Multiple Modes of Meaning-Making in a Science Center

JRENE RAHM
Départ de Psychopédagogie et d'Andragogie, Faculté des Sciences de I'Education, Université de Montréal, Montreal, Quebec, Canada H3C 3J7

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ABSTRACT: In this paper, I address some of the unique challenges of studies of learning in museums through a microanalytic case study of meaning-making among a group of youth and a curator. Through an examination of youths' forms of participation in one exhibit, I illustrate local meaning making achieved through multiple modalities—by doing, talking, and the manipulation of the exhibit. In turn, I show how multiple on-going dialogues come to interact and constitute talk and action at the science exhibit underlining the idiosyncratic nature of meaning-making. While the dialogue examined in this paper may be considered as a rather unremarkable event in terms of learning, it underlines that the study of meaning-making entails a focus on more than mere conversations in situ in that verbal and nonverbal interactions need to be considered simultaneously. Furthermore, the analysis suggests that museums may be best seen as one among many resources for science literacy development whose impact can only be understood through an assessment of learning trajectories over time and across space. Suggestions are made for museum design and future studies of learning in consideration of the issues raised. *Sci Ed* **88:**223–247, 2004; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/sce.10117

INTRODUCTION

In this paper, I take a close look at meaning-making in a science center through a detailed ethnographic microanalysis of an interaction at one exhibit. I approach such an analysis with an interest in the process of learning, which I consider as socially situated in nature and constituted by its context, participants, and verbal and nonverbal interactions (i.e., talk, action, gestures, manipulations, etc.). I also assume that thinking is not a factor that regulates talk and action or simply results from it, but instead, is an act of talk and action and must be studied as such (Sfard & Kieran, 2001). The goal of the paper is to address some of the unique

Correspondence to: Jrene Rahm; e-mail: jrene.rahm@umontreal.ca

challenges of learning in informal settings that this case study makes evident. In essence, issues raised by the detailed study of talk and action among one group of visitors will offer a means to begin the development of "an enhanced theory of real-world, lifelong learning" as emphasized in the policy statement put forth by Dierking et al. (2003, p. 109) for informal science education. While the case is useful for underlining and raising important issues about learning, the case study's implications for museum design will also be addressed.

Framing the Study: Science Centers, Discourse, and Learning

Typically, science centers offer visitors direct, self-paced, nonverbal experiences, objects, and visual displays to make meaning of science concepts (Ramey-Gassert, 1997; Rennie & McClafferty, 1996). Given such reliance on learning by doing, an examination of how contextual features facilitate and constitute meaning-making is natural. Interactive exhibits also draw visitors into learning with little conscious awareness on their part, making it difficult for researchers to extract the learning that may take place without reference to action and talk (Ramey-Gassert, Walberg, & Walberg, 1994). Yet, most research has examined what individuals learn as a *consequence* of their museum visit (Falk, 2001; Falk & Dierking, 1992; St. John & Perry, 1993) and surprisingly little research has examined learning as a dialogue between museum visitors and their manipulations and interactions with exhibits until recently. That is, the adoption of the sociocultural perspective to the study of learning in museums led to a variety of studies on family conversations in museums (Allen, 1997, 2002; Leinhardt, Crowley, & Knutson, 2002; Paris, 2002; Schauble, Leinhardt, & Martin, 1998). Central to these studies is a focus on how visitors use exhibits, talk about the exhibits, and how such action and talk are interrelated and mediated by the exhibit. For instance, Crowley and Callanan (1998) examined the mediational role of parents as well as the kinds of explanations they offer to their children. They found that scientific thinking by peers led to fewer learning opportunities than interactions with parents. They also established an interesting gender effect in that boys tend to receive more complex explanations of scientific phenomena from their parents than do girls (see also Crowley et al., 2001). Allen's work (Allen, 2002) on instances of learning talk in museums shows that families engage in exhibits with their children with a clear agenda to learn. In fact, the data underline high frequencies of conceptual and strategic talk while the making of connections between exhibits and predictions were rare. Family conversations also center on talk about how to manipulate exhibits while making visible aspects of the actual exhibits and linking such experiences with prior family ways of knowing (Falk & Dierking, 2000). Furthermore, research by Ash (2002, 2003) offers insights into the complex negotiation of thematic content in parent–child conversations in a variety of informal settings including aquariums, museums of science, and natural history museums.

Studies of peer dialogue in science museums are still rather sparse, despite the recognition that children often learn through collaborations with their peers (O'Donnell, 1999). Exceptions are studies of Tunnicliffe (1997, 2000) of the categories of biological content in children's talk in museums, zoos, and botanical gardens and the work of Guberman and Van Dusen (2001) on children's investigations in a science discovery center that make evident children's spontaneous engagement in scientific thinking even without adult guidance. Finally, some studies have addressed design features of exhibits that do give rise to and/or support meaning-making such as texts (Hapgood & Palinscar, 2002), computer prompts (Gelman, Massey, & McManus, 1991), and video traces of visits (Stevens & Hall, 1997).

While the review of studies examining meaning-making in science museums from a sociocultural perspective is by no means exhaustive, it is an approach more widely used in studies of parent–child interactions at home (Callanan, Shrager, & Moore, 1996; Ochs & Taylor,

1992) and in classrooms (e.g., Hicks, 1996a, 1996b; Scott, 1998). Accordingly, I briefly outline some of its basic assumptions from the latter context to make evident the approach taken in this paper. Most important is the underlying assumption that through interaction of multiple voices (students and teachers) reflecting diverse interpretations, understandings, and personal experiences, knowledge is taken as essentially "talked into being" (Green & Dixon, 1993). Furthermore, building on the work of Bakhtin and subsequent theorists of language and meaning (e.g., Barnes & Todd, 1995; Bruner, 1990; Cazden, 1988; Gallas, 1995; Gee, 1990; Lemke, 1990; Lindfors, 1999), language is seen as an inherently social construct whose meaning is constituted relationally between the speaker and listener. Such dialogically organized instruction has led to a variety of classroom approaches captured in terms such as the "guided construction of knowledge" (Mercer, 1995), "dialogic inquiry" (Wells, 1999), "dialogic instruction" (Nystrand, 1997), and "exploratory talk" (Fisher, 1993, 1996). Central is the notion that knowledge is *collaboratively* constructed among students and teachers as they engage in activities they are committed to and deem valuable, and that make possible the exploration of new understandings of the world.

In this paper, I examine the extent to which science centers may support such dialogic inquiry or explorative talk, and address its implications for understanding the challenges of learning in museums and museum design. For this purpose, my analysis rests on language use or language-as-doing (Edwards, 1993; Lindfors, 1999). That is, I want to explore the *content* of talk by focusing on what youth say to each other, what is being talked about, which words are being used, how words and utterances are organized interactively, what understandings are conveyed, and how these understandings are made and built on through discourse over time (Edwards & Mercer, 1987). Such a perspective also implies an interest in the nonlinguistic activities and settings giving rise to and providing the context for the discourse taking place. Meaning-making is too often equated with linguistic meaning (Lemke, 2000; Wells, 2000). Yet, nonverbal behaviors such as gaze, positioning, or gesturing also constitute conversational meaning-making (Crowder & Newman, 1993). Furthermore, silent forms of participation such as doing, hearing, reading, and seeing also need to be considered. This is particularly important in science centers, where much of the science comes into being through the manipulation of the exhibit and interpretation thereof, rather than by simply talking about it.

Through an analysis of visitors' actions and use of multiple tools or modes of meaning-making (Wells, 2000) such as artifacts, talk, gestures, and positioning, I intend to show what may count as learning here, and how learning is being accomplished. In essence, it leads to an interest in the study of situated meanings that are "image(s) or pattern(s) that we (participants in an interaction) assemble "on the spot" as we communicate in a given context, based on our construal of that context and our past experiences" (Gee & Green, 1998, p. 122). For these reasons, situated meanings are also taken to reside in the negotiations and social interactions between people and tools rather than within individual minds (Wortham, 2001). An understanding of situated meanings can provide important insights into how opportunities for learning emerge from interactions with particular exhibits and across time, groups, and exhibit displays.

The approach to the study of learning in practice outlined here is not new. Conversation and discourse analysts have taken "talk-in-interaction" (Schegloff, 1992) as the primary site for activity, whereby we make and transform meanings of cultural, social, and cognitive nature. In addition, Vygotskian scholars remind us that learning is always mediated by tools (language and psychological tools), artifacts, and persons and for this reason, analysis needs to begin with an examination of that mediational process (Lee & Smagorinsky, 2000; Wells, 1999; Wertsch, 1991). Finally, cultural anthropologists and sociologists, having studied everyday learning, have been instrumental in putting forth a practice theory of

learning where becoming a member of a community is a primary objective to the study of learning, thus avoiding a separation between learning and practice (Lave & Wenger, 1991).

Building on these theoretical propositions, the science exhibit is best perceived as a "situated activity system" (Goodwin & Goodwin, 1996) consisting of a web of interactions involving people, cultural artifacts, and tools. Furthermore, meaning-making can be "local" in that it is made evident and constituted by a single or short interactional episode or theme (Gee, 1999), or it may be "global" in that multiple simultaneously ongoing conversations and interactions come to constitute learning over time as they intersect with one another in complex ways. Hence, "crossings" or overlaps of different kinds of ongoing talk and actions at different points in time may be particularly revealing about the kinds of learning opportunities an interaction may bring about.

I begin with an illustration of local meaning-making in situ that is achieved through multiple modalities—by doing, by talking, and by manipulation of the exhibit. Then, I portray global meaning-making in that I show how multiple ongoing dialogues come to interact and constitute talk and action at the exhibit, underlining the truly idiosyncratic nature of learning.

THE DATA

The Setting and the Methodology

The discourse sample is taken from a visit to a science center within a research facility in the mid-West and was collected in the context of a larger study that assessed students' meaning-making of science and the scientists' worlds (Rahm & Downey, 2002). A group of seven 14-year-old youth (six African American and one European American) took part in this project. They participated in an inner-city summer youth gardening program for their second consecutive summer and, for this reason, were selected to participate in the science project that took place during one of the three mornings they spent in the garden. While these youth knew each other from their work in the garden the previous year, the group was also (coincidentally) made up of three sets of siblings (one set of twins, two sets of siblings 1 year apart in age). The goal of the larger projet was to broaden youths' understanding of what it means to do science and be a scientist. To achieve such a goal, the youth conducted oral histories of scientists, which were then transcribed, reflected upon as a group, and presented as a whole to the program.

The dialogue examined in this paper was recorded during the second week of the 8-week summer program as we visited the exhibit hall of the National Center for Atmospheric Research (NCAR). The goal of the visit was to interview a scientist while also exploring the kind of science that was done at this site. Our visit began with a gathering in one of the classrooms at the research center where Tom, our museum guide, offered a general description of the research center and the kinds of sciences that get done there. The brief introduction was followed by the interview. Even though Tom now works as a museum guide, he has a history as an engineer and computer scientist in the navy, which made him an interesting candidate for the interview. In turn, we toured the science center with the intention of gaining further insights into the sciences done at this site, such as weather modeling, atmospheric science, and supercomputing. At the time of the study, the science exhibit at NCAR was about 5 years old. Many exhibits were replicates of others originally designed for the Exploratorium in California (see Allen, 2002; Oppenheimer & Exploratorium, 1986; Stevens & Hall, 1997). For these reasons, NCAR also shares a similar philosophy, in that visitors' active interactions and experiences with the exhibits are

emphasized. Museum staff is only supposed to "interfere" if asked to do so, or if visitors appear to be in need of help to make the exhibits work for them (conversation with museum guide).

Youth spent approximately 20 min exploring the museum on their own while Tom stood back and explained the history of the museum to the director of the gardening program who had joined us that day. During that time, youth explored 6 of the 11 displays in the museum, some of them numerous times (e.g., tornado display, magnet display). Most explorations entailed simple manipulations of the displays without any clear indications that youth consulted the texts that accompanied the exhibits or whether they understood the science behind the exhibits. Two explorations were more profound and similar to the one described in this paper in that youth manipulated an exhibit (one on lightening, another on color mixing) and then sought out Tom for explanations of the observations and manipulations they had made. The period of free exploration was then followed by a 20-min guided tour of the super computer display at the exhibit. Our visit ended with some refreshments and reflections outside the exhibit hall.

Methods of Data Collection and Analysis

The larger study can be described as an *ethnography in education* (Green & Bloome, 1997), since youths' meaning-making of science and the scientists' worlds were at issue, making it a study of educational questions rather than a cultural group per se as would be the case in an ethnography. More specifically, a combination of participant observation and video recording was used which made possible an analysis of the process of meaning-making in context (Erickson, 1992). A research assistant was in charge of the video camera and asked to record the group of seven students as they interacted with the scientists, the scientists' workspace, and each other. A record of youths' meaning-making was of primary interest, which meant that the research assistant took a passive stance as an observer and did not engage in talk or action unless seen as necessary (e.g., when youth were not paying attention, when youth were fighting, etc.; Spradley, 1980). In contrast, the researcher and author of this article was in charge of the group and initiated reflections about the scientists' visits and the oral histories, and guided youth during their visits to scientists' workspaces. It was seen as important that the researcher would take on the role of a guide and let youth talk and come to own their talk (Gallas, 1995), and hence interfere as little as possible as they conversed with each other and with the scientists.

Given the general methodology of the project, the design shares many features with other studies of museum conversations. That is, like in typical peer and parent–child conversation studies in museums (Ash, 2002; Crowley & Callanan, 1998; Guberman & Van Dusen, 2001), our subjects were aware that their meaning-making was at issue. At the same time, the research assistant had to make "in situ" decisions which youth had to follow with the camera when they separated into smaller groups or navigated the exhibit alone, something typically avoided in studies with a focus on one exhibit only or studies using more than one camera. Clearly, the camera served as a note-taking tool, with the same purpose and subjectivity as the ethnographer's pencil and notebook in that only a selection of interactions could be captured (Erickson, 1992; Hall, 1999; Jordan & Henderson, 1995). At the same time, fieldnotes by the observer complemented such observations making the eventual record somewhat more complete (Allen, 2002).

Selection of Dialogue Sample. The dialogue examined in this paper was selected from a larger corpus of conversations in this particular exhibit hall, given its uniqueness rather than

representativeness (Erickson, 1992). What made the conversation unique were the kinds of interaction patterns that came to define it. Initially, it was a conversation between the research assistant and one youth who had just finished manipulating the exhibit. Hence, the dialogue itself was initiated by the research assistant in that she posed a question about the exhibit in a similar manner a teacher or parent would to assess students' meaning-making of science (Crowley & Jacobs, 2002; Lemke, 1990). While recognizing such an action as a possible violation of the rules set out for data collection in the larger study, such an intervention led to an exchange that was rather atypical yet interesting (Erickson, 1992), in that it began with an exchange between a youth and a researcher, then became a conversation among youth, and only later became a discussion among youth and the museum guide. In fact, the beginning of the conversation is similar to the ones brought about through texts (Hapgood & Palinscar, 2002), computerized prompts (Gelman, Massey, & McManus, 1991), or video traces (video of actual interaction which in turn is reflected upon together with a researcher; Stevens & Hall, 1997) in that such mediation makes visitors become more engaged in an exhibit or stay with an exhibit and interact with it over a longer period of time, as was the case here. It shows that the discourse excerpt selected here is not atypical from the kinds of conversations others have examined and brought about in studies of meaning-making in museums but atypical of the kinds of dialogues collected that day in that 43% of the interactions entailed youth-initiated manipulations of exhibits accompanied by little talk among youth (i.e., talk consisted of directives for manipulating the exhibit), while another 43% of the interactions were led by the museum guide. Of the 23 manipulations observed that day among the 11 exhibits, only 14% of the interactions accounted for youth-initiated explorations followed by consultations of the museum guide for detailed explanations of the scientific phenomena observed, an interaction pattern also evident in the dialogue explored in this paper.

What may make this example most atypical and particularly interesting is the manner whereby the goal for engaging in the manipulation and meaning-making of this exhibit came about and how it was defined by youth rather than the research assistant, the museum guide, or the exhibit itself. In fact, others have argued that visitors tend to be motivated to interact with an exhibit only if they do not understand it or want to accomplish a goal they have set for themselves (Guberman & Van Dusen, 2001), something that may have also motivated this conversation in that the researchers' question led one youth to articulate his understanding of the blue sky, something that was then contested by another youth and which then led to the motivation to find out how blue sky actually comes about.

Transcription and Analysis. The identified dialogue was transcribed in its entirety. In transcribing, I attended to all words, vocalized sounds (uh, um, uh huh), and restarts and repairs; only occasionally did I attend to particulars of intonation or utterance timing. Commas, question marks, exclamation points, and periods were added to aid readability. In many cases these symbols correspond to falling (period), rising (question marks), continuing (comma), or exclaiming intonation (exclamation point); however, the tapes were not checked for this level of transcript accuracy. Inaudible speech is presented in parentheses.

In addition, I noted contextual features, gestures, and gaze in a column to the right of the dialogue given my interest in nonverbal forms of meaning-making. As discourse analysts have repeatedly noted (Craig & Tracy, 1983; Jaworski & Coupland, 1999; Ochs, 1979), there is no single "right" level of transcription detail. Rather the best level is one suited to the theoretical aims of the researcher. My aim was to identify meaning-making

among a group of speakers, for which an intermediate level of transcription detail seemed warranted.

The aim of the analysis was "to make explicit what normally gets taken for granted" (Cameron, 2001, p. 7) while also showing what talk and action can accomplish (Edwards, 1993). Hence, an ethnographic microanalysis of meaning-making was pursued (Erickson, 1992). First, the transcript was divided into three parts: the exchange between the research assistant and Tracer, the exchange between Tracer and Marvin, and in turn, the interaction between the museum guide and the youth. In turn, the goals driving these pieces of conversations were inferred to understand the meaning of the whole conversation. Second, I examined individual's meaning-making and forms of participation in the dialogue over time, which led to a description of local meaning-making by Tracer and Marvin. In doing so, I paid attention to their articulations, their manipulations of the exhibit, and the concordance between their talk and exhibit manipulations. In turn, I examined at a more global level the kinds of discourses that were present and that emerged from interactions among youth, between youth and the exhibit, and between youth, the museum guide, and the exhibit. In doing so, I focused on the role of talk, gestures, and gaze in addition to the manner whereby talk and manipulation of the exhibit came to constitute meaning-making.

Video review sessions between the two researchers and among a group of communication scholars[1] contributed to the data analysis process and led to the identification of multiple forms of meaning-making apparent and noteworthy in that segment (Jordan & Henderson, 1995). Accordingly, the researcher's interpretation of the data set is presented in this paper, offering one possible story of what happened. Certainly, others could be told (Cameron, 2001). Maybe a more concise interpretation could have been obtained by showing the dialogue to the youth themselves, a member check that was not logistically feasible given their return to school. However, the museum guide participated in a follow-up interview and was questioned about his role in the exhibit, his notion of learning in museums, the kind of work he attempts to accomplish as he helps out in the exhibit hall, and in particular, about the blue sky exhibit and what he would like visitors to learn from it. Subsequently, he was also shown the video clip and asked to comment on it in terms of what he felt youth learned through this interaction and about his role. Such information offered a means to better understand the context of the conversation and was primarily used for the description of the exhibit in this paper.

RESULTS

A Description of the Context: The Blue Sky Exhibit

The conversation took place at the blue sky exhibit—one of the most abstract and, for that very reason, least popular exhibits in the center, according to Tom. It sits on a table upstairs next to a light exhibit illustrating how white light is made up of all the colors of the rainbow. At the light exhibit, visitors can combine colored yet almost transparent blocks and make inferences about how different colors affect one another and how that process is related to the interaction of different light-waves. That exhibit is purposefully

[1] Participants in the First Data Fest Symposium at the Jackson Hole Data Fest (January 2001); and participants (faculty and graduate students) from the weekly discourse analysis meetings at the Department of Communication, at the University of Colorado at Boulder; both groups consisting of scholars of discourse analysis.

positioned prior to the less intuitive blue sky exhibit. The blue sky exhibit caption reads as follows:

> *Sunsets are red, skies are blue, and clouds are white.*
> *If you want to know why this is so, scattering is right.*
>
> The scattering you see in the blue sky exhibit is not the scattering of people or objects—it's the scattering of light. Scientists define this kind of scattering as the process by which particles remove light from a beam and send it off in another direction. White light is made up of all the colors of the rainbow, each with a different wavelength. When this light gets scattered, though, you may notice a single color predominating-like the blue in the sky or in this exhibit. The atmosphere is tens of kilometers deep, but the blue sky exhibit is less than a meter long. It must use a concentrated gelatin to produce enough scattering in that small length for you to see blue. If it used atmospheric gases, it would have to stretch all the way across Boulder.

The exhibit itself consists of a light bulb, the source of light, that is then projected into a tube that is literally filled with lemon flavored jello (Figure 1). The transmitted light illuminates a round white flat surface behind the tube. Two polarizers are attached to chains at the light source. The polarizers can be used to manipulate the scattering of light. The tube is intended to represent the earth's atmosphere while the light source represents the sun, and the area the light is projected onto stands for the earth. If one looks at the atmosphere (tube) close to the sun (light source), one can see the color blue, which can be further amplified by use of the filters (which really are polarizers yet never introduced as such). In essence, the exhibit illustrates the efficiency of scattering, in that colors with short wavelengths, such as blue, suffer more scattering, while those with longer wavelengths, such as red, get scattered less. For that reason, we tend to see the sky as blue, whereas the evening or morning sky are often seen as orange or red.

The recording begins with two youth (Tracer and Mark[2]) manipulating the display. Each of them manipulates a polarizer and tries to guess its effects. Mark leaves the exhibit after

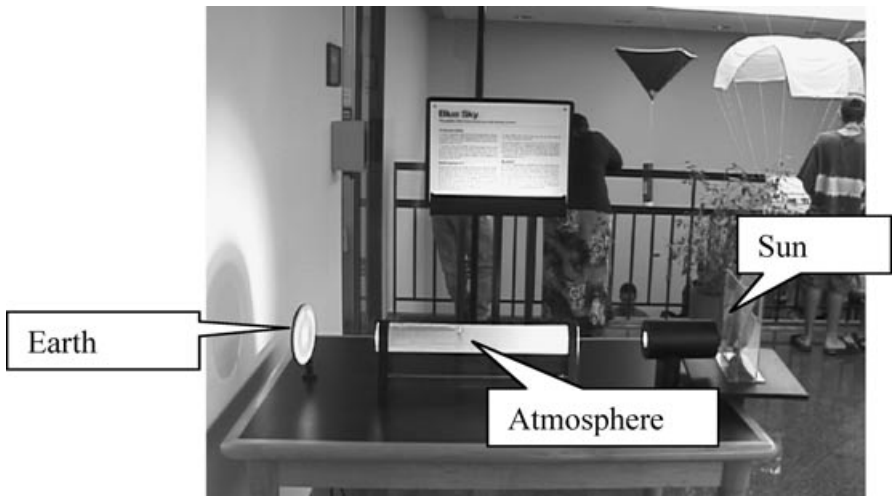

Figure 1. The blue sky exhibit.

[2] Pseudonyms are used for all subjects who participated in the study.

about 20 s of manipulation, whereas Tracer leaves after 30 s and is only held back by the researcher's question "So what did you, did you learn, trying that?" This question leads Tracer to express what he thinks the exhibit intends to show. The researcher then poses a second question, "and what's that represent in nature?" Tracer responds, "the sky" even though the referent of the question was somewhat ambiguous. This leads Tracer to share his conception about what makes the sky blue, namely "the water reflects on the sky that's why it's blue." The researcher simply nods and offers the floor to another youth, Marvin, who is approaching and who questions Tracer's explanation by noting "it does?" Some exchanges between youth follow, especially since Marvin has a different explanation of what makes the sky blue. To resolve the conflict, Tom is sought. Tom then explains the exhibit and eventually learns about Tracer's conception about blue sky.

Local Meaning-Making In Situ

How do different youth (here Tracer and Mark) make meaning of the exhibit? An analysis of local meaning-making provides some clues. In essence, such an analysis clarifies just in what ways talk and action constitute meaning-making in situ.

Talking About It. The question by the researcher that triggered this whole exchange is illustrative of a case of talk and action that can instantiate the implicit in museum learning. The researcher begins by asking "what did you learn-trying that" (line 2). The researcher thus acknowledges Tracer's play with the exhibit while also explicitly linking play with learning, suggesting that Tracer previously engaged in "mindful play" (Yahya, 1996). It put Tracer in the position of having to report and make his learning explicit, something reminiscent of teacher-talk and, in particular, IRF sequences (Initiation–Response–Feedback; Mehan, 1979). In the following exchange, Tracer explains in what ways the exhibit illustrates the relationship between light and colors.

EXCERPT 1

		Dialogue	Comments
1	Researcher:	So what did you did you learn trying that?	Tracer walks away.
2	Tracer:	Huh?	Tracer returns.
3	Researcher:	What did you learn trying that stuff?	Holds polarizers.
4	Tracer:	Different light if we have different	Demonstrates effects
5		colors different color windows change	with polarizers.
6		the light it's a different color. It gets	
7		darker each time.	
8			Manipulates and observes effects.
9	Tracer:	Blue *sky*!	Reads exhibit label.
10		Because it says, why is the sky blue? it's	Points to polarizer.
11		because of this!	
12	Researcher:	And and what's that what's that represent	Tracer manipulates
13		in in nature?	polarizers again.
14	Tracer:	The sky! Because, I mean the water	Faces researcher,
15		reflects on the sky that's why it's blue	no interaction with the exhibit.
16	Researcher:	OK.	

Even though Tracer's talk carries much meaning, it is somewhat telegraphic (i.e., incomplete) if examined on its own, and for that reason, needs to be understood as constituted by purposeful manipulation of the exhibit (i.e., actions). For instance, as he mentions the "different color windows" he simultaneously manipulates the polarizers in such ways as to illustrate the effect of "change the light" (line 5) and how "it gets darker each time" (line 6). He also labels the scientific processes of the exhibit by reading the sign next to the exhibit "blue sky!" (line 9) and by inferring, after a moment of reflection, that the exhibit explains why the sky is blue (lines 10 and 11).

Tracer's articulations and actions suggest that he understood how to work the exhibit in addition to having constructed some understanding of what the manipulation entails in terms of science. For instance, he demonstrates how the different "color windows" (polarizers that are part of the exhibit; line 5) change the color of the light in the tube. In fact, he rightly positions the polarizers between the light-bulb (sun) and the tube (atmosphere) to enhance the effect of "blue" close to the light-bulb (sun). Tracer then makes the link between "gets darker" (line 6) and the polarizers ("it's because of this"—lines 10 and 11) and rightly suggests that the exhibit illustrates the cause of blue sky.

Tracer also does more than simply explain what the exhibit is about. His actions disclose the process underlying the blue sky effect. That is, he first examines by doing how polarizers make the sky blue and then explains the process by noting that "different color windows change the light" (line 5). It is a nice illustration of situated meanings, in that his actions and talk both come to demonstrate and apparently constitute his understanding. This analysis suggests that Tracer understood the implicit meaning of the exhibit and did not merely engage in play. Talk and action clearly provide a window into Tracer's ways of meaning-making while the explaining itself most likely also contributed to Tracer's understanding.

Most important, the discursive activity between the researcher and Tracer also leads to the articulation of information that comes to constitute subsequent youth talk. That is, the researcher's second question in lines 12 and 13 about "what's that represent in nature" leads Tracer to first map the polarizers to "the sky" and then to publicly announce his conception of the cause of blue sky (lines 14 and 15). Therefore, the researcher's questions evidently played a role in Tracer's meaning-making of the exhibit in that his interpretation and prior understandings of the blue sky were made public.

Doing It. To illustrate the role of silent forms of participation, I focus on Mark, who at the beginning of the video episode manipulates the exhibit "in parallel" with Tracer but leaves before the questioning episode. He returns to the exhibit to "listen in" on the conversation that emerges once the museum guide is present, and eventually manipulates the exhibit on his own.

Tracer initiated the manipulation of the blue sky exhibit by holding one of the polarizers in his right hand and the other in the left and by sliding the two polarizers either between the sun and the atmosphere, or the atmosphere and the earth while observing its effects on the sun (or wall). Mark joins that game, first as an observer, and later as a manipulator. That is, Tracer passes one of the polarizers to Mark (an action accompanied by no talk), who then lines it up next to the polarizer, still controlled by Tracer. Both quickly examine its effects (see Figure 2a).

After that brief interaction, Mark wanders to another exhibit. However, once Tom is sought out by Marvin for an explanation of the blue sky effect, Mark joins the group again and takes on the role of a distant observer.

Mark is standing behind Tracer and Marvin, the two key figures of the ongoing debate. Yet, his attempts to "see" Tom's explaining and gesturing (as evidenced by his position and gaze) suggest that he is involved as a curious observer. Tom's behaviors provide a vicarious

(a) (b)

Figure 2. (a) Mark explores the exhibit (youth in the back); (b) Mark now tries out the exhibit (youth in black shirt).

learning experience for Mark, who also monitors the debate between Marvin and Tracer. His level of involvement is further marked by a brief utterance half-way through the clip as he seeks more information from Tracer about the process that makes the sky blue according to him, "[but] how does it, the sky, turn blue?" That brief statement is interesting in that it appeared at a time when Mark's "speaking agent" (Hatano & Inagaki, 1991), Marvin, briefly left the conversational space, which then "forced" Mark to speak up for himself.

Most interesting, at the end of the episode, when ongoing talk between Tom and Tracer no longer entails any manipulation of the exhibit, Mark seizes the opportunity to check out the blue sky effect on his own and in ways previously modeled by Tom (see Figure 2b). He approaches the exhibit and first simply observes the blue sky effect by carefully examining the light effect at the end of the atmosphere or tube, as his gaze suggests. He then takes hold of one polarizer and "correctly" positions it between the sun and the atmosphere to amplify the blue sky effect, which he carefully observes once again. He now repeats the same action with two polarizers. His careful and quiet observations of the effects are suggestive of meaning-making in situ. This case is also illustrative of the role of multiple literacies for meaning-making, in that Mark's forms of participation facilitated the development of interconnections among what he heard, observed, and did with the exhibit (Lemke, 2000). Clearly, Mark's quiet bystander stance is illusive. Through careful analysis of Mark's position within the exhibit space, Mark's active forms of participation become apparent. The analysis of Tracer and Mark illustrate different forms of engagement in an exhibit. The first analysis indicates the value of questioning and dialogue "in situ," while the second suggests ways in which passive observers may manifest their actual forms of engagement. In essence, these forms of engagement *externalize* the youths' understanding and meaning-making of the exhibit (Crowder & Newman, 1993).

Global Meaning-Making In Situ: Multiple Layers of Meaning-Making, Goals, and Actions

What makes this clip particularly interesting are the multiple layers of activities that co-occur and the kinds of windows they provide into how these participants *communicate* their evolving understandings. I am using the term "communicate" to stress a point made by Crowder and Newman (1993), in that what is externalized is not necessarily similar to what is being communicated to others. Take for instance Tracer's notion of blue sky. He argues that "the water reflects on the sky [and] that's why it's blue" (Excerpt 1, lines 14 and

15). Thereby, he is externalizing his understanding of blue sky. Yet, what meaning such an assertion has for Tracer remains difficult to assess even when examined in its context of use. To the other participants, it "communicated" something about the cause of blue sky which was somewhere on the earth for Tracer, and at odds with Marvin's idea that the cause lies in the atmosphere (see Excerpt 2, lines 23–29).

Hence, Tracer's articulation alerts Marvin to a discrepancy between their ideas about what causes blue sky and, in particular, the location of that cause. For that reason, from the youths' perspective, the remainder of the dialogue is driven by the goal to resolve this issue. While this goal is what gets Tom involved in the conversation, he seems unaware of it, and instead focuses on making the exhibit accessible to youth by mapping its parts to the real world and by engaging them in "seeing" the blue sky effect. The two kinds of dialogues (youth talk about location of cause and Tom's museum talk) come to interact with one another in interesting ways, allowing the emergence of unique learning opportunities over time, as I describe next.

Debate About Cause of Blue Sky Among Youth. The clip below is a continuation of Excerpt 1 showing the emergence of the debate and how it is framed by youth. As already noted, Tracer's sharing of the cause of blue sky is occasioned by the exhibit and its title "why is the sky blue" (Excerpt 1, line 10) and the researcher's question about what could be learned here—an issue that was further picked up by Marvin who appears on the scene at that moment. In fact, by questioning Tracer's explanation ("it does?"—line 18), Marvin gains entry into the conversation and access to the exhibit.

EXCERPT 2

		Dialogue	Comments
18	Marvin:	It does?	Marvin comes to exhibit.
19	Tracer:	Yeah.	Face each other.
20	Marvin:	I am not I am that's	Mumbles while manipulating exhibit.
21	Tracer:	that's why that's why the sky	Explains while
		is blue because the water	walking away.
22		reflects on the sun.	
23	Marvin:	I think it's, ugh from the ozone	Stops manipulation,
24		layer or something.	pause, then explains.
25	Tracer:	It's the water!	Challenges from back.
26	Marvin:	Mmmh	
27	Tracer:	I'm telling you it's the water I am it's	
28	Marvin:	It's all the chemicals in the sky	Gestures (iconic-chemicals
29		that makes (the color blue)	in sky)
30	Tracer:	well, actually actually, actually,	Tries to face Marvin
31		actually, I mean	and talk to him.
32	Marvin:	What what makes the sky blue?	Marvin seeks out museum guide.

As Marvin mumbles in line 20, he begins to manipulate the exhibit. Having gotten a hold of the polarizers, he positions them above the atmosphere, between the sun and the atmosphere, then in front of the atmosphere, and later between the earth and the atmosphere while observing the effects of such manipulations. During this time, Tracer once more articulates his reasoning behind the cause of blue sky (lines 21 and 22), yet with a new twist. Initially (Excerpt 1, lines 14 and 15) he noted that water reflected on the *sky*, whereas now he changed it to water reflecting on the *sun*. Whether such a minor change reflects a game of words or marks a more substantial struggle in understanding the cause of blue sky is

difficult to assess. Later in the exchange, Tracer uses the word sky again, suggesting that this might have just been a play of words. Despite such changes, it is clear that for Tracer, the reflection of water has something to do with the "making" of blue sky. Marvin then shares his understanding of the cause in lines 23 and 24 by noting that it is "from the ozone layer or something." Interestingly, he orients himself toward the researcher, which suggests that he is responding to the question of the researcher who framed this dialogue or attempts to elicit a response from the researcher.

That the ensuing debate is about the cause of blue sky is further apparent in Tracer's immediate response to Marvin's articulation in line 25 and the emphasis he adds by personalizing his statement in line 27 by the preface, "I'm telling you." It challenges Marvin, who notes, facing Tracer, "it's all the chemicals in the sky" (line 28). Marvin further emphasizes the difference in location with a metaphoric gesture for sky by waving his hands above his head. While doing so, he is still facing the researcher rather than Tracer. In turn, lack of response by the researcher may have prompted Marvin to seek out the expert (museum guide; line 32). That action also cut short Tracer's contribution in lines 30 and 31, whatever the intention behind those repeated words might have been.

Even though the manipulation of the exhibit led to the emergence of the dialogue about the cause of blue sky, there is no synchrony between talk and manipulation of the exhibit. That is, youth do not use the exhibit in ways to clarify what may make the sky blue or to support their claims about what makes the sky blue. Instead, they seek out adult expertise by first talking to the researcher and then by asking the museum guide for help (line 32). What would have happened if the museum guide would not have been present? Is Tracer's mumbling in lines 30–32 suggestive of a move toward the exhibit and to try to re-assess its meaning? Clearly, synchrony and asynchrony between talk and the manipulation of the exhibit (action) is important for the study of learning in situ, and its function and role in meaning-making needs to be examined more closely in the future.

Adult Talk About the Exhibit. Tom noted in our interview that he joined the conversation in order "to explain how the exhibit works and to make the science behind it explicit." His goal was to give reasons to youth to then experiment with the exhibit and manipulate it on their own, in ways discussed in the section on local meaning-making. Note how Tom begins by simply labeling the parts of the display through talk and by pointing (lines 36–42), before making the science behind it explicit (lines 44–49):

EXCERPT 3

		Dialogue	Comments
36	Tom:	This is—imagine, this is the earth's	Walks to exhibit, sits
37		atmosphere and we used lemon flavored	down on table, points
38		jello as the air—as it compares to, does it	to parts he explains.
39		slow down the light enough? So we made	Maintains eye contact
40		it really really thick. Here is the sun, here	with youth. Points to
41		is the earth. If you put these polarizers	polarizers. Marvin
42		in front of the light.	seizes them.
43	Youth:		Mumbling by youth
44	Tom:	Can you see the blue light here?	Points
45	Marvin:	Yeah.	
46	Tom:	And what do you see down here?	Points
47	Marvin:	Clearish?	
48	Tracer:	Orange?	
49		Clearish? It's kind of a yellow?	Eye contact with both.

Both youth observe quietly. Marvin is in control of the polarizers. As Tom talks about the polarizers (lines 41 and 42), Tracer first uses his hands and positions them between the sun and the atmosphere before making space available to Marvin to insert the actual polarizers. Once the polarizers are positioned, Tom asks whether they can see the blue light (line 44). While posing questions, Tom also keeps pointing to the sites where light effects can be observed and makes frequent eye contact with Tracer and Marvin. In the meanwhile, other youth also joined the conversation and observed the ongoing dialogue. Marvin and Tracer now offer an answer ("clearish" line 47; "orange" line 48), showing some level of involvement in the conversation. Note also how both answers are approximately correct in that the color showing is "kind of a yellow" (line 49). This exchange leads Tom to reiterate the fact that "the sun has all the colors of the rainbow" (line 52 below), something they supposedly gathered from the previous exhibit.

EXCERPT 4

		Dialogue	Comments
51	Tom:	The energy that comes from the sun—the	Makes eye contact with
52		sun has all the colors of the rainbow right?	youth. As notes colors,
53		Red, yellow, orange, green, blue. They are	counts on fingers.
54		all there.	
55		And the blue light that comes down to us	Points to exhibit and
56		has the most energy. It's oscillating faster	then models the
57		than any of the other types of colors. Red	oscillations of blue
58		is the slowest. So blue is kind of like this	with the right hand and
59		and red is like this.	red with the left hand.
60	Marvin:	You see? Yeah!	Faces Tracer.
61	Tracer:	I thought, I thought the water reflects on	Turns toward Tom.
62		the sky and that's why the sky is blue.	
63	Mark:	How does it the sky turn blue?	Mark takes Marvin's position.
64	Tom:	Well when—We're still going.	Tries to get them back on track.

Many gestures accompany Tom's talk. When asked about their function, Tom noted that gesturing helps keep the visitors' attention while it can also enhance the meaning of abstract concepts, as is the case here. For instance, Tom lists the colors of the rainbow and while doing so, uses his fingers to mark their number. Tom also visually displays the reason for blue light by modeling the oscillations with his hands and fingers (lines 58 and 59; see Figure 3). That is, he invokes a functional gesture that enhances what he is saying (Crowder, 1996; Crowder & Newman, 1993) by demonstrating the shape of the waveform and the speed of oscillation. This gesturing also underlines the importance of oscillation frequency for an understanding of the blue sky concept. While the emphasis rests on labeling in excerpt 3, Tom now further exemplifies the science behind the exhibit. He remains oblivious to the issue at stake for youth, however.

How Youth Came to Use Adult Talk. While the above analysis suggests youth simply followed along with Tom's explanation, they also made use of it in order to resolve their debate—something that Tom was unaware of at the time, as he confirmed later during our interview. The first cue youth pick up on is Tom's note that "the sun has all the colors

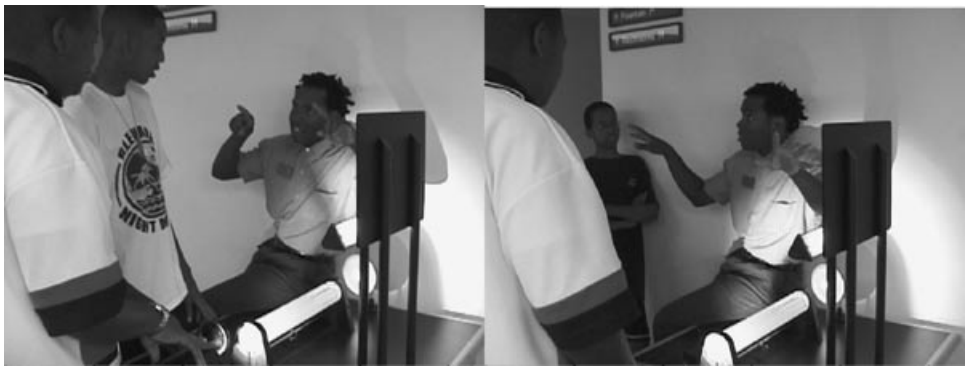

Figure 3. Gestures used by Tom (left: oscillation; right: light is spread out).

of the rainbow" (Excerpt 4, lines 51 and 52). As Tom refers to the colors of the rainbow, Marvin immediately makes eye contact with Tracer (see Figure 4a). Tom's statement probably locates the cause of blue sky in the sun or at least somewhere out there, away from the "water" or the "ocean" as Tracer suggested earlier.

Tom then continues with his explanation and Marvin waits until line 60 to jump in and publicly denounce Tracer's explanation by noting, "see, yeah." Marvin also distances himself from the exhibit at this point, thereby marking the resolution of conflict. Since Marvin moves out of the conversational space, Tracer has an opportunity to share his conception. Interestingly, Tracer now marks his interpretation in the past tense by noting, "I thought" (line 61), which suggests acknowledgment of defeat (see Figure 4b). Yet, Tracer does not simply want to make his understanding public but instead, probably attempts to engage Tom in a conversation with him. Tracer is most likely curious to hear what Tom has to say about his interpretation. Tracer's explanation is accompanied by a metaphoric gesture that adds iconic meaning to his talk about the role of water and sky in the blue sky effect.

Interestingly, Tom does not get involved in these discursive activities. Instead, Tom makes eye contact with Tracer and listens to the exchanges between Tracer and Mark while trying to catch the right moment to continue with his explanation, which he marks in line 64 by the comment "well, we're still going." Gestures immediately accompany his talk and help

(a) (b)

Figure 4. (a) Telling gaze between youth; (b) Tracer's attempt to explain.

draw the students back into the conversation. Tom also makes eye contact with Marvin to bring him back into the conversational space.

Resolution of Contention Between Adult and Youth. Despite the fact that the debate appears resolved for Marvin in line 60, Tom continues with his explanation. It suggests that Tom is more committed to getting the explaining done than to resolving the debate between the youth. Once Tom is done explaining, however, he is ready to listen and engage in a discursive act with Tracer. Interestingly, Marvin comes to join that conversation too (see also Figure 4b).

EXCERPT 5

		Dialogue	Comments
85	Tracer:	(What I thought) what I thought the	Tom makes eye contact
86		water reflected on the sky and	with Tracer.
87		that's why the sky was blue.	
88	Tom:	The water reflected	Tom repeats.
89	Marvin:	on the ocean	Helps construct it.
90	Tom:	the light?	Maintains eye contact.
91	Tracer:	Yeah!	Confirms Tom's articulation.
92	Tom:	The ocean water reflected	
93	Marvin:		Mumbles along with
94			Tom.
95	Tom:	Well, the ocean reflecting on the	Points to sky and looks
96		sky up high	at Tracer.
97	Marvin:	But what, what, what, what reflects it?	Tries to regain the floor.
98	Tracer:	and makes the sky blue	Finishes.
99	Marvin:	What reflects it?	Gains the floor.
100	Tom:	Well, it's the sunlight.	Points to sky.

Note how Tom attempts to understand Tracer's reasoning by restating what he previously said, beginning in line 88, and completing in line 90, after a brief interruption by Marvin (line 89) which Tom ignores. In essence, Tom attempts to understand the fact that for Tracer "the water reflected—the light" (lines 88 and 90) and hence tries to answer *what* was reflected, whereas Marvin attempts to intervene by laying out the *cause* and *site* of that reflection—"the ocean" (line 89), something Tom then tries to integrate in line 92. Marvin's mumbling in line 93 may underline his involvement in understanding Tracer's reasoning. Tom continues in line 95 with further restating Tracer's notion. Tom's acknowledgment of Tracer's notion in line 95 establishes the context for Marvin to question Tracer about the source of the reflection. That is, Marvin is now in a position to wonder about "what reflects it" (line 97). It creates an opportunity for Tom to offer the idea he attempted to advocate earlier, the fact that it has something to do with "sunlight" (line 100). That suggestion signals to Marvin the end of the conversation and makes it possible for him to move on and explore another exhibit.

Tracer now has Tom's full attention as he shares one more time his notion of blue sky, which prompts Tom to elaborate further on the location of the process that makes the sky blue by noting "that it starts way before that, before the sun even, before the light even gets down to the ocean." By emphasizing not just the location but the timing of the effect—"it starts way before that"—Tom is dismissing the process of reflection Tracer advocated. In

essence, he tries to convey the idea that the earth (its surface, oceans) does not necessarily contribute to the blue sky effect as Tracer suggested.

Note how the different ongoing conversations came to interact over time and mediate meaning-making in interesting ways. For instance, without Tom's explanation, youth could not have resolved their debate in the manner they did. Tom's talk provided the necessary pieces of information to potentially keep their meaning-making going. It certainly contributed to the situated constructions of what makes the sky blue, in that it confirmed Marvin's interpretation to some degree, despite its incompleteness, while it posed a challenge to Tracer's interpretation. For these reasons, it can be argued that the notion of blue sky was socially constructed and reconstructed. The participants probably left the science exhibit with an incomplete understanding of blue sky, yet with some new information that might be of use in other situations, thus contributing to their science literacy development over time.

One could also argue that youth were engaged in three lines of meaning-making simultaneously. They came to understand the meaning of the exhibit, they came to make sense of the blue sky phenomena that the exhibit intended to display, and they came to connect the two with their own meaning-making and notions of blue sky which then also made it possible to resolve their debate about the cause of blue sky. In fact, it is these kinds of discourses that constitute learning in science museums.

DISCUSSION

Through a thorough analysis of meaning-making among youth, I have shown in what ways youths' manipulation of the blue sky exhibit and talk came to constitute meaning-making in practice. In essence, I have tried to show "how people learn" and "what people do when they are learning" (Crane, 1994, p. 182). That is, I began the analysis of the interaction with the assumption that it would make evident something that we could count as illustrating the process of learning in science museums. In the remainder of this paper, I will address issues pertinent to learning in museums that this analysis has brought to the foreground and that may also contribute to the development of enhanced theories of "real-world, lifelong learning" as called for by the task force on informal science education (Dierking et al., 2003).

The Sociocultural Mediation of Learning

As noted by Rennie et al. (2003) and shown in the analysis presented here, social and cultural factors such as conversations, manipulations of the exhibits, and groupings of individuals (here adult–child and child–child interactions) mediate learning in important ways. Yet, it is not solely talk but also action and the coordination of the two that can be telling of meaning-making. Furthermore, different forms of engagement externalize meaning-making in museums. As shown, by manipulating the exhibit, through "listening in" on ongoing conversations, through observation, and the appropriation of ways of manipulating an exhibit, Mark was able to develop some understanding of the exhibit. That is, he managed to manipulate the exhibit in a manner to then observe the blue sky effect. Accordingly, detailed analysis of talk and action as the one presented here have much to offer, despite the fact that they are labor-intensive and expensive. As noted by Allen (2002), "conversations are too complex to allow for speedy yet meaningful analysis" (p. 300). Most important, it is not talk alone that matters, but the combination of talk, action, gesture, positioning of visitors in relation to exhibits, and their different forms of engagement in exhibits (e.g., silent as opposed to verbal). When examining current work on meaning-making in science

museums approached from a sociocultural perspective, few address the whole "tool-kit" of meaning-making (Wells, 2000). Yet, if we subscribe to a discursive approach to the study of learning in situ, such factors matter. As was shown here, gestures appeared particularly pertinent to Tom's teaching of the concept of color and helped illustrate oscillation speeds. It makes evident how scientific concepts are articulated across a variety of media, some being language, others being mathematical, graphical, pictorial, among a host of other modalities (Lemke, 2000). In fact, the blue sky concept was articulated across the physical display, the text at the display, and further through Tom's talk, gestures, pointing, and positioning in relation to the exhibit. Similarly, youths' meaning-making was made apparent through these modalities and hence needs to be studied as such. It leads to a number of new questions for the study of learning in museums. For instance, just how do talk, gesture, and the manipulation of exhibits constitute meaning-making? Could it be that unpolished gestures are indicative of active meaning-making as has been suggested in other contexts (Crowder, 1996; Crowder & Newman, 1993)? Furthermore, the meaning of synchrony and asynchrony among such modalities of meaning-making has to be better understood. Does it suggest different levels of expertise about scientific concepts or in visitors' understandings of the science embedded in the exhibits, or does it have some other implications for learning that we do not yet understand?

Finally, three lines of sense-making were made apparent through the detailed analysis of talk and action such as an understanding of the meaning of the exhibit, an understanding of the blue sky phenomena, and youths' own sense-making of the blue sky phenomena. Accordingly, when examining meaning-making in context, we cannot treat discourse as a unitary concept. Instead, meaning-making consists of multiple discourses driven by different goals for meaning-making and must be examined as such. In line with cultural psychology future interest lays in formally describing "the meanings that human beings create(d) out of their encounters with the world" (Bruner, 1990, p. 2). It implies meaning-making because of their encounters with exhibits, with each other around exhibits, and with third-persons in such contexts such as curators. Only through further detailed case studies can the complexity inherent in meaning-making be made visible and the role of museums in science literacy development be better understood.

Implications for Museum Design. When thinking of museum design, there is a clear need to develop museums and exhibits that support engagement in them over longer periods of time, which then makes possible the use of the tool-kit for meaning-making. While such an issue is not new and already captured in terms such as designing for social interaction (Paris, 2002), it is still poorly dealt with. When considered in the context of the case presented here, it can be assumed that the dialogue examined here would most likely not have occurred if the research assistant had not posed a question and thereby "stopped" Tracer from moving on. It forced Tracer to reflect upon his manipulation of the exhibit and the meaning behind the exhibit and also gave rise to an exchange among youth, and youth and the curator, which led to learning opportunities not embedded in the exhibit per se. That is, it led youth to voice and maybe even question their own constructions of blue sky while it also made possible an understanding of the exhibit itself. In essence, it underlines the crucial role of curators as guides in such settings and makes evident the need to explore conversations and interactions between curators and youth in greater detail.

Related to this point is the manner whereby the conversation makes evident the multiple literacy demands of science exhibits (Lemke, 2000). Youth struggled with verbal and visual information as they made meaning of the blue sky exhibit. As also shown, matching meanings of the artifacts with articulated science concepts and ongoing talk was far from

trivial. Accordingly, museum designers have to pay more attention to the kinds of demands exhibits pose for visitors and how visitors can be guided in a manner to make such demands manageable and in the end also meaningful. In fact, museum design might have to be reconsidered as an ongoing process in that the effectiveness of exhibits may need to be "tested" and "re-tested" over time through detailed case studies, as the one presented here, that offer insights into the complexity of meaning-making of visitors. Such would also make possible the adaptation of exhibits to particular contexts, meeting the cultural and political needs of that particular visitor population, a topic still little addressed in the museum literature (Leinhardt et al., 2002; Paris, 2002).

As noted by Rowe (2002), the meaning of objects in museums are up for negotiation by visitors in ways not often the case in other contexts. Yet such liberty also poses challenges in that the science is not there to be grasped, absorbed, and consumed, but instead, something that comes into being through social interaction, manipulation of tools, and "mindful play" (Yahya, 1996). In essence, "when is science" as raised by McDermott and Webber (1998) is the crux of understanding museum learning. Yet, it is also not something that can be designed for per se, but instead, something that has to be understood as emergent.

Learning as Distributed Spatially and Temporarily

The difficulty of locating learning in the detailed analysis presented here underlines that learning can no longer be understood as being located in the mind, in a time or moment, or within a specific space. Instead, learning is best thought of as emergent and dynamic, and as distributed in the flow of an activity and among activities over time and space, and hence, distributed temporarily and spatially (Barab & Kirshner, 2001; Lave, 1988; Lave & Wenger, 1991). While such a perspective of learning is not new—see for instance the addition of time in the Contextual Model of Learning put forth by Falk and Dierking (2002; see also Dierking et al., 2003; Dierking & Falk, 2001; Rennie et al., 2003)—what the implications of it are for museum studies and design have not yet been explored in detail enough.

When examining Tracer's forms of participation, it is readily apparent that learning in this case is constituted by Tracer's prior experiences and current actions and talk, and hence, is a highly idiosyncratic rather than a linear process (Falk, 2001). In addition, it is also clear that to develop an understanding of the blue sky phenomena is not something that happens at one point in time or simply during this visit. Instead, Tracer's notion of blue sky is constructed over time and such a construction is occasioned through a variety of interactions in a variety of contexts, the museum visit described in this paper being one instance possibly contributing to such a construction. For this reason, it is rather difficult and not the aim of this paper to make strong claims about learning based on the detailed analysis presented here. In fact, the dialogue is reflective of a relatively unremarkable moment (Crowley & Jacobs, 2002). Yet, it is the cumulation of such moments over time that lead to a construction of a notion of blue sky. And for these reasons, we as researchers have to pay more attention to such unremarkable moments since they hold much promise for understanding science literacy development. That is, the dialogue between the researcher and Tracer made public Tracer's notion of blue sky, a notion that then became challenged by his peer and potentially further by Tom's explanation of the exhibit. Yet, there is no clear indication that Tracer abandoned his notion of blue sky or that he appropriated the notion presented by Tom. At best, the exchange put Tracer's notion into question, leading to a disequilibrium in a Piagetian sense (Ginsburg & Opper, 1988). Piaget noted that such is the motor of intellectual development. Hence, it could be that the fact that Tracer's notion of blue sky was made public and became questioned will eventually lead to some learning. That is, if Tracer would be confronted about it again through a television show or a lesson in

his science classroom, all these unremarkable moments of confrontation may in the end help him deconstruct and reconstruct his understanding of blue sky. Of course, the challenge remains in that we simply do not know a priori which moments in persons' lives will come to constitute their understanding of a variety of concepts. At the same time, it underlines that to fully understand the value of museum visits and their contributions to science literacy development over time, a depiction of museum visitors' *learning trajectories* would be necessary. By either following individuals and assessing their forms of participation in places of science through multisite ethnographies (e.g., Marcus, 1995) or by having them report about such forms of engagements through retrospective interviews and personal narratives (Eisenhart, 2001), parts of the time-consuming and cumulative process of learning could be understood and documented. It also implies the need to explore a wide range of learning situations, some being in school and others outside of school, from multiple perspectives (Tressel, 2001).

Hence, the question is no longer whether learning happens in science museums but how science museums, among many other institutions and resources, over time, come to contribute to youths' science literacy development. Museums' actual role, if measured in and of itself, may be rather insignificant, but if taken together with other contexts, becomes important and meaningful. This is apparent in Ellenbogen's case study of one family whose engagement with science at home and in a museum through repeated visits over a 1-year time period was examined (Ellenbogen, 2002). Other studies are needed that address a wider range of contexts in an assessment of a holistic perspective of science literacy development. Such studies would also help clarify the methodological challenges inherent in studies of learning trajectories and facilitate an expansion of research methods needed to address the much more complex questions such notions of learning pose.

Implications for Museum Design. If indeed learning "happens" over time and space, visitors most likely profit most if they can return to the same exhibit numerous times. In light of the case presented here, a second visit by Tracer would certainly not guarantee a further development of his understanding of blue sky, but it could potentially contribute to such a development. Yet, for Tracer, the exhibit at issue here is neither physically nor culturally accessible. Tracer, living in a poor inner-city neighborhood does not have the means to travel 30 miles to revisit the exhibit. The cost of museum visits create another barrier for many. While the science center studied here was free to the public, few museums are financially accessible to impoverished youth and families.

When examining the cultural accessibility of the museum, it is even more problematic. Even though the curator is African American and hence share a certain heritage with this group of students, there is a large gap in terms of socioeconomic standing between these students and the majority of people employed and represented by this research center and exhibit. Accordingly, it is not a context that any of these students would seek out on their own and feel comfortable in. And as alluded to by Duensing (2002), the visitor's perspective on an actual visit also constitutes meaning-making. Accordingly, the mind-set with which youth approached this visit has to be taken into account. In this case, youth felt comfortable with Tom as made evident by their many spontaneous questions during our visit. However, reflections following our visit made it also clear that the world of science that I attempted to make accessible to them through the larger project remained a world distinct of their own (Rahm & Downey, 2002).

Accordingly, barriers, whether physical, economical, or cultural, need to be removed if we want to make science accessible to all. The program Youth ALIVE (Youth Achievement through Learning, Involvement, Volunteering, and Employment) may serve as a model for

sustained engagement (Beane & Pope, 2002). In that program, youth help develop the actual exhibits and, in turn, take on the role of curators in the museum and share their expertise with visitors. Through such sustained opportunities of involvement in the museum, they were able to develop not only a deeper understanding of the science embedded in the exhibits, but also came to realize their potential as learners in a general sense. Accordingly, sustained involvement as supported in that study has local as well as broad implications for science literacy development, and may serve as a model for the design of additional programs of that nature.

CONCLUSION

The case study makes evident the manner whereby a group of youth makes meaning out of their encounter with an exhibit (Bruner, 1990). The analyses also show just how unpredictable learning really is, in that the kinds of learning opportunities the blue sky exhibit supported had as much to do with the participants and their interactions with the exhibit and each other, as it had with the exhibit itself. A close examination of another group of visitors would most likely tell another story. Furthermore, how that learning experience then comes to be integrated into old and new ways of knowing is also unpredictable, yet very much at the heart of the matter if we perceive learning as a continuous process of becoming rather than the mere accumulation of facts. It is these kinds of issues that need to be taken more seriously if we are to truly understand learning in science museums and the contributions of such sites to science literacy development in general. And to achieve such goals, detailed case studies as the one presented here can be fruitful. A possible next step would be microanalytic studies of science literacy development across institutional boundaries—and hence space—and time. That is, what could we say about Tracer's, Mark's, or Marvin's science literacy development if we would have other snapshots of meaning-making in situ, as detailed as the case presented here.

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