# Reflective Scientific Sense-Making Dialogue in Two Languages: The Science in the Dialogue and the Dialogue in the Science

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**ABSTRACT:** In this paper I focus on the transition from everyday to scientific ways of reasoning, and on the intertwined roles of meaning-making dialogue and science content as they contribute to scientific literacy. I refer to views of science, and how scientific understanding is advanced dialogically, by Hurd (Science Education, 1998, **82**, 402–416), Brown (The Journal of Learning Sciences, 1992, **2**(2), 141–178), Bruner (Acts of Meaning, Cambridge, MA: Harvard University Press, 1990), Roth (In J. Brophy (Ed.), Social Constructivist Teaching: Affordances and Constraints (Advances in Research on Teaching Series, Vol. 9), New York: Elsevier/JAI, 2003), and Wells (Dialogic Inquiry: Towards a Sociocultural Practice and Theory of Education, New York: Cambridge University Press, 1999). I argue that family collaborative dialogues in nonschool settings can be the foundations for scientific ways of thinking. I focus on the particular reflective family dialogues at the Monterey Bay Aquarium, when family members remembered and synthesized essential biological themes, centering on adaptation, from one visit to the next, in both Spanish and English. My approach is informed by sociocultural theory, with emphasis on the negotiations of meaning in the zone of proximal development (Vygotsky, 1978), as learners engage in joint productive activity (Tharp & Gallimore, Rousing Minds to Life: Teaching, Learning and Schooling in Social Context, New York: Cambridge University Press, 1988). Over the past decades, researchers have discovered that observing social activity, conversation, and meaning-making in informal settings (Crowley & Callanan, 1997; Guberman, 2002; Rogoff, 2001; Vasquez, Pease-Alvarez, & Shannon, Pushing Boundaries: Language and Culture in a Mexicano Community, New York: Cambridge University Press, 1994) has much to teach us regarding learning in general. To date there has been little research with Spanish-speaking families in informal learning settings and virtually none that integrates the home with both formal and informal learning. © 2004 Wiley Periodicals, Inc. *Sci Ed* **88:**855–884, 2004

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## INTRODUCTION

Learners regularly cross the boundaries between home and school, between first and second languages, between everyday and scientific discourse, and between formal classroom and informal (museum, aquarium, or after-school club) settings. Crossing between these different contexts has been labeled border crossings (Aikenhead, 1996, 2000; Solomon, 2003); some have even specifically argued that "in all cultures a gap exists between the culture of science and society" (Cleghorn & Rollnick, submitted). According to Aikenhead (2002) "enculturating is not a problem for [only] a small minority of students whose worldviews resonate with the scientific worldview conveyed most frequently in school science" (p. 1). While this is true across cultures, most countries have the goal of including all members in science learning. So how can this new language be effectively taught to people who want to learn?

In this paper I suggest possible beginning answers to this question, focusing on the boundary between meaning-making in everyday settings like aquariums and museums, and the meaning-making that occurs in the "system used by scientists" (Yore, Bisanz, & Hand, in press). I have gathered several family dialogues from an informal setting; the focal points of my analysis of these conversations are dialogic inquiry (Ash & Wells, in press; Wells, 1999) and deep generative content, and my data were gathered from my work with Head Start Spanish-speaking families, a group typically under-served by all science education. I intend (for both formal and informal learning settings) to expand the concept of "what science dialogue looks like" and to deepen our understanding of how science dialogue can become the basis for broader scientific literacy. I propose that fleeting and opportunistic dialogues, in informal learning settings such as aquariums, are critical starting points for more scientific ways of thinking, and represent collaborative scientific sense-making across learning contexts. By considering boundaries to be opportunities rather as discontinuities, we can expand our comprehension of science learning, as well as make progress toward the goal of creating more equitable access to science for populations who have previously been excluded from science fields.

I start with the belief that meaning is created dialogically over time, among collaborating speakers and listeners, and that science understanding is talked into being (Gallas, 1995; Green & Dixon, 1993; Lemke, 1990), over time, between speakers. This emphasis does not exclude understandings derived from physical interaction with scientific phenomena; rather I view physical activities (doing) and dialogic processes (talking) as a necessary consideration that together lead to increased understanding. Scientific dialogue is never a single event, but a series of progressive events where meanings evolve to create coherence (Edwards & Mercer, 1987; Wells, 1999). While viewing language as doing (Lindfors, 1999; Rahm, in press; Rogoff, 1995, 1998), some researchers have suggested that we include a wider range of cultures in our analyses of scientific doing and talking: "it is important to take seriously the ideas and ways of talking and knowing that children from diverse communities bring to science, the profound continuities between everyday and scientific ways of knowing and talking" (Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2000, p. 47).

Past research has determined that English-speaking parents guide, question, explain, describe, gesture, and read signs for their children to teach them in informal settings (Crowley & Callanan, 1998; Diamond, 1986; Gleason & Schauble, 2000; McManus, 1989). McManus noted that parents "identify and name the new items encountered by the children, and, in teaching mode, comment on, or interpret, the information broadcast by the children . . . " (1994, p. 91). She calls this the hunter/gatherer pattern for visiting museums. In these cases, with all English-speaking parents, signs fulfilled parents' need for information. Non-English-speaking members often do not as readily use these standard European American middle class learning strategies. When this kind of interpretation, teaching or participation does not happen, because there are no signs in languages other than English, family collaborative activity differs from those interactions seen with English-speakers.

Rogoff (1998) argues that "we need greater understanding of collaboration and cognition in populations other than middle-class European American groups, or in situations other than those devised or managed by middle-class European American researchers" (p. 722). We can assume that learners need to be engaged in authentic science-learning activities, in which they answer questions that have relevance in their daily lives and which allow for discourse in each learner's main language to be linked to formal science concepts in the language of learning and teaching (Warren et al., 2000). In line with this thinking Lee (2002) has advanced the notion of "compatibility," which explores the use of everyday experiences and resources to enhance scientific understanding. My aim in this research is to expand our current research agenda by centering on dialogic inquiry in informal learning settings to include everyday understanding in languages other than English.

Defining everyday science is not easy. Vygotsky (1987, p. 147) suggested that everyday concepts arise form the simple situations of daily life. Guberman (2002) has suggested that the systematic, but often decontextualized, nature of science and the highly situated, but localized, nature of everyday concepts have much to offer each other in museum contexts. I assume that the origins of everyday science lie in the lived cultural, historical, gestural, and spoken practice of children and adults as they directly and indirectly interact with phenomena, including objects that are both living and dead. Assuming that young and naïve learners are not expert in life science, we can expect them to bring an idiosyncratic assortment of everyday experiences to museums and aquariums. Yet, we also know that certain patterns of reasoning are generalizable to young children. We know, for example (Ash, 1995, 2002; Keil, 1992), that even very young learners assume that biological forms have functions, for example, sharp teeth are useful for eating. Cognitive development research has given us glimpses into several reasoning patterns that young children might bring to their learning experiences, both inside and outside the classroom.

We also know from Vygotsky that everyday (or spontaneous) ideas become more (or academic) scientific over time, when given assistance, in both formal and informal settings. Parents are the ideal teachers in these learning settings. Parents are their children's first and most permanent teachers, so by examining parent–child interactions we can gain further insights into the nature of the everyday science that permeates their thinking, as they interact with the canonical science presented in books, museums, and schools. Guberman (2003, p. 2) has argued that "with extensive information of their children's knowledge and everyday experience, parents are well-suited to help children connect the academic concepts presented in museum exhibits with previously acquired, everyday concepts."

The particular context for this research is the Splash Zone exhibition at the Monterey Bay Aquarium in Monterey, CA. Both my research agenda and the Splash Zone exhibition rely on people, signs, and mediators with different levels of expertise. My goal was to track the growth of understanding of biological content, as learners use one another, signs, objects, and a docent as their dialogic mediators. I explore how parents and children learn together as they participate in scientific conversations and reflective interviews. I analyze the biology content members share verbally with each other, the questions they ask, and how they negotiate understanding, including with language and gestures. I describe how family dialogue progresses toward what we call scientific, and how access to scientific dialogue in two language enhances, rather than detracts from, science literacy.

The data include a series of interviews, aquarium visits, postinterviews, and reflective prompts (stimulated recall) of one bilingual family. This particular data set is part of a larger research effort using a similar theoretical framework and similar methodologies, with dozens of families[1] in different learning settings. In the following sections, I establish the theoretical foundations of my research, particularly the concepts of the zone of proximal development, the role of dialogue in science, and the nature of scientific literacy. Second, I present the dialogic data. I conclude with a discussion of the implications of this research.

## THEORETICAL FOUNDATIONS

### Sociocultural Theory

Many researchers have studied meaning-making in scientific dialogue within a sociocultural framework, both in and out of the classrooms (Ash, 2003a, 2003b; Brown, 1992; Lemke, 1990; Rogoff, 1998; Rosebery & Warren, 1995; Tharp & Gallimore, 1988; Warren et al., 2000; Wells, 1998). Most build their own work at least partially on Vygotsky's theories. Vygotsky (1978) emphasized the inherently social nature of learning through his construct of the "zone of proximal development (zpd)" which can be described as "the zone in which an individual is able to achieve more with assistance than he or she can manage alone" (Wells, 1999, p. 4). The zpd allows us to interpret how an individual's or group's development can be assisted by others, both face-to-face and with artifacts such as exhibits, books, computers, or signs. I use an expanded concept of the zpd, recognizing dialogue as one of a variety of mediation tools, including signs, displays, books, videos, and other learners in collaborative activities (Ash & Wells, in press). It is in the zpd that learners, at home, at museum exhibits, or in the classroom, "undergo quite profound changes ... by engaging in joint activity and conversations with other people" (Edwards & Mercer, 1987, p. 19). The zpd in this research consists of the family, mediator, researchers, and the exhibit.

Vygotsky (1978) suggested that signs, utilizing language and other cultural symbols, mediate all human activity, as language is the medium for learning and teaching. This notion of mediation via symbolic tools of all kinds is important in all learning settings; it is especially interesting in nonschool settings, such as museums and aquariums, where a rich assortment of interpretive materials is available for learners and teachers. These objects interact with humans in a number of ways (Paris, 2002). Halliday (1993) suggested that language is the means by which experience becomes knowledge. Leont'ev (1981) said that language "mediates activity and thus connects humans not only with the world of objects but also with other people" (p. 55).

Wells (1999) has also argued that "two features of the dialogue that support knowledge building are paramount: responsivity and the attempt to achieve enhanced understanding" (p. 25). Whether in museum, classroom, or after school setting, learners respond to each other's ideas both dialogically and gesturally. As they appropriate each other's ideas, they progressively build on each others' knowledge and on the information gained from artifacts and objects. Meaning is built over time by successive dialogic episodes that can be discontinuous in time (Linde, 1993). Bakhtin (1986) argued that all discourse is dialogic, as the meanings of words and expressions are "borrowed" from the speech of others, and he noted that each "utterance is a link in a very complexly organized chain of other utterances" (p. 69). Bakhtin specifically advanced the notion of "responsivity," which applies to both speaker and listener; thus "understandings are enhanced through the successive contributions of individuals that are both responsive to the contributions of others and oriented to

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their further responses" (Wells, 1999, p. 22). To understand each other, both speaker and listener must "perceive and understand each other's words . . . [and they must] take an active, responsive attitude towards it" (Bakhtin, 1986, p. 68).

Taking this view then, dialogue is both process and product, continually changing in response to prior understandings. Bereiter (1994) called this "progressive discourse," where sharing, questioning, and revising of opinions leads to "a new understanding that is progressively constructed by the participants, move by move, meaning by meaning, so that its meaning and structure are constantly emerging" (Wells, 1999, p. 4).

This perspective requires a close analysis of the dialogue between and among individuals, without neglecting the broader context within which the dialogue is situated. Wenger (1998) argues that in any community of practice we expect that members have the "ability, facility and legitimacy to contribute to, [and] take responsibility . . . in the negotiation of meaning [which] involves both the "production and adaptation of ideas . . . [that] shape meanings that matter within a social configuration" (p. 197). This adoption of ideas has often been termed appropriation, that is, taking up another's idea and making it one's own, within the context of co-construction of understanding as part of joint productive activity (Brown et al., 1993; Tharp & Gallimore, 1988; Wells, 1999). I have borrowed the term "mutual appropriation" (Moschkovich, 1989; Newman, Griffin, & Cole, 1989) to refer to

> the bi-directional nature of the appropriation process, . . . [whereby] learners of all ages and levels of expertise and interests . . . [contribute] ideas and knowledge that are appropriated by different learners at different rates, according to their needs and to the current state of the [zpds] in which they are engaged (Brown et al., 1993, p. 193).

## Views of Scientific Literacy

I focus in this paper on the boundary between everyday understandings and scientific literacy, by analyzing both the science in the dialogue and the dialogue in the scientific sense-making, recognizing that they are thoroughly intertwined. Adapting a dialogic perspective and advocating science for all both force us to reexamine just what is meant by the practice of science and by science literacy. Many argue that a progressive and overlapping mixture of activity and dialogue is the way real science occurs (Latour & Wolgar, 1986).

Science represents people's attempts to systematically describe and explain patterns of events in the natural world (Cobern & Loving, 2001; Good, Shymansky, & Yore, 1999). This includes providing explanations about the natural world that are testable. Science is different from other ways of knowing because it uses empirical standards, logical arguments, and skepticism to generate explanations (Hofer & Pintrich, 1997). Explanations need to be consistent with events and need to address questions of causality. Roth (2003, p. 3) argued that both scientists and students in elementary classrooms can come to understand that science is characterized by the following elements:

a. [Science] is connected [and] well-structured;
b. It is useful in describing, predicting, explaining, designing, and appreciating real-world phenomena;
c. It is constantly changing, building, deepening over time, and raises questions for further exploration;
d. It is developed within and shared by a community that cooperatively constructs new knowledge and understanding.

Scientific literacy has been described by Hurd (1998) as having the following three features[2]:

a. Distinguishes data from myth and folklore, and knowledge from opinions;
b. Recognizes the ongoing and cumulative nature of science, and the influence of science on society; and
c. Knows about data, its processing, and that there can be multiple solutions and answers to scientific questions that impact society in many ways.

Expanding on Hurd's and Roth's characteristics, and focusing specifically on science content, I start with Bruner's criterion of "lithe and lively, immensely generative scientific ideas" that spiral through the development of understanding, in this case through science dialogues. Wells (1999) insisted that students need productive curricular activities that are both personally and socially significant. The Fostering a Community of Learners (FCL) project, Brown et al. (1993), relied on disciplinary underpinnings of deep content in order to move understanding toward the fundamental principles of science, for example, adaptation. Relying on biological themes that grow out of these principles allows dialogue to become generative, endure over a long period of time, and be lively enough to keep a family interested across many months, multiple visits, and several interviews. In this paper, as in past research, I describe how biological content becomes more coherent and complex over time, and how it begins to parallel scientific conversations, specifically when scientists generalize across a number of events in order to isolate a larger principle.

In line with Brown, Bruner, and other researchers, I argue that scientific dialogue functions best when centered on deep principles of science. I contend that complex content best captures and sustain learners' interest over time. One example of such a topic is adaptation, a larger principle that subsumes mechanisms for plant and animal survival in hostile environments. Adaptation is an example of lithe and lively and immensely generative biological content, and it is also a prerequisite for a deeper understanding of natural selection and conservation.

I have focused, in all my research, on deeply rooted biological content principles, such as the structures and functions of survival, for example, feeding, breeding, or protection from predators. Yet, research on education and diversity have suggested that "too many of [second language learning] students are not challenged with the same content as mainstream children" (Tharp, 1997, p. 47). Biological adaptation, though, is compelling and challenging for all learners. This is also consonant with the content goals set by the museums, zoos, and aquariums in which I conduct research, as these centers are concerned with conserving natural habitats and the species within them.

The family dialogue in this paper started by focusing on the properties of coral. Family members asked questions concerning the basic biological categories of dead vs. alive, and plant vs. animal, in relation to coral. Evidence from research by Carey (1985) indicates that children younger than 11 years typically do not yet count plants as living things. That makes this family's questions (dead vs. alive, and plant vs. animal) both appropriate and critical for building scientific understanding for the children. After considering several similar biological areas of interest, typically by asking questions, they jointly discussed several forms of species reproduction. Later they arrived at the understanding that animals need to reproduce more frequently than they die, in order to maintain the species. At the end, they understood that coral are endangered because of this problem. These questions

[2]This is a greatly abbreviated list from the original in Hurd (1998), and as described in Yore, Bisanz, and Hand (in press).

formed a link between their everyday understanding and more canonical science as well as fundamental building blocks to more principled life sciences knowledge.

I have written elsewhere (Ash, 1995, 2002, 2003a, 2003b) about the possible origins of such biological themes as adaptation, and of the research that informs our views of the kinds of thematic material that will most attract young students and learners with less formal schooling. These thematic areas of interest arise from the developmental roots of cognition. They have been the focus of research by Carey (1985) and many others who have informed our understanding of the development of children's scientific thinking (Brown et al., 1998; Lee, 2002; Lehrer & Schauble, 1998; Metz, 1995).

In Table 1, I suggest a possible trajectory of the development of biological understanding for the family in this paper, and in general, starting with the question of whether coral is a plant or animal, using biological topics in family dialogue, biological fundamentals, and the cognitive developmental underpinnings as elements. This trajectory starts with the belief that there are certain fundamental essences that characterize living things (Medin & Ortony, 1989), which nonliving things do not share. One cannot, for example, change a raccoon to a skunk simply by painting a stripe on its back (Keil, 1992). Living things tend to reproduce their own kind and have life cycles. In addition, if a thing moves of its own agency, then is assumed to have innards, that is, something inside that allows the movement (Gelman & Wellman, 1991).

**TABLE 1**
**A Proposed Trajectory of Understanding: Starting with Coral as Plant or Animal**

| Biological Topics in Family Dialogue | Biological Underpinnings | Cognitive Development Underpinnings |
|---|---|---|
| • Plants vs. animals<br>• Plants have different characteristics than animals. | • **Coral looks like a plant but in fact is a primitive animal.** | • **Most people don't care about plant vs. animal.** |
| • Animals and plants have different survival strategies. Survival strategies for animals include—feeding, breeding, protection from predators, protection from the elements. | • **Coral has the requisite animal characteristics—they move, they eat other animals. Some protect themselves from predators by stinging cells.** | • **Plants are living but they don't move of their own agency—an important characteristic (Gelman & Wellman, 1991).** |
| • Living things breed and reproduce, successful ones do so faster than they die.<br>• Endangered species don't reproduce fast enough to match the death rate for a variety of reasons. | • **They require hotter water to survive.**<br>• **Coral grows slowly, and because of its destruction (for a variety of reasons (e.g. collecting)), it is not able to out reproduce as fast as it is being destroyed.**<br>• **This is one cause for becoming an endangered species.** | • **Research shows that school children don't subsume plant into the category of living thing until about age 11 (Carey, 1985).** |

Similarly, when learning about life cycles, children may understand that things grow; yet they may not understand that there are different patterns of growth. For humans, the baby looks like the parent and continues to get bigger. With coral, the baby is very different from the adult. This makes coral an invaluable teaching tool, because it is an exception to the more basic growth pattern. Such discontinuities help children learn more realistically how different things grow (Rosengren et al., 1991).

## Dialogic Inquiry in Science

While it is critical to understand the nature of science and how it informs our view of scientific literacy, as well as the role of deeply generative content from which to generalize scientific principles, neither can explain a learner's journey from everyday to scientific understanding. For this we need the lens of dialogic inquiry. In dialogic inquiry we look to the oral, written, and gestural activities that help advance understanding (Ash & Wells, in press; Wells, 1999) out of the deeply generative content, allowing learners to generalize to scientific principles; we also take note of what learners bring to the setting. In this section, I discuss the role of dialogic inquiry in science.

Scientific inquiry is an "active, process-driven, problem-oriented approach to sense-making which invites active participation in tool-mediated activity" (Ash & Wells, in press). Inquiry is concerned with learners asking and answering questions, so that learners choose their own path toward greater understanding (Ash, 2002; Ash & Klein, 1999; Lee, 2002). Dialogic inquiry occurs in a zpd, here consisting of the family, the mediator, researchers, and the exhibit. I discuss below a few of the collaborative activities that supported this particular dialogic inquiry, which included active scaffolding and modeling by participants and the exhibit. I focus on the role of questions in the family's complex dialogue. Dialogic inquiry allows content to be layered progressively, so that "participants recognize [the understanding gained] as superior to their previous understandings" (Bereiter, 1994, p. 7).

Dialogue in science (including spoken and written language, and other symbolic representations such as graphs and diagrams) is a specialized way to talk and think, distinct from the conversational practices of everyday life (Yore et al., in press). It is how scientists and others describe, explain, predict, synthesize, and argue. This is true whether collaborators are face-to-face, or at a distance. Scientific discourse is also discontinuous, including events over time, rather than as linear sequences. A discontinuous time frame is incomplete in any one of its component parts, and cumulative over time (Linde, 1993), combining related ideas, actions, and themes into a cohesive whole. Linde (1993) argued that in certain narratives, "we confront a unit that is **necessarily** (emphasis is Linde's) discontinuous" (p. 27). She also suggested that, in non-task-driven conversation, "participants do tend to perform the work required to achieve a resumption of the narrative after an interruption" (p. 25). Scientific dialogues can easily be taken up again as the social group continues to interact with exhibits and with each other.

## Informal Learning Settings

Often, learning in informal settings occurs within short, seemingly unrelated events. This can make it challenging for scientists and science educators to clearly delineate the longer-term learning that occurs through these social dialogues and activities. Precisely because informal settings inherently offer less insight into context, purpose, or the long-term effects of any single event, I use a methodology in my research that captures social meaning-making over time, by emphasizing the fruitful, unfruitful, and cumulative outcomes of seemingly disconnected dialogues. I analyze how content can be generative and how it develops and transforms over time.

Over the past 2 years I have analyzed the content and negotiation patterns of a small group of Spanish-speaking families with young children in a Head Start program, in collaboration with the Monterey Bay Aquarium (Ash, 2002). I have compared these events with prior research with English-speaking families. The patterns seen in research with European American families have not been treated as representative. Recently, I have proposed (Ash, 2002) three generalizations for Spanish-speaking families in informal settings: first, they regularly use thematic biological material; second, they regularly use questioning and other strategies in information gathering, but they typically do not use known-answer questions; and third, they use varied dialogic strategies when in a non-Spanish-speaking learning setting.

Expanding on this prior work, I focus in this paper on the ongoing conversations of one Spanish-speaking family at the Monterey Bay Aquarium's Splash Zone, gathered over the course of 6 months. These conversations took place during two extended visits, 6 months apart, the second visit directly following an intervening guided reflective interview conducted as stimulated recall. In my analysis and discussion I argue that these family conversations are scientific and gradually grow to become more scientific over time, as members collectively cross the boundary from everyday to scientific. The "science" gradually builds in a nonlinear network of distributed expertise and, eventually, a richer and more complete picture emerges. Second, the family uses many different resources to make sense of what they see and experience, including, but not limited to, their prior experiences, each other, pictures, live and preserved objects, the facilitator, and both Spanish and English. Finally, in their stimulated recall interviews they appear to collectively remember what has come before (Wertsch, 2002), when reviewing their prior activities at the exhibits.

One of the desired outcomes of this research is to illustrate how family conversations can provide a foundation for tracing the development of deeper biological understandings. I argue in this paper that social scientific dialogue in informal settings may even serve as a necessary antecedent to deeper understandings, and describe how this may come to pass by following this one representative family over their multiple visits. Their conversations across these visits provided evidence of their increased understanding of scientific principles. I use a methodology and an analytic scheme that enable identifying potential outcomes of single-event dialogues.

Informal learning settings have proven to be excellent places to test socioculturally framed research questions (Ash, 2003a, 2003b; Martin, 1996; Matusov & Rogoff, 1995). In my research I assume that collaborative groups such as families share the following characteristics:

- They are a constantly changing social group (dyads, triads, etc.) or ensemble (Granott, 1998) in which
- their dialogic or gestural activity is informed by the individuals who comprise the group, yet the activity reciprocally informs the group; and
- their dialogic or gestural activity is mediated by tools, signs, people, symbols, language, and actions and, in this case, by two languages.

I assume that young children are "predisposed to learn certain classes of information relevant to science, notably conceptions of physical and biological causality" (Brown et al., 1998, p. 14). "The idea is to understand children's emergent theories about biology and to lead them gradually toward deep principles, such as interdependence, biodiversity, adaptation and evolution" (Brown, Ellery, & Campione, 1997, p. 24). These early biological understandings can include personification, essences, and functional reasoning. I assume that different family members know different things, that is, that knowledge is distributed in depth and topic. Distributed knowledge allows family members to develop multiple ways into biological dialogue, using thematic areas of interest as the focus (Brown et al., 1993).

### Mediating the Museum Experience

> There are debates in the museum learning community and museum literature about the roles museums have, and ought to have, in mediating experience. (Martin & Toon, 2003)

Museums differ greatly in their philosophy of mediation, arguing both for and against the interpretative role of museums, as well of the roles of the professional employees and volunteers who teach about museum artifacts. These debates raise a number of related questions, including who has the right to interpret objects for visitors?; what kind of objects and experiences count as authentic?; and whose authority matters in designing and interpreting exhibits? It is outside the scope of this paper to fully address these issues, yet these tensions impact how researchers collect, analyze, and evaluate collaborative conversations as learners consider museum objects.

Those who design learning environments grapple with how to provide best practices for interpretation/teaching for a variety of learners (family members, students, adult and child visitors, school groups), and how to be sensitive to cultural and linguistic cultural differences. Typically museums provide people, signs, maps, and other mediation tools. Because museums want to foster dialogic or gestural inquiry, and to invite questioning and finding answers, exhibits typically facilitate learning by using materials, signs, videos, audio recordings, animation, pictures, and others kinds of mediation. As exhibits are being designed, these mediation tools are typically prototyped, in English, for European American families. There have been many evaluation studies, both formative and summative, which assess the efficacy of pictures, docents, and signs (Diamond, 1999; Falk & Dierking, 1992, 2000; Hein, 1999) for European American visitors.

Similarly, the field of interpretation has designed ways that humans can "interpret" or teach material from exhibits, dioramas, zoos, and aquariums, with materials that are either alive or dead. There has also been a great deal of discussion of the use of guided inquiry in the classroom, much of which has centered on how best to scaffold students' learning, dialogically and otherwise (Brown et al., 1993; Roth, 2003; Warren et al., 2000; Wells, 1999), involving multiple individuals interacting with each another in culturally rich, socially situated environments.

The degree of mediation in any social interaction can range from the didactic, or telling mode, to an unbridled discovery mode. In designing the research in this paper, my original goal of fostering collaborative dialogue among social groups, containing individuals with different expertise in both the content and processes of science, has guied the choice of mediation protocol. Because I wanted a mediated, yet not a teaching environment, I have consciously selected a defensible style of mediation which I consider neither completely didactic not discovery, yet sufficient to accomplish my main goal. In the spirit of design experiments (Brown, 1992), the research protocol has evolved over several iterations. In the first studies, mediation involved no outside human mediation other than the family's own actions and dialogue. We found that, without outside mediation, non-English-speaking families physically explored signs and materials explained in English, but were not dialogically active. The design team then added a bilingual, trained mediator to foster scientific dialogue in the non-English family talk. As the study progressed, the role of the mediator evolved into a proscribed format, which involved asking fewer questions, but answering all questions. The intent was to create conditions to foster the family's access to material and talk without being unduly influenced by the mediator.

We took the Vygotskian view that mediation is most productive when the learner is "just" ready to learn new material, while simultaneously being offered material that encourages more complex ways of talking, acting, and understanding. The trained mediator, in this research, was asked to work within the collective zone of proximal development of the exhibit and the family. To foster movement to new levels of understanding, there must first be some mechanisms for assessing current understanding. The mediator used her own and the family members' questions to provide this assessment, in order to stay within the zone of proximal development (Ash & Levitt, 2003). Parents are excellent at assessing their own children in this regard; practiced teachers also do this effortlessly; trained docents, such as the mediator in this paper, with training and practice, can learn to do this as well. Thus, in much of the dialogue presented in this paper, the bilingual interpreter carried the authority for guiding this family's discussion, using questions as her guide. She was allowed this authority because she was both trained in marine science and fully bilingual. Whenever she actively questioned the family, she was acting on the advice of the research team, in order to probe understanding; this method of mediation thus resembles dynamic assessment (Brown & Campione, 1994).

These, then, are the theoretical underpinnings for my analysis of the data presented in this paper.

## METHOD

### Dialogic Unit of Analysis: Significant Events

To work with a discrete unit of analysis, I have chosen the construct Significant Event (SE). Each significant event (Ash, 2002) is just large enough to encompass one meaning-making event. Each SE contains

1. recognizable beginnings and endings, generally but not always centered on one particular exhibit;
2. sustained conversational segments that differ from short, unsustained interactions, which can precede and follow SEs;
3. different sources of knowledge, i.e., distributed expertise; and
4. various inquiry strategies, such as questioning, inferring, or predicting.

To date, most museum learning research has not established clear, theoretically bound criteria for selection of analytic units. By using a level intermediate in both size and purpose (White, 1993), I can show how SEs arise from other events and how they subsequently affect future outcomes. No single SE, therefore, is a final product but is a potentially rich analytic slice in time. An SE marks progress to date, with the understanding that any meaning made at a given moment will subsequently be changed. One salient feature of the participation of family members in an SE is that they are "involved in a mutually constructed activity rather than as individuals that are influenced by outside forces" (Rogoff, 1998, p. 692).

In this paper SEs are selected at each of the two different aquarium visits; these SEs are then discussed in relation to an analytic frame (Ash, in press) designed to place dialogue in its naturally occurring context. Before selecting SEs, I typically preview the video several times, along with other researchers. I begin to identify the major events within a visit. Then I create a flow chart of that visit, which, by using time codes and other identifying features, includes an outline of the most likely areas for future in-depth investigation. The resulting flow chart is a broad reflection of the time, participation, theme, use of inquiry skills and

**TABLE 2 Partial Sample of Family[a] 4 Flow Chart**

| Time | Exhibit | Overview | Thematic Content |
|---|---|---|---|
| 0–30:00 | Pre interview with Splash Zone cards | Long, rich, Mom talks most<br>Use the SZ cards to start conversation,<br>*Mom the lead* | Frequent museum goers, family event, fun, better than flea market, all have favorite animals. |
| 30:00–33:00 | Walk to museum | *Eva the lead* | |
| 33:33:00 | Entry way to main aquarium | Eva is animated about the whales pointing at things<br>Eva is excited now but was quiet before | |
| 34:50:00 | Whole family looking at otters | Some preliminary talk about animal behavior<br>*Dad/kids lead* | Is otter asleep—how would you know? |
| 37:00:00 | Looking at video of whales | Eva and Mom separate<br>Mom listens attentively & questions her<br>*Eva/Mom colead* | Whale is Eva's favorite animal, they communicate, have smaller flippers. |
| 39:02:00 | DA[b]/Eva talk about whales | *Eva the lead*,<br>DA listens, Eva explains her classroom work with killer whales | |
| 40:10:00 | At the SZ | Get their bearings<br>Start at first tank | |
| 41:00:00 | First coral tank | Looking closely, not in a hurry<br>*Dad the lead*<br>*Mom takes lead next* | Conversation about coral—Is it plants or animal; what do they eat?—they eat other animals and live in layers. |

[a]Five members: Mother, father, daughter (10 year old), son (8 year old), and son (5 year old).
[b]Researcher (DA).

other features of any given visit. From this flow chart (a preliminary series of analyses) I and other researchers select the SEs to be analyzed in greater detail and for particular purposes. In most family visits there are several SEs (Ash, 2002). Table 2 contains a portion of a flow chart for this particular family during the first part of their first visit.

I analyze SEs in a variety of ways. In this research I have modified the coding scheme presented in other work (Ash, 2002, 2003a, 2003b). I represent family utterances in a box with two portions. A brief example is given below:

| | |
|---|---|
| Eva: (in English) **Hey, look in there! Isn't that cool? . . . There's a skeleton on the bottom and there's more on top right there.**<br>(she is pointing excitedly, and has tried several times to gain the others' attention) | **Eva is looking closely at the coral and noticing the live material on top of the dead skeletons.** |

On the left side of the box I present the utterances offered by parent, child, or the exhibit, in this case in English. This sometimes includes descriptions of gestures or actions of the speaker. On the right side, in a parallel commentary, I amplify on its function in the dialogue. This scheme allows the analyst to look closely at a self-contained segment of conversation, still embedded within a larger activity. It allows each utterance to be analyzed separately, and also to be linked to its segmental context. Thus, segments can be analyzed in isolation or collectively. In this research, each SE is situated within the larger social and cultural context.

## Phases of Research

The research described here was carried out in three phases: a baseline first phase, in which six families participated, and a second, reflective phase in which two families participated in a stimulated recall interview based on video segments of SEs of the first visit. This second phase was immediately followed by a third phase, a second visit to the SZ exhibition by the participating families.

***Phase One.*** As part of the first phase, six Spanish-speaking families were solicited for in-depth visits to the SZ exhibition; all had several children—the Head Start child was 4–5 years old and in a Head Start program associated with the Monterey Bay Aquarium. Families were selected on the basis of desire to participate, appropriate configuration (parents with children from 3 to 9 years), and their availability and interest over time. All families chose their own path through the exhibits at the SZ, and were video- and/or audiotaped for all conversations. The duration of visits was variable and interruptions were kept to a minimum.

The family visits ranged from approximately 25 min to over 80 min long. It was important that families felt their visit was natural and self-selected. Two forms of data were gathered: audio- and video-recorded family conversations at and between exhibits, and pre- and postvisit family interviews. In the previsit interview families were asked about their museum-going patterns, their reasons for coming to museums, their goals or expectations for this visit, their interest in the life sciences, and about general areas of interest in the sciences. Typically preinterviews lasted 15–20 min. The postinterview was conducted immediately after the visit and consisted of feedback on the visit, in particular which exhibits had interested them the most. These lasted 10–30 min. All conversational and interview data were transcribed. Just as in any other social occasion, family members were free to talk about other topics that interested them.

***Phase Two.*** In phase two, 2 families were invited back for a second visit to the MBA approximately 6 months after the original visit. They started the second visit with an opportunity to view selected (SE) video snips of their first visit, using stimulated recall methodology (Gass & Mackey, 2000). This stimulated recall viewing was accompanied by a semistructured interview, in which the family was probed to reflect on their actions and thought at the time of the prior visit. The videotape was shown and stopped at opportune moments. Family members were free to comment; the interviewer asked questions at both prearranged and opportunistic moments. The researcher had determined in advance which segments were to be viewed, after analyzing videos and studying transcripts. Typically, the reviewed segments met the criteria for SE and were between 1 and 3 min in length.

***Phase Three.*** The third phase was a second visit to the SZ, in which families typically revisited the exhibits they had discussed in the stimulated recall interview. The interpreter was cued in advance as to which exhibits had been discussed in the first visit and/or in the reflective conversations. Again, all families chose their own path through the exhibits at the SZ and were video- and/or audiotaped for all conversations. The duration of these repeat visits was variable and interruptions were kept to a minimum.

In all phases an interpreter, who was trained by the aquarium and who consulted regularly with the researchers, was present. Some of the researchers were also present. The interpreter was invited to join the Spanish-speaking family visit, once the pilot study had indicated that Latino families had more to talk about when translation mediation was made available as they viewed exhibits. The exhibit signs were in English, and the Latino families had different levels of English skills, both across and within families.

In this paper I have selected two related SEs, one each from phases one and three (at the same Coral exhibit), as well as selected portions of the stimulated recall interview (phase two) that specifically probed one family on their ideas that relate to these SEs.

## Exhibition Background

The Splash Zone at the Monterey Bay Aquarium is an exhibition designed for young children and their families, in collaboration with the Head Start program in the Santa Cruz/Watsonville/Monterey/Salinas area. As part of this program, Head Start children visit the SZ exhibit three times per year. Head Start parents sometimes accompany children on these field trips. In this study Head Start children and their families were invited to visit the SZ exhibit as a family group rather than as part of an official class visit. This SZ exhibition offers viewing opportunities of live animals, such as sharks, moray eels, and penguins; a touch tank; a simulated tide pool; and several play areas for young children.

> The Splash Zone program targets young children and provides them and their instructors with a wealth of resources and opportunities to spark curiosity and interest in the natural world . . . The SZ program is designed to instill a conservation ethic with young children and their caregivers, to help develop a sense of respect and caring for the natural environment; to foster a child's emerging sense of wonder, inspire curiosity and interest, and to introduce and reinforce the age-appropriate science, mathematics and language arts concepts and skills. The program is designed for students and their parents and caregivers. The role of the adult is as a facilitator rather than a leader . . . [and to] involve young children in hand-on manipulations, sensory engagement and self-initiated explorations. Young children will not be expected to "watch and listen" for extended periods of time.
> (Excerpts taken from Monterey Bay Aquarium Program Description)

## The Family

The selected family had five members: mother, father, daughter Eva (age 10), son Antonio (age 8), and the Head Start son, Ricardo (age 5). The Head Start child had already been to the aquarium twice by the time of this visit, and the family itself had visited many times. By Hood's taxonomy this family belongs to the frequent-visitor category (Hood, 1989). The family had lived in the Monterey area for 9 years. Only Eva, the oldest daughter, and the parents were born in Mexico. The interview reveals that the family is quite interested in seeing and learning new things.

The parents visited Monterey Bay Aquarium more "for the sake of the children than for ourselves." According to the father it is "hard going to the aquarium, particularly working 6 days a week." The mother believes that "one cannot stay home, one has to take children to see things," such as camping and the ocean. In that regard, life here is very different than in Mexico. The mother says: "if you go to the flea market you end up paying more money than one might at the aquarium." The adults tried to convince adult friends to do the same but "they don't listen to them." The parents view the aquarium as if it were a different world, "a world one does not even imagine that exists." The mother says that the first visit is for curiosity, "each time one discovers something different, or sees the same things in a different light, for instance microscopic life." Eva says that whales are her favorite animals and she knows a lot about them. The mother was very interested in providing her family with a variety of learning experiences. This family was quite typical of many families in the frequent museum-goer category who want enjoyable learning activities for their children. The mother and father spoke little English, the older daughter was fully bilingual, the 8-year-old son spoke English less fluently, and the 5-year-old son was learning English.

In the first visit, as the family traveled through the aquarium, Eva and the mother went first to an area outside the SZ exhibition where they stopped to look at and remark upon a large gray whale skeleton on the ceiling, as well as to watch and talk about a whale video. The entire family also viewed the sea otters before they entered the Splash Zone (SZ) exhibition. The second visit was longer, with more conversation before, during and after the SZ visit. The second visit included side trips, to the otters again, and to a telescope overlooking the Bay, and it was followed by a second postvisit interview.

## RESULTS AND ANALYSIS

I focus my analysis on the dialogue of one family in some detail. The results of the analysis indicate the following:

1. Complex biological understandings, such as conservation, can be achieved in aquarium settings.
2. Family conversations gradually can grow more scientific over time, but they require the necessary antecedents.
3. The family uses many different resources to make sense, including prior experiences, each other, pictures, live and preserved objects, the facilitator, and both Spanish and English.
4. Knowledge is distributed across the family, the exhibit, and the interpreter.
5. In stimulated recall interviews, families collectively remember what has come before (Wertsch, 2002).

### Examples of Participation in Thematic Dialogue

Themes in past, related research have focused on issues of feeding, breeding (life cycles), protection from predators, and taxonomic relationships, among others. These basic categories of interest have emerged in visits in many different settings, by many different kinds of families (Ash, 2002, 2003a, 2003b; Ash, Ostrenko, Steier, & Borun, 2000). The themes these Spanish-speaking families chose were not different from families in past research.

All members of this family used thematic content regularly, in conversations with each other and with an interpreter. The first theme to emerge was the idea of life cycle/growth over time, especially using size at birth as a referent. This theme was advanced first by the mother (in reference to sharks) and repeated later by the father (in reference to penguins). A second theme was the notion of predators hiding so as to surprise their prey, advanced by the youngest son (the Head Start child) and then by the interpreter. A third theme was the notion of animal vs. plant (in relation to coral), advanced first by the father and later by the mother and both older children, as well as by the interpreter. The fourth theme, the notion of taxonomic relationship, was advanced by the father and taken up by the daughter.

In my analysis I focus on one of these themes, which is advanced and changed throughout both visits and in the intervening stimulated recall interview. The dialogue in the first visit began with questions by both the mother and father about whether coral is a plant or an animal. The dialogue continued as a discussion of how coral live and grow and what they eat. During the stimulated recall interview, three members of the family collectively recalled most of the dialogue of visit one. During the second visit the coral conversation continued; this time, however, it grew to include the concept of how coral can become endangered, both because its growth pattern is slow and because it is so easy to destroy. Thus, over time the family built a more complex story about coral, with the help of the interpreter. The dialogue culminated in the issue of endangerment. Coming to understand the role of reproductive rate (when lower than destruction rate) as the prime cause for extinction, is critical to understanding endangerment, whether the species concerned is coral, primates, otters, or elephants.

## Phase One—Significant Event from the First Visit

In the first SE, at the very first tank at the SZ, the conversation starts with the following, as the mother asks about the coral:

| | |
|---|---|
| Mom: Esta, ‘ira. ¿Es planta, o es animal?<br>**This one, look, is it a plant or an animal?** | **The family is looking in the tank and the mother asks about the “plants.”** |
| Antonio: Es planta. Esas allá.<br>**It’s a plant. Those over there.** | **She is often the dialogic leader.** |

In a few turns, the father asks the interpreter “what the plant in the tank eats.” The interpreter tells him that they (coral) are in fact animals and that they eat other animals. This is a surprise to the whole family (and many others), and it is a theme that runs throughout the entire dialogue, with each member at some point making mention of it. It starts with the father’s question.

| | |
|---|---|
| Dad: Y esas, ¿Qui comen? Y Las plants esas, ¿De qui se alimentan?<br>**What do those eat? . . . And these plants, what do they feed on?**<br>Las plants, la planta esa.<br>**The plants, this plant.** | **The father asks the question about the coral as the children and the mother listen.** |
| Exp: En realidad, en realidad, ¡Son animales! Se llaman coral.<br>**Actually, actually, they’re animals! They’re called coral.** | **The interpreter tells the father that coral are in fact animals.** |
| Dad: Oh . . . | |

Meanwhile, the rest of the family is very actively involved in looking and doing. The children are looking into the aquarium, as all five members are gathered round the interpreter. The three children are pointing, looking, and manipulating the lift-up signs. During this interchange the younger son, who has been to the aquarium before as part of the Head Start program, bids for attention by asking the interpreter about the name of a particular fish.

| | |
|---|---|
| Ricardo: ¿Cómo se llaman estos?<br>**What are these called?** | **Boy bids for attention. He yells for the interpreter, but the interpreter is still engaged with the father's questions.** |
| Int.: . . . es que los vivos son muy chiquititos animalitos que viven en el superficie, arriba de todos los esqueletos de los antepasados.<br>. . . **it's that the live ones are very teeny tiny little animals that live on the surface, on top of the ancestors' skeletons.** | **Both adults are listening carefully.** |
| Ricardo: ¿Cómo se llama? ¿Algo de pescados?<br>**What's it called? Something about fish?** | **The boy asks again. He is pointing to a fish.** |
| Int: Ah, hah, ¿Este? Mira, aquí está y dice que se llama **Long-finned Banner Fish.** Pescado de banderas. Parece una banderita, ¿verdad?<br>**Ah, hah. This one? Look, here it is and it says that it's called "Long-finned Banner Fish. Banner Fish. It looks like a little flag, right?** | **The interpreter says it is a bannerfish and introduces the cognate bandera—banner. The picture of the banner fish is above the tank.** |

Right after this the mother also asks about coral, wondering (as did the father) if they are animals or plants, and she requests information of the interpreter about the stinging ability of the animals. She acts as if she does not believe coral are animals and needs to have it verified. The interpreter says (again) that coral are animals and then gives more information, specifically: coral lives in layers, growing new generations on the bodies of the older ones, the ancestors of the living animals. The rest of the family is listening to this interchange. The mother starts by asking about the coral.

| | |
|---|---|
| Mom: Es animal?<br>**It's an animal?** | **The mother joins the questions and needs to verify the fact that this is an animal.** |
| Exp: Se llaman coral. Se llaman coral. Y el coral es un animal que crece arriba de los esqueletos de los antepasados. Y son muy chiquititos . . .<br>**It's called coral. It's called coral. And coral is an animal that grows on top of the skeletons of its ancestors. And they're very teeny tiny** . . . | **The interpreter explains how coral live. She tells about their growth patterns and is providing more background for a complex story of coral.** |
| Mom: Entonces, ¿Estas también son animales estas plantas, todas los que están aquí, son animales?<br>**So, are all of these plants animals, all the ones that are here, are they animals?** | **The mother asks again.** |
| Int.: Sí, son animales.<br>**Yes, they're animals.** | **The interpreter repeats. The mother now asks if coral can sting humans.** |

| | |
|---|---|
| Mom: Pero, ¿No le hacen daño al hombre? ¿Cómo a los buzos?<br>**But, don't they hurt man? Like the scuba divers?** | **The interpreter repeats that it is coral but does not answer the question.** |
| Int.: Se llama coral y su nombre es coral.<br>**It's called coral and its name is coral.** | |

The mother asks the interpreter many times if this particular coral has harmful properties to humans (which some species have). These parents are eager to learn, to question, and to try to understand. In the video the children pursue their own agendas, while the parents are engaged with the interpreter, although the children do listen to their parents as they ask questions. The children listen respectfully; only the youngest child interrupts. It seems that everyone in the family, with the exception of the youngest child, has heard and remembered the father's question. The younger son interjects again, this time talking about the comment that coral is animal.

| | |
|---|---|
| Ricardo: ¡Dice que es un animal ella!<br>**She says it's an animal!** | **Boy bids for attention again by talking about the same topic as his parents.** |
| Mom: Pero, ¿No le hacen daño al hombre, como cuando se meta al mar?<br>**No, but, don't they hurt men, like when they go into the sea?** | **The mother goes back to her question about coral stinging. She seems not to believe the answer.** |
| Int. No, no.<br>Mom: ¿No, no le afecta, no le pica, no nada?<br>**They don't affect you, don't sting, nothing?** | **She is discussing coral protection from predators.** |
| Int: No. | |
| Mom: Oh . . . . | |

As an aside, as the interpreter and the older daughter talk, the daughter answers that coral are animals when asked by the interpreter. The middle child (Antonio) asks (in English) if the coral outside (in front and below the tank) are real—they are, but they are not alive. In asking this question he may either be concerned with plant vs. animal characteristics, or with living vs. dead. The children have paid attention to the original dialogue with the interpreter, even though the transcript may make it seem as though only the father and mother are interested in coral as plant or animal.

| | |
|---|---|
| Antonio: **Are these real?**<br>(pointing to the real but dead coral outside the tanks, placed there for touching)<br><br>Int.: **It's coral. What is coral?** | **The 8 year old asks this question in English, while the rest of the conversation had been taking place in Spanish.** |
| Eva: **Um . . . tiny animals?**<br><br>Int.: **That's right! You're absolutely correct.** | **The 10 year old answers the interpreter's questions about coral.** |

This SE, which lasts approximately 3 min, illustrates how in a complex setting such as the aquarium, many actions and conversations occur simultaneously. The young boy tries to get attention from the interpreter by asking about the banner fish; the older son tries out his English in public; the mother and father, hungry for information, bombard the interpreter with questions; and the interpreter tries to answer their questions while also quizzing the daughter on her understanding.

Clearly part of the interpreter's agenda was to distinguish the biological characteristics of plant vs. animal. The parents' agendas were different. The father originally wanted to know about feeding when he asked what those plants ate. The mother wanted to know about the stinging quality of the coral, which would be a form of protection for the animal. The interpreter wanted to explain about the growth properties of coral, specifically how they grow one layer, or generation, on top of the other. The older son wanted to know how to distinguish real vs. fake or, more likely, alive vs. dead, and the youngest son wanted to enter the conversation by asking the names of selected things. There were at least six different agendas, with important crossovers and different distribution of knowledge.

The parents and children seem on equal footing much of the time, regarding both obtaining information and understanding the aquarium's content material. The children are respectful of the mother's questions and of the interpreter, yet they use their time maximally while listening. They seem to understand the dialogue, as evidenced when the daughter answers the interpreter's question. This question and answer aside has a school-like quality, in that it is a check for understanding. These parents, unlike the interpreter, do not ask such known-answer questions. The mother checks in often with the expert, by repeating the questions whose answers have surprised her, obviously hoping to obtain more information. These patterns repeat over several exhibits and are typical of this family's interactions.

## Phase Two—Stimulated Recall of Visit One

In this phase of research, selected video snips of the SE discussed above were shown to the entire family, while the interviewer asked questions and the researcher video- and audiotaped the stimulated recall session. The researcher had determined in advance which sections of tape were to be shown and which questions were to be offered in what order. The conversation therefore proceeded in a semistructured fashion. This stimulated recall session occurred 6 months after the original visit.

In the segment below the family talks about the coral tank after being cued by the interviewer (who was also the interpreter for both exhibit visits).

| | |
|---|---|
| Int: Señor ¿Usted se acuerda que estábamos discutiendo si era planta o era animal?<br>**Sir, do you remember that we were discussing if it was a plant or if it was an animal?** | **The interpreter asks for information about the coral.** |
| Father: Mm, hmmm. ¿Si, sobre las, que están sobre la roca?<br>**Mm, hmm. Yes, that were on, that were on the rock?**<br><br>Int: Exacto. Que parecen, parecen plantitas en piedras, pero, ¿en realidad que era? | **After a slow start the father answers that he understands what she is referring to and answers about the animals that live on the rock.** |

| | |
|---|---|
| **Do you remember?**<br>**Exactly. They look like, they look like little plants on rocks, but, in reality what are they? [Switches to English] Do you remember?**<br><br>**Eva: (answers in English)**<br>**They were little animals. And, when they die they fall down and they grow over it (making a motion with her hands of one thing falling and another on top.** | **The daughter amplifies by telling how generations live and grow on each other.** |

The daughter Eva talks easily about how coral live one layer on the other, the point that the interpreter had made most strongly in the original visit. Next the interpreter probes to determine if anyone in the family has remembered the characteristics of plant vs. animal. This time the middle son Antonio answers, in English, saying that you can tell that coral are alive by the fact that they move. The family and the interpreter are visibly impressed with the answer.

| | |
|---|---|
| Int: To see it again, and see which is the part that is still alive. A ver, ¿Cómo se van a dar cuenta cuál es la parte que está viva? How are we going to tell which is the part . . . | **The interpreter probes to see if anyone can suggest how to tell living vs. dead coral apart.** |
| **To see it again, and see which is the part that is still alive. [Switches to Spanish] Let's see, how are you going to know which is the part that is alive? [Switches to English] How are we going to tell which is the part** . . .<br><br>Antonio : when you see it move<br><br>Mother: [Giggles.]<br><br>Int: **Very good.** Eso. Allí donde ves movimiento. **Where you see movement, huh?**<br>**Very good. [Switches to Spanish] That's it. Where you see movement there. [Switches to English] Where you see movement, huh?** | **The 8 year old—the quietest of the children, who was not entirely fluent in English—answers in English that one can tell by the fact that they move. Everyone is pleased with this answer, especially the parents.** |

In the stimulated recall reflective interview, which lasted about 20 min, different family members remembered different things, and each offered information, one after the other. The information is relatively esoteric and is over 6 months old. Three different members had different parts of the knowledge—the father remembered that the animals lived on the rock, the daughter remembered that they grew layer upon layer, and the son remembered that the living part moves. This distributed knowledge occurred not only at the coral tank, but at other tanks and areas of understanding throughout the SZ exhibit.

### Phase Three—Significant Event at the Coral Tank in Visit Two

In the second visit, immediately following the stimulated recall interview, the family went back to the SZ exhibition and immediately to the same coral tank. Conversations similar to the conversations of the first visit arose; this time, though, they could build on prior dialogue and grow toward the notion of conservation of coral. The father started the conversation again by asking how the aquarium keeps the coral tanks clear. This is similar to the beginning of the first visit. The whole family was gathered around the tank again. The children pointed to different kinds of coral. The interpreter asked in English if they could find a brain coral or a disc coral. The three children eagerly pointed to them.

Much of this action was gestural and took place in the midst of other conversations. Eva paid attention to all the conversations, then took the next step of looking more closely at the coral. Her brothers appeared equally interested; their noses were pressed against the glass. The 8 year old said several times, "I saw it move! I saw it move!" while pointing to the coral.

| | |
|---|---|
| Mom: A ver, Bella, ¿Cuáles son las que crees que están vivas?<br>**Let's see, Belle, which one do you think is alive?** | **The mother is picking up on the original themes of this child if something is alive or not.** |
| Antonio ¿Look, it moves a lot. | **The 8-year-old boy says that he sees coral move.** |
| Mom: ¿Cuál crees que está viva?<br>**Which one do you think is alive?** | |
| Eva: **I think those are, right there.** | |
| Mom: ¿Las que están atrás también son plantas, o son ....?<br>**The ones in the back are also plants, or are they . . . .?** | |

The mother repeats her original themes about stinging coral, a question that was never answered to her satisfaction.

| | |
|---|---|
| Mom: Si uno agarraba una de estas se moría o se le pegaba un . . . como si agarraba uno se le, se agarraba . . .<br>**If one grabbed one of those would you die or get some . . . like if you grabbed one, you would, you'd get . . .** | **She still wants to know about stinging cells and coral. She probably has had direct experience with them.** |

The daughter has noticed that new coral is growing over the skeletons of older coral and is very excited to show it to others. The interpreter is occupied with the parents' questions.

| | |
|---|---|
| Eva: (in English) **Hey, look in there! Isn't that cool? . . . There's a skeleton on the bottom and there's more on top right there.** | **She is looking closely at the coral and noticing the live material on top of the dead skeleton.** |

The next portion of conversation starts by discussing algae, a plant that lives in this water. The mother then enters the conversation by asking—how long does one of these plants live? It is unclear if she means the algae, which has just been discussed, or the coral. In either case the interpreter answers the question *as if* she were speaking about coral.

| | |
|---|---|
| Mom: ¿Cuánto dura una planta de estas?<br>**How long does one of these plants live?**<br><br>Int: ¿Sabe qué? Um, la parte que está, la colonia puede existir millones de años.<br>**You know! Um, the past that is, the colony can exist for millions of years.** | **This conversation starts at the tank then moves away into the main area of the SZ as the parents are talking with the interpreter.** |
| Mom: ¿Oh, sí?<br>**Oh, yeah?** | **Eva is standing and listening intently to this conversation.** |
| Int: Ah, hah, porque, cada, cada parte viva se trepa arriba de los esqueletos de los otros y las, los mares tropicales, se ve, se ve así. Parecen montañotas . . .<br>**Uh huh, because, each, each live part climbs on top of the skeletons of the other ones, and the, the tropical seas look like, like this. They are like big 'ole mountains.** | **The interpreter amplifies the conversation, discussing ages, size, etc. of the coral.** |
| Mom: ¡Y es de la misma!<br>**And it's from the same one!**<br><br>Dad: Entonces, ¿El de abajo se está muriendo yarriba . . .?<br>**So, the one underneath is dying and the one on top** . . .**?** | **The mother says "Oh Si", which she uses often in a tone of voice that implies not quite believing the answer from the interpreter.** |
| Mom: Dice que va así, 'ira, dice que va así.<br>**She says it goes like that, look, she says it goes like that.**<br><br>Int: Y crecen como montañas. Tanto tiempo se lleva para hacerse, ¿verdad? Es que, ahorita la gente está quitando mucho.<br>**And they grow like mountains. It takes so long to make, right? It's that, now, people are taking a lot out.** | **The parents seem to understand by the end of the talk that coral are fragile and delicate creatures that need protection.**<br><br>**This is the intention of the interpreter.** |
| Mom: ¿Oh, sí?<br>**Oh, yeah?** | |
| Int: Quieren hacer, um, collares y todo eso. Y para hacer eso están destruyendo . . .<br>**They want to make, um, necklaces and all of that. And to do that they are destroying** . . . | |
| Mom and Dad: Ooohh . . . (**Loudly and in unison**) | |

The family members (especially the parents) begin to understand the fragility of the coral. Eva is listening as the interpreter brings home the argument in her final comment. The younger sons are restless, while the three adults and Eva discuss coral in the middle of the exhibit, away from the tank. They are clearly engrossed in the dialogue. The interpreter brings home the argument about disappearing coral and the mother argues that they grow slower than they can reproduce. This pairing of destruction and reproduction is a crucial connection with coral conservation (the main message of this exhibit); and it seems to have built directly on the prior conversations about coral's animal characteristics. The younger son pulls the mother away and the family leaves right after this last interchange. The second visit to the coral tank lasted approximately 4 and one half minutes.

| | |
|---|---|
| Int . . . muchos coralcitos. Por eso hay problema que . . . educar a la gente<br>. . . **So many little coral. That's why there's the problem of** . . . **educating people** . . . | **The interpreter delivers the essence of an argument for any animal or plant that is facing endangerment or extinction.** |
| Mom: Para que deje la naturaleza cómo es.<br>**So they leave nature alone.** | |
| Int: Ah, hah. Que dejen naturaleza. Se llevan tantos años para crecer coral . . .<br>**Uh huh. So they leave nature alone. It takes so many years for the coral to grow** . . . | **This is the fundamental biological imperative. The mother repeats this at the end.** |
| Mom: ¡Y tan rápidos que se los traen! (Giggles.) ¿Verdad?<br>**And so fast for them to bring them in! (Giggles.) Right?** | |

## DISCUSSION

In this section I first revisit the initial framework for this paper and reevaluate its claims in light of the data presented. I then discuss the larger implications of this work. I began this paper by discussing boundaries, focusing primarily on the perceived boundary between an everyday understanding of science and the types of reasoning that meet scientific literacy criteria. The question posed in the introduction—whether these fleeting and opportunistic dialogues are starting points for more scientific ways of thinking—can now be directed toward the data from this research.

### Scientific Literacy

Let us first consider Hurd's criterion of distinguishing real data from myth and folklore, and knowledge from opinion. This family used many different resources, including prior experiences, pictures, live and preserved objects, the facilitator, and both Spanish and English, to advance scientific dialogue aimed at achieving this very goal. They used these resources to cross the boundary from folklore and their previously less-informed opinions to begin assimilating data presented by the experts and the exhibits. They actively probed for appropriate scientific data, by asking, for example, about whether coral is dead or alive.

Once that issue was clarified, they pressed for more scientific information, such as whether it is plant or animal, what is the temperature of its environment, how it moves, etc. In this way, as the conversation progressed toward a more scientific understanding the family moved away from opinion and myth.

Hurd's second scientific literacy criterion concerns recognizing the ongoing and cumulative nature of science, and the influence of science on society. With the support of the exhibits and the expert mediator, the family used compelling biological information to gradually advance their scientific understanding. Their own interests and everyday knowledge (from the community, the workplace, or the home) meshed sufficiently with the material presented by the exhibit and the interpreter, in order for them to understand, by the end of their second visit that coral is fragile and needs to be protected. They were thus able to gradually and cumulatively arrive at some reasons for a need for the conservation of coral, a growing current social concern. Such scientific understanding is achieved over time and slowly, much as coral grows.

Hurd's third criterion, knowing about data and data processing and multiple solutions and answers to scientific questions, is more complex than these dialogues could possibly reflect. We can, however, notice that the family was well able to generalize across data sets, understanding, for example, that slow-growing coral represents a different set of reproductive concerns than the shark,[3] which can either give birth to live young or alternatively, produce egg sacks called a mermaid's purse. The family thus spontaneously began to generalize across multiple cases as they considered reproduction.

For much the same rationale, these dialogues also met Roth's criteria, as the science in these dialogues was interconnected, useful (describing, predicting, etc), constantly changing, as well as a product a community's collaborative construction of new knowledge.

## Dialogic Inquiry About Generative Content

I next examine the ways in which this family met three criteria for dialogic inquiry: distributed expertise, joint productive activity, and "progressive" meaning-making.

Regarding distributed expertise, family members knew different things and shared their understandings in characteristic ways. Participants in these discontinuous SEs acted as Linde predicted they would, sharing different interests and abilities, that is, distributed expertise, while building thematic content coherence over time. Each family member was involved in the thematic talk centered on characteristics of living things and the nature of plants vs. animals, but they each understood this at different levels. For example, Eva remembered that the generations live on top of each other, while Antonio remembered facts about its movement. The conversational emphasis often focused on the parents' questions, but the children were full participants. The mother asked questions repetitively and gathered information for others to use.

Regarding joint productive activity, the family was actively engaged as a unit, as members used multiple resources in their dialogue, relating to pictures, and to the sample objects outside and inside the tanks. Regardless of their different understandings of background material both parents and children modeled learning behaviors for each other. All three children repeatedly gestured, particularly pointing and asking. All five members repeatedly asked the bilingual mediator for information, often competing with each other with their questions. Because they all wanted information in their own language, the dialogic pace was fast, bilingual, and overlapping. The two older children used both languages and they seemed

[3]In later dialogue in the first and second visit and in the interviews, family members discussed the shark egg case and reproduction.

to know when to switch from one language to the other to get the interpreter's attention. All appreciated new biological information, and all appeared to listen and remember.

Third, even though they were discontinuous and incomplete, the family's coral conversations progressed slowly, gaining additional pieces over time and, eventually, became much more than the beginning talk or the sum of the parts of the total dialogue. Many distinct but related biological survival strategies formed the foundation for an emergent cohesive narrative about coral as a delicate and long-lived animal that lives and creates a mountainous warm environment. These emerging understandings are presented in Table 1, as a proposed trajectory of growth over time. Ultimately the family's assimilation of all these ideas helped create a story line that led to questions of survival. Conservation was, in fact, the Aquarium's agenda for this exhibit, and the family achieved this level of insight by the end of their second visit.

The science content in this family's dialogues also fulfills Bruner's requirements for "lithe and lively and immensely generative ideas" in several ways. These dialogues[4] were held together by deep biological themes, which (in the case of coral) included characteristics of living vs. dead, life cycles, and eventually coral conservation. Family members talked about how animals feed, protect themselves, grow, and change over time, and they relied on their own fund of everyday language, the exhibits, the docent, the signs, and each other as a resource for increasing understanding of scientific ideas. The biological content enabled more sophisticated understandings and encouraged different levels of understanding.

Also, it appears that certain understandings needed to precede others. For example, understanding that coral is a living thing, and that it is an animal, not a plant, were prerequisites, for this family, for the more complex ideas; for example, to understand that coral has an environment, that it eats other things, and that it has multiple generations living together on top of each other. These features were revisited several times in order for the adults and the children to fully assimilate them. In the end, they each possessed a picture of coral that is very different from "those rocks."

In their collective and distributed talking, doing, and remembering, the family members and interpreter, together, built a knowledge framework and gradually remembered many component ideas. Seemingly unrelated data began to make sense and was interwoven into a cohesive whole. If any piece of these conversations were considered in isolation, one might believe that each episode represented only isolated facts, too incomplete to be truly scientific. This would be a serious misrepresentation, however, since it is in the overall emergence of the ongoing dialogue that their scientific sense-making can be discovered. Seen over time, this family, with significant help from the interpreter, gradually pieced together a more sophisticated understanding of coral. Their biological insight started at a basic level, with a crucial differentiation of what is alive, then what is plant or animal.

## Linking Everyday and Scientific

I started this paper by discussing differences between everyday and scientific thinking. I have suggested that links between everyday and scientific knowledge were created in these dialogues. However, they were not made in the ways heretofore described. For example, McManus's description of the typical roles for parents and children in commenting on broadcast information did not occur in the same way for this particular family. Signs fulfilled the need for information and acted as a mediator for McManus's English-speaking families. Non-English-speaking members cannot use these strategies. When this kind of participation does not happen, for linguistic reasons, the dynamic changes. One interpretation might be

[4]This research is part of a larger study including 20 Head Start families at marine science centers.

that, because of a differential understanding of everyday and scientific English, Spanish-speaking families need to rely on multiple mediation styles to gather the same information. For this family questioning was at the center of their fact-finding.

Because these parents were not afraid to ask questions of an expert they trusted, they modeled how to get information and how to make it available to their children. They used these questions to link their everyday understanding to scientific ideas. The children also served as intermediaries or translators. Because of the lack of written information in their native language, they solicited information in Spanish, rather than reading English-language signs. The children also modeled ways of getting information: they too asked questions and used nonverbal gestures (based on their formal education experiences that had addressed scientific content). Eva, for example, knew about aquatic mammals, such as whales, and explained Blue Whale size and feeding to her family. She knew what mermaid's purses (shark eggs) were and explained that as well in the interview. Thus, ability to obtain or advance information was distributed throughout the family in multiple ways.

I have considered Hurd's and Roth's view of scientific literacy, Brown and Bruner's notion of generative ideas, and Wells and Ash's interpretation of dialogic inquiry in the context of science. By any of these criteria, this family crossed the border into scientific literacy. Further I analyzed how dialogic events give glimpses into how families obtain, use, and negotiate meaning in two languages. While I have used life science as the content material, the analysis of these discontinuous dialogic events can also inform research agendas and methodologies in literacy as well as demonstrate how informal settings are rich resources for the learning sciences. My analysis has followed the example set by Warren et al. (2000), who argued against a "narrow view of what constitutes scientific ways of knowing" (p. 48).

Finally, using dialogic inquiry, I showed where and how the family was pulling together information to make cognitive leaps into further complexity. I argued that these leaps relied on the funds of experience that members brought with them, complex and generative content, mediation of several kinds, as well as strategies for meaning-making. Taken together, these suggest that the border crossings are occurring and that we can rely on the synthesis of exactly these kinds of methodologies to reveal where and how to build bridges across boundaries in informal and formal learning settings. This broadening of our view of collaborative interactions in this type of social learning activity is the focus of ongoing research.

## CONCLUSION

This research expands our view of collaborative scientific sense-making by studying social groups with diverse cultural backgrounds. The larger aim is to understand how collaborative social family groups interact, talk, and make meaning in a variety of learning settings, and how these interactions can serve as pathways to increased formal schooling opportunities and for advancement in science.

In this research I have outlined the role of thematic material in meaning-making during several visits of one Spanish-speaking family to the Splash Zone exhibit at the Monterey Bay Aquarium. Life science themes were important to this family as they discussed the workings of nature, with different members always finding things of interest to them at a variety of levels. In doing so they crossed several boundaries between everyday and scientific talk, between Spanish and English languages, and between home and aquarium. All of these factors came into play in the stimulated recall interviews, as together they collectively remembered what had come before. They used a variety of mediation tools; in particular, the adults asked many questions, in order to obtain information from knowledgeable sources. While based on only one family, these results have significance for the design of museum environments and larger implications for the kind of research currently conducted at informal learning sites.

These are preliminary analyses, yet they point to some interesting areas for future research. If Latino families use a greater variety of mediation techniques, in English-speaking or all settings, what are these techniques, and under what circumstances do they predominate? What kinds of analytic methodologies do we need to use to capture these events? And what new analytic tools do we need to design in order to break away from past patterns that reify dominant cultures?

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