points) was greater than the difference in the Hispanic group (means 5.38 and 4.65 points, difference of 0.73 points) and the difference in the African American group (means 5.67 and 5.23 points, difference of 0.44 points).

Qualitative analyses of students' science knowledge. In contrast to detailed memories of personal experiences, students generally had limited knowledge of the hurricane. First, the explanations of the hurricane included: (a) the nature of the hurricane in terms of shape, size, and parts; (b) the formation and development of the hurricane; and (c) hurricane prediction, preparation, and damage. Students had the most difficulty providing explanations for how the hurricane formed, developed, and dissipated. Common patterns of student responses included: (a) short, incomplete explanations in terms of the mixing of warm and cool air, high and low air pressure, or warm and cold fronts and (b) simple descriptions in terms of warm water, strong winds, heavy rain, storms, or tornadoes. Many students also had misinformation about the shape, size, and parts of the hurricane. They did not have a sense of how huge the hurricane was or how the hurricane's eye, eye wall, and tail were related. In contrast, students'

knowledge of hurricane prediction, preparation, and damage was generally accurate and elaborate. They could explain how the hurricane caused the damage, how to prepare for the hurricane, and how to make predictions using various weather instruments and satellites. Many also described how they and their families prepared for Hurricane Andrew and what they learned from their experience.

Second, in terms of map readings, many students recognized maps of Hurricane Andrew and located their neighborhoods on the maps. They recalled seeing similar maps in classroom discussions, on television, and in newspapers. However, many students could not explain these maps in relation to hurricane activities at particular times and locations. For example, while looking at a satellite photograph of the hurricane with the eye located at the southwest coast of Florida, they could not explain what was happening in different areas of Florida at that particular time. Instead, many students considered the hurricane as a uniform system.

Although most students had difficulties, some gave accurate and elaborate responses, as presented below:

S: Hurricane forms in the ocean. It starts as a tropical depression, becomes a storm, and then into a hurricane.

S: First, the eyewall is really bad. That's the really bad part. Then, after you get past the eyewall, it's really clear and calm in there, so you can go out for a minute to look around. Then the other side of the eye comes in and you have to get back in.

S: It forms over the ocean and holds in the heat. The more heat is generated with the more cold air coming in, because when they mix, they form a hurricane . . . You have a lot of cold air, and on top of that you have a lot of warm air. This creates a big confusion, and that's how you have it rotating. As soon as it keeps rotating, it gets bigger and bigger because of the heat and the more cold air coming in.

S: When it hits land, it disintegrates. Anything that gets into its path, it gets destroyed. But it also loses its energy and dies out.

Qualitative analyses of student responses indicated several other important points. First, students with less science knowledge of the hurricane tended to talk about personal experiences even when the interviewers probed their science knowledge and explanations. In contrast, students with more knowledge provided science explanations as they were describing personal experiences. These students used their knowledge of the hurricane to explain and make sense of personal experience.

Second, related to the first point, the research procedure of asking about

personal experiences before asking about science knowledge provided multiple opportunities for students to demonstrate their knowledge in both informal and formal contexts. This procedure provided both a reliability check and triangulation of student responses in different contexts. Generally, student responses were consistent across contexts. In addition, the informal contexts dealing with personal experiences were particularly necessary for students with limited science knowledge who, otherwise, might not have fully cooperated throughout the interview process.

Third, students with greater science knowledge were also more intent on figuring out the maps and more willing to give explanations. They often stood up, leaned over the maps, stared at the maps, exchanged ideas with one another, and attempted explanations. In contrast, students with less knowledge simply said, "I don't know," or provided short responses after being probed and prompted by the interviewers.

World Views

Students' world views were examined in two ways: (a) personal views and (b) perceptions of a scientist's and a weatherperson's views. In addition to statistical results, qualitative analyses of students' world views among ethnic, SES, and gender groups are described.

Students' personal views. Students were asked to respond to the following open-ended questions: "Why do you think Hurricane Andrew happened? What caused the hurricane to happen?" Because of the small number of 10 or 11 students in each of the 12 groups across multiple categories of responses, the results are organized more globally in terms of the ethnicity, SES, and gender variables, as shown in Table 3.

As the cause of the hurricane, the majority of students indicated nature in terms of wind, rain, storm, warm and cool air, high and low pressure, and warm and cold fronts. (n = 84 or 66% of the 127 students in the sample). Some responded in terms of God (n = 24 or 19%), and a small number indicated people or society (n = 7 or 6%). No student indicated self, parents, other family members, or the devil as causes of the hurricane.

The results indicate significant differences among ethnic, SES, and gender groups. Caucasian students indicated nature as a cause more frequently (81%) and God less frequently (9%), compared to African-American students (47% for nature and 30% for God) and Hispanic students (71% for nature and 17% for God). Higher SES students indicated nature more frequently (70%) and God less frequently (15%), compared to lower SES students (62% for nature and 22% for God). Boys also indicated nature more frequently (73%) and God less frequently (16%), compared to girls (59% for nature and 22% for God).

After the open-ended question, students were asked to respond "yes" or "no" for each of the potential causes. Frequencies and percentages of yes responses are presented in Table 4.

Students generally indicated multiple causes of the hurricane and expressed a wide range of beliefs. Of the 127 students in the sample, several

Table 3

World Views: Student-Generated Responses (Frequencies and Percentages)

Variables	Groups	*n*	Self	Parents or family	People or society	Nature	Supernatural forces		I don't know	No response
							God	Devil		
Ethnicity	Caucasian	43	0	0	0	35 (81%)	4 (9%)	0	2 (5%)	2 (5%)
	African-American	43	0	0	6 (14%)	20 (47%)	13 (30%)	0	0	4 (9%)
	Hispanic	41	0	0	1 (2%)	29 (71%)	7 (17%)	0	1 (2%)	3 (7%)
SES	Higher	64	0	0	3 (5%)	45 (70%)	10 (15%)	0	3 (5%)	3 (5%)
	Lower	63	0	0	4 (6%)	39 (62%)	14 (22%)	0	0	6 (10%)
Gender	Boys	63	0	0	3 (5%)	46 (73%)	10 (16%)	0	0	4 (6%)
	Girls	64	0	0	4 (6%)	38 (59%)	14 (22%)	0	3 (6%)	5 (8%)
Total		127	0	0	7 (6%)	84 (66%)	24 (19%)	0	3 (2%)	9 (7%)

Table 4

World Views: Forced Choice of Yes or No (Frequencies and Percentages of Yes Responses)

Variables	Groups	*n*	Self	Parents or family	People or society	Nature	Supernatural forces*		
							God	Devil	Subtotal
Ethnicity	Caucasian	43	1 (2%)	1 (2%)	18 (42%)	40 (93%)	15 (35%)	9 (21%)	16 (37%)
	African-American	43	0	6 (14%)	15 (35%)	35 (81%)	31 (72%)	23 (53%)	37 (86%)
	Hispanic	41	5 (12%)	2 (5%)	12 (29%)	34 (83%)	27 (66%)	11 (27%)	30 (73%)
SES	Higher	64	2 (3%)	4 (6%)	22 (34%)	59 (92%)	31 (48%)	18 (28%)	39 (61%)
	Lower	63	4 (6%)	5 (8%)	23 (37%)	50 (79%)	42 (67%)	25 (40%)	44 (70%)
Gender	Boys	63	2 (3%)	5 (8%)	20 (32%)	59 (94%)	37 (59%)	17 (27%)	42 (67%)
	Girls	64	4 (6%)	4 (6%)	25 (39%)	50 (78%)	36 (56%)	26 (41%)	41 (64%)
Total		127	6 (5%)	9 (7%)	45 (35%)	109 (86%)	73 (57%)	43 (34%)	83 (65%)

* Some students responded yes to both God and the devil. Because of this double counting, the percentages for God and the devil combined exceed the subtotal percentage.

(n = 6 or 5%) related the hurricane to personal causes, such as "I have been bad," "I might have been [a cause] because I got into a fight in my old school . . . It was violent," and "Maybe because I wished for a hurricane to come so I wouldn't have to go to school, but not a bad one like Andrew."

A small number of students (n = 9 or 7%) also attributed the cause of the hurricane to parents or family members because of domestic violence, personal problems, or interpersonal conflicts. The responses included: "I think my family had back luck and probably made the hurricane come;" "My cousin, he used to always break the law, and he went to jail several times," "My aunt is doing drugs, real bad," and "I think the hurricane was sent to punish my mother because of my grandmother. My grandmother makes me mad a lot."

Students generally believed that nature was the predominant cause of the hurricane (n = 109 or 86% of the 127 students in the sample). However, many also believed supernatural forces of God or the devil were causes (n = 83 or 65%). In addition, some believed people or society were a cause (n = 45 or 35%).

As presented in Table 4, the differences among the groups were evident, especially with regard to students' beliefs about nature and supernatural forces as causes. Caucasian students emphasized nature more strongly (93%) and supernatural forces less strongly (37%), compared to African-American students (81% for nature and 86% for supernatural forces) and Hispanic students (83% for nature and 73% for supernatural forces). Higher SES students emphasized nature more strongly (92%) and supernatural forces less strongly (61%), compared to lower SES students (79% for nature and 70% for supernatural forces). Similarly, boys emphasized nature more strongly (94%) and supernatural forces less strongly (67%), compared to girls (78% for nature and 64% for supernatural forces).

Students' perceptions of a scientist's or a weatherperson's views. Students were asked to respond to the questions: "What do you think a weatherperson, like Dr. Bob Sheets or Bryan Norcross,[2] would say about what caused the hurricane?" and "What do you think a scientist would say about what caused the hurricane?" The results of students' perceptions of a scientist's views are presented in Table 5. Students' perceptions of a weatherperson's views were similar to those of a scientist's views and, therefore, not presented here.

Most students (n = 107 or 84%) said that a scientist would respond in terms of nature. A small number (n = 10 or 8%) indicated God. A small number (n = 10 or 8%) also said they did not know how a scientist would respond. None mentioned people, society, or the devil as a cause from a scientist's view.

The differences among the groups were noticeable. Caucasian students emphasized nature more strongly (98%) and supernatural forces less strongly (0%), compared to African-American students (79% for nature and 12% for supernatural forces) and Hispanic students (76% for nature and 12% for supernatural forces). Higher SES students emphasized nature more strongly (94%) and supernatural forces less strongly (3%), compared to lower SES

Table 5

World Views: Students' Perceptions of Scientist's Views (Frequencies and Percentages of Yes Responses)

Variables	Groups	*n*	Self, parents, or family	People or society	Nature	Supernatural forces		I don't know
						God	Devil	
Ethnicity	Caucasian	43	0	0	42 (98%)	0	0	1 (2%)
	African-American	43	0	0	34 (79%)	5 (12%)	0	4 (9%)
	Hispanic	41	0	0	31 (76%)	5 (12%)	0	5 (12%)
SES	Higher	64	0	0	60 (94%)	2 (3%)	0	2 (3%)
	Lower	63	0	0	47 (74%)	8 (13%)	0	8 (13%)
Gender	Boys	63	0	0	55 (87%)	3 (5%)	0	5 (8%)
	Girls	64	0	0	52 (81%)	7 (11%)	0	5 (8%)
Total		127	0	0	107 (84%)	10 (8%)	0	10 (8%)

students (74% for nature and 13% for supernatural forces). Boys emphasized nature more strongly (87%) and supernatural forces less strongly (5%), compared to girls (81% for nature and 11% for supernatural forces).

Qualitative analyses of students' world views. Student responses indicated valuable insights into ethnic, SES, and gender differences. Compared to lower SES students, higher SES students seemed to be more assured and articulate about their beliefs. Compared to boys, girls tended to show more caring for people and nature—for example, "Me and my mom are crazy about manatees. And with all the debris and stuff, they are so curious they come up to see what it is and they can get like cut and stuff." "Right after the hurricane, my mom had a baby because she thought of how precious life was." And "after the hurricane, I started keeping a diary of how I felt about things."

The patterns in both descriptive statistics and qualitative results indicated that ethnicity was a key variable for differences in world views. Regardless of SES and gender backgrounds, Caucasian students generally interpreted the hurricane as a natural event. In contrast, African American and Hispanic students expressed world views in which people or society, nature, and supernatural forces all played important roles in an integrated manner. Major patterns for each ethnic group are described next.

Caucasian students tended to interpret the hurricane as a natural phenomenon. Many also interpreted the cause of the hurricane as a consequence of actions by people or society, especially environmental pollution. They responded that, in return for the environmental pollution, "Mother Nature is wanting to get back at us for all the pollution and cutting down trees," or it was "Mother Nature's way of treating us bad because of what we are doing using aerosol cans and throwing trash and littering and stuff."

In contrast to strong beliefs in nature and people/society as causes, Caucasian students generally expressed tentative beliefs in God as a cause, as they said, "Perhaps, God did," "He could," and "Maybe, maybe not." A few offered explanations in terms of God's punishing people or teaching them a lesson for bad things, such as being mean to one another or committing crimes and violence. Many students denied the devil's having anything to do with the hurricane. Some expressed a strong disbelief, such as, "I don't believe in the devil," or "there is no such thing called the devil." However, a few students changed their minds after their hurricane experience. As one student said, "I don't believe in the devil either, but, when this happens, I do."

The following example with a dyad of higher SES boys illustrates a common pattern of the world views expressed by Caucasian students. Early on in the interview, the interviewer (I) asked the boys to explain how the hurricane formed (science knowledge):

I:	How was Hurricane Andrew formed?
Brian:	A tropical storm around the water.

John: A lot of cold air and a lot of warm air hit each other, like in Africa. It started a tropical depression, and it started going up into a tropical storm and forms a hurricane.

Later in the interview, the interviewer probed the boys about the cause of the hurricane (world views). Both students related science knowledge and world views in a consistent manner and expressed their belief about the hurricane as a natural event:

I: I want to know what you think or believe about the hurricane. Why do you think Hurricane Andrew happened?

Brian: You already asked the question.

I: No, this is a different kind. All right, I will go on. Do you want to answer that, John?

John: No.

I: Do you think the cause of the hurricane has anything to do with you personally?

B & J: No.

I: Does it have anything to do with your family?

B & J: No.

I: Your parents?

B & J: No.

I: With people or society?

B & J: No.

I: How about nature?

Brian: Yes.

John: No, not really.

I: Brian says yes, and John says no. Tell me why you answer that way, Brian?

Brian: Because a hurricane forms in nature and starts in the water because of the wind.

John: Because it just happens. You don't know when it's going to happen, you can't tell when it happens. It just happens.

I: Do you think supernatural things, such as God or the devil, have anything to do with the hurricane?

Brian: No.

John: Not really.

I: Anyone or anything else causes the hurricane?

B & J: No.

I: So, what do you think causes the hurricane?

John: It is just that, when winds hit each other, it forms storms, and it builds on that.

African-American students often expressed world views in which people or society, nature, and supernatural forces interacted to cause the hurricane. While some students emphasized nature more strongly than other

causes, others stressed supernatural forces. Many also emphasized social issues as causes of the hurricane. African-American boys were the only ones who pointed out race issues. Generally, most students responded that people or society, nature, and supernatural forces were equally plausible causes. Two common patterns of responses emerged: (a) People have been doing bad things, such as violence, crime, shooting, killing, and race problems; God is angry, sends a message of His displeasure through the hurricane, and intends to teach a lesson; and (b) people have done something wrong; God is too nice to hurt people; instead, the devil wants to punish people and causes the hurricane.

The following example with a dyad of higher SES boys illustrates this pattern. Although this example is more extensive and dramatic than most others in this group, the components in the example were observed in many African-American students. Early on in the interview, the interviewer asked the boys to explain how the hurricane formed (science knowledge):

I:	What do you know about how hurricanes form?
Willie:	When it gets real hot, the moisture starts coming together, and it forms a hurricane. The weather like the wind currents and stuff get put together, and it gets harder. Then, it starts turning, then it starts coming, and it starts turning.
Chuck:	First, it starts way back out in the sea. Then, the clouds start to form up. When it first started, Dr. Bob Sheets gave us a little warning about how it was forming. And they had the tower camera out there to see how it's coming this way. Then, he said it wasn't going to be a big problem. But when it started to get closer, it got to be a problem because it got stronger by the water starting to push in. They didn't know where it was going to hit, so it started to move in all kinds of directions. Then, we waited a couple of days and the wind started to get harder.

Later in the interview, the interviewer probed the boys about the cause of the hurricane (world views). One boy (Chuck) responded immediately in terms of supernatural forces. He also included his family and society as contributing to the hurricane happening. As the conversation continued, he expressed his belief in racial conflicts as a primary cause. At this point, the other boy (Willie) expressed the same opinion. The following example indicates how the students believed in multiple causes of the hurricane in an integrated manner:

I:	Why do you believe hurricanes happen?
Chuck:	I think God is teaching us a lesson. He just sends out a hurricane to make people get straightened out, teach them a lesson, make them cooperate with people, and stop littering and violence.
Willie:	I think it's raining and stuff, so it can clean up. Three years

ago, we had one, I think it was Hurricane Hugo. When it came, it cleaned out a lot of stuff in North Carolina. Now, Andrew is going to hit us and clean up all the trash.

I: Do you think the hurricane was caused by anything you did personally?

C & W: No.

I: Do you think the hurricane was caused by what your family did?

Willie: No.

Chuck: Shooting people. One of my family shot someone in the butt robbing the house.

I: Does a hurricane have anything to do with people or society?

Chuck: The way I think it caused the hurricane is because most people just pick on people. The hurricane happened to teach us to get along with people . . . Every time they beat Rodney King or something like that, it seems that something always happens, like a hurricane getting ready to form or something like that. Like the William Lozano thing here [in Miami]. People just got mad. He had no right to hit that Black guy on the motorcycle . . . .

Willie: Like when they beat that man up, Reginal Denny. The people made him get out of his truck, and they were throwing bricks at his head. I think it is wrong.

Chuck: To me, it was the whole deal. Blacks and Whites. They think about hurting someone, and Black people think about hurting them back. And when they start, God might just be up there saying, "When are they ever going to learn?"

Willie: Both of them [Rodney King and Reginal Denny] happened to be in Los Angeles. So I don't know why God couldn't make it [the hurricane] go around there?

Chuck: I think God did that because He knows he could form up an earthquake to hit there . . . .

I: Do you think that hurricanes are caused by nature?

C & W: Yeah.

Chuck: Hurricane happens in nature.

Willie: How we pollute the air and stuff.

Chuck: Yeah, people throw things in the bushes, and they know they got a city dump. They just have destroyed our land and made it gross.

I: Does the hurricane have anything to do with God whom you talked about before?

Chuck: God is helping us through nature. He just used the water and the moisture in the air, and caused the hurricane.

I: How about the devil?

Willie: I read in the magazine. They said that the devil was inside of the hurricane.

Chuck: I heard that the devil wanted to control people.

Hispanic students expressed world views in which people or society, nature, and supernatural forces interacted to cause the hurricane. Unlike Caucasian students, Hispanic students generally did not emphasize environmental pollution as a major cause. Unlike African-American students, Hispanic students did not emphasize social problems. Three common patterns of responses were as follows: (a) God is the creator of everything, as one student said, "Because He makes everything happen. He does everything, makes everything. Whatever happens, He does it;" (b) God is angry when people do bad things and punishes people; and (c) God does the good things, and the devil does the bad. In the following example, a higher SES boy expressed his belief about how God and the devil interacted to punish people for bad things:

I:	Why do think Hurricane Andrew happened?
Carlos:	I think when a wave came up like a tidal wave, the wind came and took it, and they combined. Then, it started like a whirlpool and it moved toward us . . . .
I:	How about people and society?
Carlos:	Might . . . It partly does because people do bad things . .
I:	How about nature?
Carlos:	Yes, the wind and the rain.
I:	How about supernatural things, such as God?
Carlos:	Yes. Because God makes everything. He makes nature. He makes rain. He makes lightning. He makes the sun.
I:	How about the devil?
Carlos:	The devil is the one that performs bad things, and God wants to stop it.

Information Sources

In response to the question, "I want to find out where you have learned the information about the hurricane," students gave "yes" or "no" responses to each of the information sources. The results are presented in Table 6. Students chose television as the most important source of information (n = 101 or 80% of the 127 students in the sample). Students also indicated parents (n = 93 or 73%) and teachers (n = 92 or 72%) as important sources. Some indicated radio (n = 74 or 58%) and books (n = 59 or 46%) as information sources.

Students were also asked to determine the three most important sources of information. Differential weights were given among the three choices: 3 points for the most important source, 2 points for the second most important source, and 1 point for the third most important source. The results are presented in Table 7.

The results in Table 7 are generally consistent with those in Table 6. Again, television was emphasized as the most important source (229 points), followed by parents (192 points). Radio was selected as the distant third choice (79 points), teachers as the fourth (57 points), and books as the fifth

Table 6

Information Sources: Forced Choice of Yes or No (Frequencies and Percentages of Yes Responses)

Variables	Groups	*n*	Parents	Grand-parents	Other family	Teachers	Friends	TV	Radio	News-papers	Books	Neighbors	Church
Ethnicity	Caucasian	43	35 (81%)	13 (30%)	8 (18%)	33 (77%)	19 (44%)	38 (88%)	22 (51%)	17 (40%)	17 (40%)	14 (32%)	10 (23%)
	African-American	43	31 (72%)	14 (33%)	7 (16%)	28 (65%)	13 (30%)	31 (72%)	20 (47%)	21 (49%)	18 (42%)	7 (16%)	10 (23%)
	Hispanic	41	27 (66%)	10 (24%)	16 (39%)	31 (76%)	24 (59%)	32 (78%)	32 (78%)	17 (42%)	24 (59%)	15 (37%)	11 (27%)
SES	Higher	64	43 (67%)	16 (25%)	13 (20%)	45 (70%)	23 (36%)	56 (87%)	38 (59%)	31 (48%)	30 (47%)	20 (31%)	21 (33%)
	Lower	63	50 (79%)	21 (33%)	18 (29%)	47 (75%)	33 (52%)	45 (71%)	36 (57%)	24 (38%)	29 (46%)	16 (25%)	10 (16%)
Gender	Boys	63	44 (70%)	18 (29%)	18 (29%)	46 (73%)	27 (43%)	55 (87%)	36 (57%)	27 (43%)	33 (52%)	17 (27%)	15 (24%)
	Girls	64	49 (76%)	19 (30%)	13 (20%)	46 (72%)	29 (45%)	46 (72%)	38 (59%)	18 (28%)	26 (41%)	19 (30%)	16 (25%)
Total		127	93 (73%)	37 (29%)	31 (24%)	92 (72%)	36 (28%)	101 (80%)	74 (58%)	45 (35%)	59 (46%)	36 (28%)	31 (24%)

Table 7

Information Sources: Three Most Important Sources (Total Weighted Values)

Variables	Groups	*n*	Parents	Grand-parents	Other family	Teachers	Friends	TV	Radio	News-papers	Books	Neighbors	Church	Other
Ethnicity	Caucasian	43	63	1	5	26	9	78	31	15	14	4	5	5
	African-American	43	71	7	5	5	8	81	18	16	24	4	6	0
	Hispanic	41	58	8	20	26	10	70	30	7	14	1	1	0
SES	Higher	64	71	7	18	36	10	129	36	22	37	5	8	1
	Lower	63	121	9	12	21	17	100	43	16	15	4	4	4
Gender	Boys	63	83	6	16	33	11	123	45	14	32	2	6	2
	Girls	64	109	10	14	24	16	106	34	24	20	7	6	3
Total		127	192	16	30	57	27	229	79	38	52	9	12	5

(52 points). Compared to the results in Table 6, teachers here were perceived as a considerably less important source of information.

The results indicate differences among ethnic, SES, and gender groups. Although both SES and gender groups indicated television and parents as the two most important sources, there were noticeable differences. Higher SES students emphasized television as a more important source (129 points) and parents as a less important source (71 points), whereas lower SES students emphasized parents as more important (121 points) and television as less important (100 points). Similarly, boys emphasized television as a more important source (123 points) and parents as a less important source (83 points), whereas girls emphasized parents (109 points) and television (106 points) as equally important. In terms of ethnic differences, African-American students indicated teachers as a much less important source (5%), compared to Caucasian (26%) or Hispanic students (26%).

Qualitative analyses of information sources and discourses. Although both SES and gender groups indicated television and parents as the two most important sources (see Table 7), there were notable differences in their discourses. Lower SES students and girls relied on parents as the most important source, but their parents often provided limited or inaccurate information. In contrast, higher SES students and boys used television as the most important source and obtained scientifically sanctioned information from television as well as their parents. For example, an African-American girl from a lower SES background described her failure to obtain information from her mother, as follows:

S: I just kept asking my mom what is a hurricane 'cause we were visiting my cousin, and then on the radio they said that there was going to be a hurricane. I asked my mom why hurricanes come.

I: What did she tell you?

S: She said she didn't know . . . .

S: I asked my mom where hurricanes come from and why it happens. She said she didn't know.

In terms of ethnic differences, for many Caucasian students, the ideas from different sources seemed to be relatively consistent with one another as well as the view of Western science. In the following example, a Caucasian boy from a higher SES background described how he learned about the hurricane from television, his father, and his teacher in a consistent manner:

S: I was watching Channel 7 and Channel 4, telling you that this hurricane is coming and it shows Florida . . . Then, I saw that [pointing out the eye on the map] in the middle of the hurricane. I asked my dad what is was, and he said, "It's the eye, the eye of the hurricane, and there is nothing inside." I saw it coming closer on television. And then, when it was August 24th, my dad said, "Today in the

> middle of the night, Hurricane Andrew is coming . . . ." [Describes how his family prepared for the hurricane] . . . When we went back to school, my teacher taught us about the hurricane, how it formed, how strong was the wind, how to prepare for the hurricane, and stuff like that.

For African-American and Hispanic students, the ideas they obtained from different sources were often incompatible with one another as well as the view of Western science. In the following example, a Hispanic boy from a higher SES background described his experience of confusion about the hurricane because of inconsistent information from various sources:

> I: I would like to know where you got your information. What did you learn from your parents?
>
> S: They told me how the hurricane forms and why the hurricane forms.
>
> I: What did they tell you about why it formed?
>
> S: 'Cause probably we sinned against God, and the storm was sent to punish us.
>
> I: Did you believe that?
>
> S: I did not know what to believe. I was only 9. I got so confused . . . .
>
> I: What did you learn from TV?
>
> S: It showed how strong the wind was and how to prepare. And on television, it said that God did it and the devil did it . . . .
>
> I: Did you study hurricanes in school?
>
> S: Yes, it was in fourth grade when we came back, the teacher was asking us, "How do you think it happened?" She was giving us information about how fast it was going. She drew an outline of Florida and drew a circle, and it showed where the eye was and the outside of it . . . .

Some African-American and Hispanic students also expressed folk-oriented or myth-oriented theories about the hurricane that they heard from others, especially grandparents, parents, and other family members. Some examples include:

> S: My grandma said that when the mango tree blew a mango, that is when a hurricane will be.
>
> S: My mom told me that other people from other countries, they wanted to mess up with Florida and get them off track.
>
> S: My mom said that she got all this strength. Once she lifted a whole mattress, a queen mattress to the window. She thought, she said, "It's like the devil or evil something going around."
>
> S: The devil is in the ground, and God is in the sky. So God has the wind, and the devil has the water, so they put together.

S: When lightning and thunder comes and it rains, my sister always says it's God and the devil fighting. Because the sun dot is God and orange is the devil. She says that the water comes from when he beats someone up, and someone is crying.

Conclusions, Discussion, and Implications

The study examined elementary students' science knowledge and world views after they personally experienced a major natural disaster. The study also examined how science knowledge and world views were related to sources of information and discourses. The study addressed these questions with diverse ethnic, SES, and gender groups.

Conclusions

Even 1 1/2 years after the hurricane, most students provided detailed descriptions about their experience of it, gave reasonably accurate responses about hurricane preparation and damage, and recognized satellite maps and drawings of the hurricane. These responses were generally based on personal experiences or personally relevant information. In contrast, students' formal knowledge of the formation and development of the hurricane was limited, even though they had been exposed to information about the hurricane during the intense period of preparation and the long period of recovery. Thus, the students demonstrated an adequate knowledge based on their personal experiences, but they failed to develop a coherent understanding beyond their personal experiences or concerns. The experience of the hurricane, despite its profound impact on the lives of all in the large community, did not ensure students' knowledge of this natural phenomenon (Ross & Shuell, 1993). In addition, there were significant differences among the groups. Overall, Caucasian, higher SES, and male students were more knowledgeable about the hurricane than African-American and Hispanic, lower SES, and female students, respectively.

Students generally understood that nature is the only, or primary, cause of the hurricane. Even those students, who personally believed in people/society and supernatural forces as causes of the hurricane, responded that a scientist or a weatherperson would explain the hurricane in terms of nature. For example, one student said, "I'm talking about God, and they [scientists] are talking about scientific stuff like wind and rain." Despite their understanding of the hurricane as a natural event, many students personally believed that the hurricane was caused by social and supernatural forces as well as nature. There were significant differences in students' world views among ethnic, SES, and gender groups. Compared to lower SES students and girls, higher SES students and boys, respectively, emphasized nature more and supernatural forces less. Differences in world views were most significant among the ethnic groups. Caucasian students generally interpreted the hurricane as a natural event, separate from supernatural forces. They also believed that people or society, when they played a role, were the instru-

mental agents of change in nature. African-American and Hispanic students generally expressed alternative views, in which people or society, nature, and supernatural forces played a role in causing the natural disaster.

Students constructed the meaning of the hurricane based on multiple information sources, including their personal experiences, family members and neighbors, scientifically sanctioned versions from school and news media, and social organizations such as churches. Although television and parents were the two most important sources, there were notable differences among ethnic, SES, and gender groups. Lower SES students and girls generally obtained limited or inaccurate information from parents as the most important source, whereas higher SES students and boys obtained scientifically based information from television as the most important source. Caucasian students generally obtained information from different sources that were relatively consistent with one another as well as the view of Western science, whereas African American and Hispanic students obtained information from sources that were often incompatible with one another and the view of Western science.

Discussion

The results indicate that information sources and discourses were related to students' science knowledge and world views in social and cultural contexts. In terms of ethnic differences, for Caucasian students, compatibility among information sources and discourses which were also consistent with Western science was related to the students' view of nature as a primary cause of the hurricane. In contrast, for African-American and Hispanic students, incompatibility among information sources and discourses which were often inconsistent with Western science was related to the students' alternative views of multiple causes of the hurricane. These differences might also be related to more science knowledge of the hurricane of Caucasian students than African-American or Hispanic students.

In terms of SES and gender differences, limited and inaccurate information from parents as the most important source for lower SES students and girls was related to their lesser science knowledge. In contrast, scientifically based information from television as the most important source for higher SES students and boys was related to more science knowledge. These differences might also be related to alternative world views expressed by lower SES students and girls compared to the view of nature as a primary cause of the hurricane by higher SES students and boys.

The study was guided by three theoretical perspectives: cognitive science, sociocultural, and sociolinguistic. These three perspectives provide explanations for the interplay of science knowledge, world views, and information sources among diverse ethnic, SES, and gender groups. Information sources and discourses in children's social and cultural contexts present to the children new information which continuously interacts with their personal knowledge and experiences. Some of the information sources and discourses present scientifically based information and mainstream

Western views of the world, whereas others present limited or inaccurate knowledge and alternative views. The task of reconciling different, and sometimes incompatible, ideas poses greater challenges for African-American and Hispanic, lower SES, and female students compared to Caucasian, higher SES, and male students, respectively (Aikenhead, 1996; Cobern, 1991; Dart, 1972; Maddock, 1981). The relationships among science knowledge, world views, and information sources from the three theoretical perspectives require further investigation.

Implications for Science Teaching and Learning

The results offer important implications for science teaching and learning for students from diverse social and cultural backgrounds. The research questions highlight major issues in science education, such as what counts as science, what should be taught in school science, and how to make science accessible to all students, particularly for those who have traditionally been by-passed in science (Lee, 1997). Science education reform documents (AAAS, 1989, 1993; NRC, 1996) define a body of knowledge and a way of knowing in Western science as the proper domain of science. This notion of science has been challenged by scholars in emerging areas of multicultural education, feminism, and sociology and philosophy of science (Atwater & Riley, 1993; Eisenhart, Finkel, & Marion, 1996; Hodson, 1993; Matthews, 1994; Rodríguez, 1997; Stanley & Brickhouse, 1994).

Although science knowledge and understanding is an important goal for all students, the issue of world views or belief systems is a complex topic. The results indicate incongruence between the scientific world view as espoused in school science (AAAS, 1989, 1993; NRC, 1996) and the alternative world views of many students. Even students who interpreted the hurricane as a natural event from a scientist's perspective personally believed that the hurricane was caused by social and supernatural forces as well as nature. These alternative views were often expressed by African American and Hispanic, lower SES, and female students who came from sociocultural environments in which Western science might not play a central role.

The science education community has been debating how to reconcile students' science knowledge and understanding with their world views or belief systems (e.g., debate between Cobern, 1994, and Smith, 1994). It has been a topic of contention whether science as a subculture can or should force students to accept the scientific world view at the expense of the world views dominant in their own sociocultural environments (Aikenhead, 1996; Loving, 1997). In this regard, the notion of "scientifically compatible views" has gained attention (Cobern, 1991, 1996; Cobern & Aikenhead, 1997). This notion promotes the scientific world view while recognizing and valuing alternative world views of diverse cultures. There needs to be recognition of diverse, alternative views in defining what counts as science and what should be taught in school science (Lee, 1999).

The results indicate that one way to assess students' knowledge and

world views is to examine information sources and discourses in their social and cultural contexts. Ethnic minority, lower SES, and female students are more likely to bring into the science classroom their prior knowledge and world views, which may be incompatible with scientific knowledge and the scientific world view (Allen & Crawley, 1998; Cobern, 1991; Hewson, 1988; Loving, 1997). Science educators need to consider various social and cultural issues as well as individual needs of students from diverse backgrounds in the science teaching and learning process.

To achieve scientific literacy for all students, it is important to establish a sound knowledge base about various ways of knowing, thinking, and communicating among diverse student groups in the science classroom. The results of this study indicate similarities and differences among diverse ethnic, SES, and gender groups of elementary students. The results also provide insights about how these students' ways of knowing are compatible or incompatible with school science. Such a knowledge base is necessary to design instructional interventions and curriculum materials that can meet the learning needs of all students, including socially and culturally diverse students.

Notes

The work is supported by the National Academy of Education Spencer Post-Doctoral Fellowship. Any opinions, findings, and conclusions and recommendations expressed in this article are those of the author and do not necessarily reflect the position, policy, or endorsement of the funding agency. The work is also partially supported by the University of Miami General Research Support Award. The author acknowledges the support of Charles Anderson, Sandra Fradd, Andrew Porter, and Walter Secada. The author also acknowledges many others who have assisted the study at various stages of data collection and analysis, including Linda Anthony, Victor Budzyn, Diane Aguilera, Susie Edwards, and Karen Paiva. The author appreciates the cooperation of all the students and teachers in the study.

[1]Students did not show emotional outbreak during the interviews. Most students welcomed the opportunity to share their experiences and ideas. The teachers of the students often shared with the researcher positive responses from their students. To facilitate communication with the students and their teachers, the researcher worked with a coordinating teacher at each school site. The principals at both school sites were also supportive of the study.

[2]Dr. Bob Sheets and Mr. Bryan Norcross were known throughout the period of Hurricane Andrew in South Florida. Dr. Sheets was Director of the National Hurricane Center located in Miami, Florida. Mr. Norcross was a weatherperson on a local television who became a local hero for his coverage of Hurricane Andrew.

References

Aikenhead, G. S. (1996). Science education: Border crossing into the subculture of science. *Studies in Science Education, 27,* 1–52.

Allen, N. J., & Crawley, F. E. (1998). Voices from the bridge: Worldview conflicts of Kickapoo students of science. *Journal of Research in Science Teaching, 35,* 111–132.

American Association for the Advancement of Science. (1989). *Science for all Americans.* New York: Oxford University Press.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy.* New York: Oxford University Press.

Atwater, M. M. (1994). Research on cultural diversity in the classroom. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 558–576). New York: Macmillan.

Atwater, M. M., & Riley, J. P. (1993). Multicultural science education: Perspectives, definitions, and research agenda. *Science Education, 77,* 661–668.

Barba, R. H. (1993). A study of culturally syntonic variables in the bilingual/bicultural science classroom. *Journal of Research in Science Teaching, 30,* 1053–1071.

Carey, S. (1987). *Conceptual change in childhood.* Cambridge, MA: MIT Press.

Cazden, C. (1988). *Classroom discourse: The language of teaching and learning.* Portsmouth, NH: Heinmann.

Cobern, W. W. (1991). World view theory and science education research. *Monograph of the National Association for Research in Science Teaching, No. 3.* Manhattan, KS: Author.

Cobern, W. W. (1993). College students' conceptualizations of nature: An interpretive world view analysis. *Journal of Research in Science Teaching, 30,* 935–951.

Cobern, W. W. (1994). Point: Belief, understanding, and the teaching of evolution. *Journal of Research in Science Teaching, 31,* 583–590.

Cobern, W. W. (1996). Worldview theory and conceptual change in science education. *Science Education, 80,* 579–610.

Cobern, W. W., & Aikenhead, G. S. (1997). Culture and the learning of science. In B. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 39–52). Dordrecht, the Netherlands: Kluwer.

Confrey, J. (1990). A review of the research on student conceptions in mathematics, science, and programming. *Review of Research in Education, 16,* 3–56.

Dade County Public Schools. (1994). *Statistical abstract, 1993-94.* Miami, FL: Author.

Dart, F. E. (1972). Science and the worldview. *Physics Today, 25,* 48–54.

Dart, F. E., & Pradhan, P. L. (1967). Cross-cultural teaching of science. *Science, 155,* 649–656.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher, 23,* 5–12.

Eisenhart, M., Finkel, E., & Marion, S. F. (1996). Creating the conditions for scientific literacy: A re-examination. *American Educational Research Journal, 33,* 261–295.

Erickson, F. (1986). Qualitative methods in research on teaching. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed., pp. 145–158). New York: Macmillan.

Eylon, B., & Linn, M. (1988). Learning and instruction: An examination of four research perspectives in science education. *Review of Educational Research, 38,* 251–301.

Gee, J. P. (1990). *Social linguistics and literacies: Ideology in discourses.* London: Falmer Press.

Gee, J. P. (1991). What is literacy? In C. Mitchell & Weiler (Eds.), *Rewriting literacy: Culture and the discourse of the other* (pp. 3-12). New York: Bergin & Garvey.

Green, J. L. (1983). Teaching as linguistic process: A state of the art. *Review of Research in Education, 10,* 152–252.

Hampton, E. (1991). Toward a redefinition of American Indian/Alaska Native Education. *Canadian Journal of Native Education, 20,* 261–309.

Hewson, M. G. (1988). The ecological context of knowledge: Implications for learning science in developing countries. *Journal of Curriculum Studies, 20,* 317–326.

Hicks, D. (1995). Discourse, learning and teaching. *Review of Research in Education, 21,* 49–95.

Hodson, D. (1993). In search of a rationale for multicultural science education. *Science Education, 77,* 685–711.

Jegede, O. J., & Okebukola, P. A. (1992). Differences in sociocultural environment perceptions associated with gender in science classrooms. *Journal of Research in Science Teaching, 29,* 637–647.

Kearney, M. (1984). *World view.* Novato, CA: Chandler & Sharp.

Kuhn, T. S. (1970). *The structure of scientific revolutions.* Chicago: University of Chicago Press.

Lawrenz, F., & Gray, B. (1995). Investigation of worldview theory in a South African context. *Journal of Research in Science Teaching, 32,* 555–568.

Lee, O. (1997). Science literacy for all: What is it, and how can we achieve it? *Journal of Research in Science Teaching, 32,* 797–816.

Lee, O. (1999). Equity implications based on the conceptions of science achievement in major reform documents. *Review of Educational Research, 69* (1), 19–51.

Lee, O., & Fradd, S. H. (1998). Science for all, including students from non-English language backgrounds. *Educational Researcher, 27*(3), 1–10.

Lee, O., Fradd, S. H., & Sutman, F. X. (1995). Science knowledge and cognitive strategy use among culturally and linguistically diverse students. *Journal of Research in Science Teaching, 32,* 797–816.

Lemke, J. (1990). *Talking science: Language, learning, and values.* Norwood, NJ: Ablex.

Loving, C. C. (1997). From the summit of truth to its slippery slopes: Science education's journey through positivist-postmodern territory. *American Educational Research Journal, 34,* 421–452.

Maddock, M. N. (1981). Science education: An anthropological view point. *Studies in Science Education, 8,* 1–26.

Matthews, M. (1994). *Science teaching: The role of history and philosophy of science.* New York: Routledge.

Michaels, S., & O'Connor, M. C. (1991). *Literacy as reasoning within multiple discourses: Implications for policy and educational reform.* Paper presented at the Council of Chief State School Officers 1990 Summer Institute on "Restructuring Learning." Newton, MA: Literacies Institute, Education Development Center.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: A sourcebook of new methods* (2nd ed.). Newbury Park, CA: Sage.

Mitchell, C., & Weiler, K. (1991). *Rewriting literacy: Culture and the discourse of the other.* New York: Bergin & Garvey.

National Center for Education Statistics. (1992). *Language characteristics and academic achievement: A look at Asian and Hispanic eighth graders in NELS: 1988.* Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

National Research Council. (1996). *National science education standards.* Washington, DC: National Academy Press.

National Science Foundation. (1994). *Women, minorities, and persons with disabilities in science and engineering: 1994* (NSF-94-333). Arlington, VA.

O'Sullivan, C. Y., Reese, C. M., & Mazzeo, J. (1997). *NAEP 1996 science report card for the nation and the states.* Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

Posner, G., Strike, K., Hewson, P., & Gertzog, W. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66,* 211–227.

Proper, H., Wideen, M. F., & Ivany, G. (1988). Worldview projected by science teachers: A study of classroom dialogue. *Science Education, 72,* 547–560.

Rakow, S. J., & Bermúdez, A. B. (1993). Science is "Cicencia": Meeting the needs of Hispanic American students. *Science Education, 77,* 669–683.

Reif, F., & Larkin, J. H. (1991). Cognition in scientific and everyday domains:

Comparison and learning implications. *Journal of Research in Science Teaching, 28,* 733–760.

Robbins, R. (1983). John Dewey's philosophy and American Indian: A brief discussion of how it could work. *Journal of American Indian Education, 22,* 1–9.

Rodríguez, A. J. (1997). The dangerous discourse of invisibility: A critique of the National Research Council's National Science Education Standards. *Journal of Research in Science Teaching, 34,* 19–37.

Ross, K. E. K., & Shuell, T. J. (1993). Children's beliefs about earthquakes. *Science Education, 77,* 191–205.

Roth, W-M. (1995). *Authentic school science: Knowing and learning in open inquiry science laboratories.* Dordrecht, the Netherlands: Kluwer.

Roth, W-M., & Lucas, K. B. (1997). From "truth" to "invented reality": A discourse analysis of high school physics students' talk about scientific knowledge. *Journal of Research in Science Teaching, 34,* 145–179.

Smith, M. U. (1994). Counterpoint: Belief, understanding, and the teaching of evolution. *Journal of Research in Science Teaching, 31,* 591–597.

Stanley, W., & Brickhouse, N. (1994). Multiculturalism, universalism, and science education. *Science Education, 28,* 387–398.

Strauss, A., & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques.* Newbury Park, CA: Sage.

Suzuki, D., & Knudtson, P. (1992). *Wisdom of elders.* New York: Bantam Books.

Tamir, P., & Zohar, A. (1991). Anthropomorphism and teleology in reasoning about biological phenomena. *Science Education, 75,* 57–67.

Thelen, L. J. (1983). Values and valuing in science. *Science Education, 67,* 185–192.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Wertsch, J. V. (1991). *Voices of the mind: A sociocultural approach to mediated action.* Cambridge, MA: Harvard University Press.

Manuscript received October 3, 1997
Revision received February 16, 1998
Accepted March 16, 1998

References

A Review of the Research on Student Conceptions in Mathematics, Science, and Programming

Jere Confrey

Review of Research in Education, Vol. 16. (1990), pp. 3-56.

Stable URL:

http://links.jstor.org/sici?sici=0091-732X%281990%2916%3C3%3AAROTRO%3E2.0.CO%3B2-8

Cross-Cultural Teaching of Science

Francis E. Dart; Panna Lal Pradhan

Science, New Series, Vol. 155, No. 3763. (Feb. 10, 1967), pp. 649-656.

Stable URL:

http://links.jstor.org/sici?sici=0036-8075%2819670210%293%3A155%3A3763%3C649%3ACTOS%3E2.0.CO%3B2-%23

Constructing Scientific Knowledge in the Classroom

Rosalind Driver; Hilary Asoko; John Leach; Eduardo Mortimer; Philip Scott

Educational Researcher, Vol. 23, No. 7. (Oct., 1994), pp. 5-12.

Stable URL:

http://links.jstor.org/sici?sici=0013-189X%28199410%2923%3A7%3C5%3ACSKITC%3E2.0.CO%3B2-C

Creating the Conditions for Scientific Literacy: A Re-Examination

Margaret Eisenhart; Elizabeth Finkel; Scott F. Marion

American Educational Research Journal, Vol. 33, No. 2. (Summer, 1996), pp. 261-295.

Stable URL:

http://links.jstor.org/sici?sici=0002-8312%28199622%2933%3A2%3C261%3ACTCFSL%3E2.0.CO%3B2-G

LINKED CITATIONS

Learning and Instruction: An Examination of Four Research Perspectives in Science Education

Bat-Sheva Eylon; Marcia C. Linn

Review of Educational Research, Vol. 58, No. 3. (Autumn, 1988), pp. 251-301.

Stable URL:

http://links.jstor.org/sici?sici=0034-6543%28198823%2958%3A3%3C251%3ALAIAEO%3E2.0.CO%3B2-9

Research on Teaching as a Linguistic Process: A State of the Art

Judith L. Green

Review of Research in Education, Vol. 10. (1983), pp. 151-252.

Stable URL:

http://links.jstor.org/sici?sici=0091-732X%281983%2910%3C151%3AROTAAL%3E2.0.CO%3B2-P

Discourse, Learning, and Teaching

Deborah Hicks

Review of Research in Education, Vol. 21. (1995 - 1996), pp. 49-95.

Stable URL:

http://links.jstor.org/sici?sici=0091-732X%281995%2F1996%2921%3C49%3ADLAT%3E2.0.CO%3B2-Q

Equity Implications Based on the Conceptions of Science Achievement in Major Reform Documents

Okhee Lee

Review of Educational Research, Vol. 69, No. 1. (Spring, 1999), pp. 83-115.

Stable URL:

http://links.jstor.org/sici?sici=0034-6543%28199921%2969%3A1%3C83%3AEIBOTC%3E2.0.CO%3B2-G

Science for All, including Students from Non-English-Language Backgrounds

Okhee Lee; Sandra H. Fradd

Educational Researcher, Vol. 27, No. 4. (May, 1998), pp. 12-21.

Stable URL:

http://links.jstor.org/sici?sici=0013-189X%28199805%2927%3A4%3C12%3ASFAISF%3E2.0.CO%3B2-U

From the Summit of Truth to Its Slippery Slopes: Science Education's Journey Through Positivist-Postmodern Territory

Cathleen C. Loving

American Educational Research Journal, Vol. 34, No. 3. (Autumn, 1997), pp. 421-452.

Stable URL:

http://links.jstor.org/sici?sici=0002-8312%28199723%2934%3A3%3C421%3AFTSOTT%3E2.0.CO%3B2-L