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Describing and Supporting Collaborative Scientific Thinking in Parent-Child Interactions

KEVIN CROWLEY AND MAUREEN CALLANAN

In this article we review a collaborative project between two developmental psychologists and the staff of Children's Discovery Museum of San Jose. Under the broad agenda of studying the development of scientific literacy, we have been exploring the hypothesis that the guidance of parents is an important bridge between the intentions of the exhibit designer and the experience and knowledge of the child. Our research is guided by a framework inspired by a combination of sociocultural and information-processing theories of how children learn. In the first section of this article we describe our research framework. In the second section we review its implications for the methods we have used to study learning in museums. In the final sections we present two examples of how we have analyzed parent-child learning in the museum.

Our collaboration with Children's Discovery Museum began when we approached the director, Sally Osberg, about the museum serving as a site for our research on parent-child learning about science. We were delighted to find not only enthusiastic cooperation but strong interest in developing an ongoing working relationship. Serendipitously, the museum was at that time preparing a proposal to the National Science Foundation to develop a new set of exhibits designed to encourage children to view everyday objects from multiple perspectives. As our discussions with the museum developed, it quickly became clear that our own research goal of understanding scientific thinking in parent-child interactions was consistent with the museum's goal of designing exhibits that, among other things, support parent-child interactions. We were very pleased when Osberg invited us to expand our plans so that we could pursue our own research agenda while at the same time providing the evaluative component for the NSF-funded exhibit development.

The resulting collaboration has been extremely fruitful. With a team of undergraduates, graduate students, and research assistants, we have collected and analyzed videotapes of naturally occurring family interactions in the museum. Our analyses of these data address current questions about informal science learning and are simultaneously being used to inform exhibit development. At least one of us attends biweekly project meetings at the museum, where we coordinate our data collection and analysis plans with the museum staff's inquiries, provide summaries of our emerging research findings, and act as informal consultants on issues of child development, scientific thinking, and parent-child learning.

Scientific Literacy as Collaborative Learning

The dual focus of our research is to understand how parents contribute to the development of children's scientific literacy and to describe the potential of museums as environments for facilitating this process. What is scientific literacy? Perhaps many people would answer this question in terms of the products of science: the types of factual science information that children can find in textbooks, television shows, and Web pages. This includes information on scientific findings (e.g., the Loma Prieta earthquake measured 7.1 on the Richter scale), scientific theories (e.g., some earthquakes are caused by plate tectonic forces), and scientific tools (e.g., seismographs can be used to locate the epicenter of an earthquake). Findings, theories, and tools are essential content in a complete science education. However, books, television, teachers, and the World Wide Web can be far more efficient delivery systems for this information than museum exhibits.

Our approach is guided by the premise that the products of science are not what children can primarily learn from visiting science museums. Instead, the benefits of the museum-based experience derive from the fact that children can exercise more general competencies in forming expectations, evaluating evidence, and constructing explanations. At its core, science is a way of making sense of the world. It is a way of building up new theories to explain existing evidence and a way of seeking out new evidence to revise existing theories. Successful exhibits are those that support opportunities for children to think through the process of coordinating theory and evidence.

Prior developmental research has

Kevin Crowley is on the faculty of the University of Pittsburgh with joint appointments as a research scientist at the Learning Research and Development Center and an assistant professor in the School of Education. His research focuses on museum learning, scientific thinking, and problem solving.

Maureen Callanan is an associate professor of developmental psychology at the University of California, Santa Cruz. Her research focuses on cognitive and language development in preschool children, exploring how children come to understand the world through everyday conversations with their parents.

described how individual children coordinate theory and evidence while engaged in solitary scientific problem solving (e.g., Klahr, Fay, and Dunbar 1993; Schauble 1990, 1996). The basic finding is that children's understanding of theory and their evaluation of evidence are mutually interactive processes. For example, the way children interpret evidence depends on their current personal theories about the relevant domains or phenomena. When new evidence contradicts a strongly held theory, children sometimes distort the evidence to make it consistent with their theories, or they ignore the evidence altogether. A frequent conclusion of this literature is that the key developments in children's scientific thinking relate to children's metacognitive abilities to reflect upon their own thinking processes and thus better coordinate evaluation of evidence and the construction of personal scientific theories (e.g., Kuhn 1989).

Our hypothesis is that, in everyday interactions, parents play a fundamental role in shaping the ways that children coordinate theory and evidence. We agree that it is important to understand the scientific thinking that occurs when children reason alone, but we argue that it is equally important to understand the shared scientific thinking that occurs when children are with their parents. Although much (if not most) of young children's early science learning probably occurs in everyday parent-child settings, developmental psychologists know very little about the ways parent participation shapes children's scientific thinking.

Our research focus on parent-child interaction is consistent with approaches that describe learning and development as fundamentally collaborative. Much of the history of developmental and educational research on learning and instruction can be understood as a debate between at least three distinct models of how children learn (Matusov and Rogoff 1995; Rogoff, Matusov, and White 1996). First, consistent with the classroom organization of traditional schools, the adult-directed model of learning holds that adults should control the learning agenda, set appropriate tasks for children, and provide feedback about when children have finished a task and whether their answers are correct or incorrect. This model casts children in the passive role of sponges who soak up knowledge presented by an expert.

In direct opposition, the child-directed model puts the primary control of learning in the hands of the child. Inspired by Piaget's ideas, proponents of this view see children as constructivist learners who set their own goals, choose their own tasks, build up understanding through activity, and decide when they are finished. In the child-directed model, adults may be considered resources who answer questions and provide materials, but the choices that will guide the path of learning are to be left in the hands of the child.

A third model holds that learning is fundamentally collaborative. Neither the child nor the adult necessarily assumes control of learning. Instead, all participants in a learning situation negotiate how they will understand the goals of learning, how a task should be construed, what they have learned, and whether they are done. Collaborative models of learning are at the heart of the sociocultural theories inspired by Vygotsky (1978) and recently instantiated in the work of Tharp and Gallimore (1988), Newman, Griffin, and Cole (1989), and Rogoff (1990), among others. In the previous issue of the *Journal of Museum Education*, Schauble, Leinhardt, and Martin (1997) explored the implications of sociocultural theory with respect to museum learning.

Any of these three models of learning could be logically applied to designing museum exhibits to support the development of scientific literacy. However, hands-on museums are often seen as alternatives to adult-directed school learning; thus, the emerging debate in the museum world is between the traditional child-directed constructivist models and the more recent collaborative models inspired by sociocultural theory.

One of the arguments often advanced in favor of a child-directed model is that individual discovery is the most powerful form of learning. It is a romantic notion supported by images of artists, scientists, and writers toiling alone late into the night in search of the next dramatic breakthrough. Reflecting on our personal learning histories may also lend support to the notion. Many people can vividly recall a moment when they had some sudden, powerful insight that catapulted them abruptly from complete confusion to clear understanding.

Individual insight is one mechanism of human learning. However, it is not the only way we learn, and it is probably not the primary way. For every insightful intellectual leap, there are thousands of mundane moments of learning where we cobble together bits of observation, demonstration, and conversation that we picked up through social interaction. Children are born into sociocultural contexts: they do not have to reinvent the wheel to learn something new. Parents, siblings, teachers, and peers are important sources of new ideas, behaviors, and explanations.

It would be maladaptive to ignore these readily available social sources of knowledge in favor of the often slow and painful process of struggling to make individual breakthroughs, unless there was evidence to suggest that individual discoveries are, in fact, more potent and long-lasting than collaborative discoveries. Recent evidence, however, points the other way. Laboratory studies of children's learning show that children who one minute discover powerful new strategies on their own often forget the discoveries the next minute and go back to using their prior, less powerful approaches (Siegler and Crowley 1991; Siegler 1996). However, when children explain their learning to other children or to adults, they remember their discoveries better and are also more likely to transfer the new knowledge to subsequent problem solving (Chi et al. 1994; Crowley and Siegler 1998). These recent findings are consistent with the long history of research showing that when children collaborate with each other or with their parents, their learning is more advanced than when they think and learn in isolation (e.g., Azmitia 1996). Thus, developmental research suggests that socially situated learning, rather than being weaker than isolated learning, is often a more powerful and general form of learning, particularly in the case of children.

Translating the Model into Research

Models of learning shape the methods used to study learning and the assessments used to determine whether learning has occurred (Matusov and Rogoff 1995). To a museum researcher with an adult-directed model, knowledge is thought to be taught by the museum through exhibits, signage, docents, and other means. The most straightforward approach to assessing adult-directed learning is to give children a test. In museums this test most often takes the form of a structured interview. Children are considered to have learned something if they can talk accurately about what the museum believes is the key exhibit content. By the same token, if children cannot talk about it, they are considered not to have learned about it.

Researchers with child-directed models assess learning by tracking children's activity. Researchers might shadow children to see if they stop at a particular exhibit; might collect time-on-task measures to see how long children stop at an exhibit; and, less frequently, might describe in more depth what it is that children are doing when they stop at an exhibit. Depending on the specific research questions, children who visited a broader group of exhibits, spent more time at particular exhibits, or completed a higher proportion of intended manipulations at an exhibit are considered to be the children who learned more. Although a child-directed model of learning could also be consistent with assessing learning by measuring affective variables such as curiosity, fun, or interest, such measures are rare. The operational problem is that it is extraordinarily easy to shadow visitors or measure time-on-task, and it is extraordinarily difficult to construct reliable measures of curiosity, fun, or interest.

A collaborative model of learning focuses the researcher on analyzing family interactions. It would not be appropriate to conduct posttest interviews or administer questionnaires to see whether children can verbalize scientific explanations or repeat definitions of scientific concepts. The basic competencies we are studying do not exist as isolated chunks of knowledge. Rather, one can be said to "know" these concepts by virtue of being able to skillfully weave together thought and action in ways that are specific to certain sciences, and eventually in ways that are applicable to science in general. This process is fundamentally interactive both between the visitors and the exhibit and among the visitors themselves. Thus, methods consistent with the collaborative model focus on ways of describing visitor activity in terms of how visitors use exhibits, how visitors talk to each other while using exhibits, and ways that action and talk are related. (Callanan, Shrager, and Moore [1996] describe related methods for analyzing parent-child activity at home.)

To capture naturally occurring family interactions in the museum, we have refined our research methods to make them as unobtrusive as possible. Before each day of data collection, video cameras were set up at three to five target exhibits throughout the museum and wireless microphones were integrated into the exhibits to provide high-resolution audio recording. Signs informed visitors of our research activities at the museum entrance and at each exhibit being filmed. Researchers greeted families entering the museum, explained that we were videotaping as part of a research project, and asked families for written consent to participate. Most families we approached (94 percent) agreed to participate.

Obtaining informed consent in museums is not trivial. Initially we had spoken to families as they approached the exhibits we were filming. Consent rates were low for this procedure because children often approached exhibits without the parents who needed to sign for them. Even when parents were present, they were less inclined to interrupt the flow of their visit to talk to us. Moving to the front door gave us a much more appropriate setting to approach parents and ask them to consider participation—just after leaving the admission desk but before becoming engaged with the museum exhibits.[1]

Children in consenting families were given large stickers identifying them as participants; children of different ages were distinguished by distinct stickers. If, in the normal course of their visit, children with stickers chose to engage one of the target exhibits, the camera operator turned on the camera for the length of the engagement.

Below we present brief summaries of two studies coming out of this project. The first study is a detailed look at the way parents guide children's experience at one hands-on exhibit. In the second study, research findings were used to inform the redesign of an exhibit to support parent-child interactions. We review some of the main findings here; the full presentations are currently in preparation for submission to scientific journals.

Parents Mediate Children's Museum Experience

The first study compares the experience of 49 children who visited an exhibit with their parents to the experience of 41 children who visited the same exhibit while their parents were occupied elsewhere in the museum. We chose to focus on a zoetrope for this study because it is a popular and common exhibit in science centers and children's museums. The zoetrope we studied consisted of a series of frames from an animation of a running horse inside a cylinder that visitors can spin. When visitors spin this particular zoetrope and look through the slots, they see a smooth animation of a galloping horse. Looking through the slots is essential because it produces a stroboscopic presentation of the individual frames. When visitors look over the top of the spinning zoetrope, the individual frames of the animation blur together.[2]

The actions and verbalizations of all participants in each interaction were first transcribed from videotape and then coded. As we describe below, coding included measures of how children explored the zoetrope and measures of what parents and children talked about while engaging the exhibit. Coding was conducted by two independent raters who periodically compared their codes to ensure that the coding scheme was reliable.

First we considered the ways children explored the zoetrope. We coded the three basic actions afforded by the exhibit: spinning the zoetrope; looking at the pictures over the top of the zoetrope; and looking at the pictures through the slots of the zoetrope.

Regardless of whether children were with or without their parents, most children spun the zoetrope at least once and most looked over the top at least once. However, children who visited the zoetrope with their parents were twice as likely to look through the slots at least once—the essential vantage point for seeing the animation. Furthermore, when children visited the zoetrope with their parents they stayed at the exhibit longer and performed each kind of exploration repeatedly. Children who visited the zoetrope without their parents may have explored different aspects of the zoetrope once or twice, but most often they moved on to another exhibit after less than one minute of engagement.

These findings suggest that children who visited the zoetrope with their parents had a broader and deeper experience than children who visited without their parents. Even if one adopted the radical constructivist stance that all of children's understanding is the result of individually making sense of their own experiences, these data suggest that, at the very least, children engaged in exploration with their parents have a richer set of experiences to think about.

However, we would argue that parents play a more direct role than simply expanding the scope of their children's exploration. Parents can also construct explanations around their child's activity to help their children begin interpreting actions in light of a theory of what is going on in each exhibit. Our analysis of parent-child conversations detected three distinct types of parent explanation: explanations focused on the mechanisms that made the exhibit work; explanations linking the exhibit to real-world devices and phenomena; and explanations linking the exhibit to formal scientific principles.

About half of the parent-child interactions included at least one explanation. Most parent explanations were volunteered by parents rather than offered in response to children's questions. In interactions where parents explained, children were more than twice as likely to talk about what they were seeing while exploring the exhibit. Children rarely offered their own explanations for the zoetrope; however, in almost every case where children explained, they did so in response to an adult explanation.

The implication of these findings is clear: Parent participation deepened children's engagement with the exhibit, both at the level of parents guiding activity and at the level of parents constructing explanations around that activity. The fundamental role of parent participation that we identified is at odds with the typical portrayal of children's scientific thinking in the developmental literature, a portrayal that emphasizes the individual child's ability to consider evidence and construct theories in isolation of other people. To the extent that our observations at the zoetrope are typical, our findings suggest that theories of the development of scientific thinking need to be reformulated to account for the parents' central role as guide and interpreter.

Our findings also suggest that museums interested in supporting children's scientific thinking must consider designing not just for an audience of children but for an audience of children and parents engaged in collaborative learning. Next we present a study focused particularly on issues of designing to support parent-child interaction.

Designing for Collaborative Learning

Effective parent-child scientific thinking depends on parents and children adopting complementary goals. The elegance of the zoetrope is in part due to the simplicity of the interface. A casual glance is sufficient to expose the necessary manipulations and observational vantage points. Parents and children can spin the cylinder together, look at the same animation at the same time, and, importantly, look at each other to gauge mutual understanding and interest.

Not all exhibits are as simple as a zoetrope. We now present a study illustrating how parent-child interaction can undermine learning when obstacles in the exhibit interface lead parents and children to adopt conflicting rather than complementary learning goals.

The exhibit we focus on—*Map Your Head*—gives children an opportunity to see a side-by-side comparison of a regular three-dimensional view of their heads and a "mapped" two-dimensional view. To engage the prototype exhibit, a child climbed a ladder until his or her head poked up into the opaque exhibit enclosure (fig. 1). Inside the enclosure a video camera rotated around the child's head, taking a series of shots that were then assembled by a Macintosh computer into a two-dimensional projection. The child could see two side-by-side video monitors, one displaying a continuous feed from the rotating video camera and the other displaying the two-dimensional projection when the mapping process was complete. By juxtaposing the three-dimensional and two-dimensional views of the child's head, the exhibit was designed to encourage wondering about mapping, spherical projection, and the functions of satellites orbiting the earth.

The *Map Your Head* prototype was most consistent with a child-directed model of learning. The exhibit enclosure was opaque, and the ladder leading up into the exhibit had room for only one visitor at a time; thus, the exhibit isolated the learning experience of the individual child. From the outside, parents could read a small sign explaining what was going on inside the exhibit, see world maps that were pasted to the outside of the opaque enclosure, and see a video monitor that displayed a continuous feed from the rotating camera, but they had no direct access to the ongoing experience of their child inside the exhibit.

The prototype exhibit was videotaped on three separate days; participants included 160 children and 93 adults. Coding schemes that addressed the ways visitors used and talked about the exhibit were developed, tested for reliability, and then applied to the videotaped data by a team of three researchers.

Findings suggested that the prototype encouraged children and parents to adopt conflicting learning goals for the exhibit. Of the 160 children, 97 climbed up into the exhibit enclosure. Of these 97, only 13 percent kept their heads in position long enough to be mapped. The other 87 percent either climbed back down the ladder before the mapping cycle was complete or swiveled their heads around to watch the rotating video camera.

Why did so many children fail? Much of the failure can be traced to parent

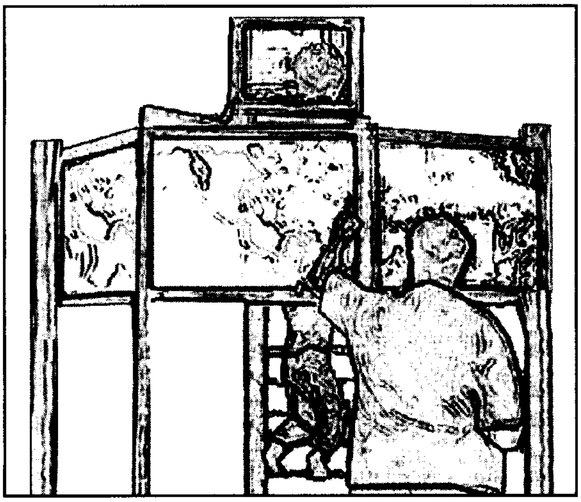

Figure 1 (left)
The prototype for the *Map Your Head* exhibit separated children's experience inside the exhibit from parents' experience outside the exhibit.

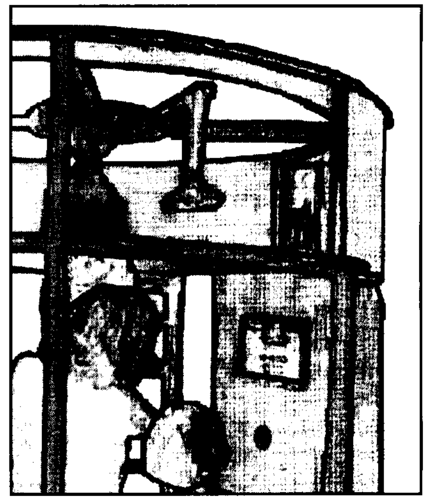

Figure 2 (right)
The revised version of *Map Your Head* supported close interaction between parents and children.

guidance. Consider the interpretation problem faced by parents standing outside the exhibit. From the outside, the most salient feature was the monitor displaying a continuous feed from the orbiting camera. Quite reasonably, parents often concluded that the point of the exhibit was simply to show their child on television: 46 percent of parents shouted out to their children that they could "see them on TV." By the same token, parents rarely provided support for the mapping interpretation. Only 30 percent of parents talked to children about climbing the ladder, standing still during the mapping process, and comparing the two images of the child's head. Meanwhile, inside the exhibit, children had the necessary information to adopt either the television or the mapping goal. However, parent support for the television goal, paired with lack of parent support for the mapping goal, encouraged children most often to show off for their parents by turning their heads to follow the camera, making faces, and waving.

A major focus of the revision of *Map Your Head* was to give children and parents the information they would need to adopt complementary learning goals (fig. 2). Where the prototype isolated the child inside the exhibit, the revision opened up the interface to include both parents and children. The enclosure has been reconstructed of plexiglass so that all visitors immediately see the rotating video camera. The enclosure now sits a few feet higher from the floor, making it easier for adults to approach the ladder without bending over. In addition to the video display at eye level for a child standing on the ladder, another video display was installed at what would be eye level for parents standing next to the ladder helping their child climb up. Finally, designers implemented a computer voice that guides visitors through the interaction and provides a few simple words of commentary to cast the experience as a mapping activity.

Interactions at the revised exhibit were recorded on three separate days and included 205 children and 154 adults. As opposed to the 13 percent success rate of the prototype, 84 percent of children who climbed the ladder in the revised exhibit got mapped. Along with the increase in children's success, more parents adopted mapping goals for the exhibit. Parent talk about the television interpretation dropped from 46 percent of parents at the prototype to 6 percent of parents at the revised exhibit, while the percentage of parents talking about the mapping interpretation rose from 30 percent to 66 percent.

By tuning *Map Your Head* to support complementary learning goals for parents and children, the project team made a commitment to support a collaborative model of learning. This collaborative model would not have been necessary if the only targeted outcome had been to increase the percentage of children who got mapped while using the exhibit. The prototype encouraged competition between parent learning goals and child learning goals. This competition could just as easily have been eliminated by suppressing parent input. For example, if the opaque enclosure had been extended to the floor and a child-sized door became the only entrance to the exhibit, children would have been isolated to the point that they could not have heard their parents suggesting the television goal. More subtle approaches exist as well. We have observed that in rooms with only one way in or out, parents often rest on benches near the door while children browse the space on their own. Simply moving the prototype into a such a room would probably have minimized parent "interference" and would certainly have been an easier (and cheaper) solution than redesigning the exhibit.

Before concluding, we would like to reflect briefly on the role of our research team in the exhibit design process. The exhibit designers at Children's Discovery Museum were not oblivious to the problems of the prototype; in fact, their recognition of the problems is precisely why our research team was invited to participate in the revision. Nor did our research team suggest design changes that were not already under consideration by the exhibit designers. We see the contributions of our research as primarily providing (1) an empirical basis for decisions about which revisions should be implemented; (2) a method to evaluate the success of exhibits in terms of collaborative learning processes; and (3) a more general framework for understanding how museum experiences can contribute to broader issues of learning and development, such as the development of scientific literacy.

Conclusion

In their dual roles as guide and interpreter, parents fundamentally shape children's scientific thinking during museum visits. We have reviewed evidence describing how parent participation can broaden and deepen children's experience in the museum. We have also presented evidence showing how children's learning can be undermined when exhibits lead children and parents to adopt competing learning goals. Although there are times when children learn in relative isolation, much of what they learn about their world they learn in the context of parent-child interaction. Our findings suggest that the most potent hands-on exhibits are those that recognize and support the collaborative learning of parent-child interactions.[3]

We believe the parent's roles as guide and interpreter generalize beyond the museum context. Hands-on exhibits provide children and parents opportunities to manipulate devices, explore possibilities, test ideas, and explain something new about the world. Although science and children's museums may have an unusually high density of these opportunities, we see no reason to believe that learning about science in a museum differs in any fundamental way from learning about science in other out-of-school settings. If we observe parents mediating children's scientific thinking during museum visits, perhaps they are acting as mediators in other contexts as well. Although we view this statement as noncontroversial, many existing models of children's problem solving and scientific thinking have yet to account for the ways cognitive development occurs through parent-child interaction. We hope our analysis of parent-child interactions in the specific setting of the museum can provide empirical evidence to guide new theorizing about cognitive development in general.

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NOTES

1. Many prior museum studies have not included fully informed participant consent. As university-affiliated scientists, we are required to obtain prior approval of research protocols from an institutional review board. Review boards require that when people are in direct contact with a researcher or when they are being videotaped, they must be informed about the nature of the study and asked to sign a release before participating. Parents must sign for any child under 18 years of age. Aside from our ethical and legal obligations as scientists, it also occurred to us that it was common courtesy to ask permission before filming families. Neither our research team nor the museum wanted to violate visitors' trust by subjecting them to covert video surveillance.

2. This particular zoetrope had an additional uncommon feature. Above each frame of the animation, there was a metal tab that could be raised or lowered by the visitor. A photoelectric switch was placed above the rim of the zoetrope so that when a raised tab broke the beam of light, it triggered the sound of a single hoof beat. We do not present analysis of the tabs here because of space limitations and because use of tabs was fairly infrequent.

3. We suspect that there are also social and emotional benefits to supporting parent-children collaboration during museum visits, but this is an open research question. Our current research focus is restricted to cognitive descriptions of scientific thinking and the development of scientific literacy.

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COMMENTARY

Compatible Goals and Continuing Questions: A History Museum Response

MARY LYNN HEININGER AND GRETCHEN WALTER

Mary Lynn Heininger has worked in curatorial and public programming capacities at Henry Ford Museum and Greenfield Village in Dearborn, Michigan, since 1989. Currently, she is the director for program research and development, responsible for developing and overseeing major new programmatic efforts, electronic learning projects, and museum learning theory and practice for program staff. She has also worked at the Strong Museum and the Minnesota Historical Society.

Gretchen Walter is a project developer at Henry Ford Museum and Greenfield Village, where she works with the furniture collection and conducts research on how museums can help visitors learn about the decorative arts. She recently completed her master of science in historic preservation at Eastern Michigan University.

We found much of value in Kevin Crowley's and Maureen Callanan's article, and we would like to comment briefly on three aspects of their work as presented here. First, we see the article's single most valuable insight—the one most universally applicable across science, history, and art museums—as the authors' insistence that practitioners develop compatible goals and experiences for the audiences with whom they intend to interact in an exhibition. The example of the *Map Your Head* prototype was painfully familiar. The solution to the problem was reassuringly, if ironically, common-sensical: *Map Your Experience!* As museums' educational ambitions grow and we attempt to engineer collaborative learning, we cannot be reminded too often of the tremendous and humbling power of this "new" variable of social interaction. Its power is far greater than that of all our careful work on content and design. The time visitors spend in our exhibitions is grafted onto the experiential foundation of their own interactions, interactions that can make learning in any environment sink or swim. A commitment to compatible goals and experiences—fully articulated, imaginatively implemented, and rigorously tested—gives us our best odds that groups will discover the intended message and enjoy teaching and learning from each other.

Second, this article raises a number of questions for further consideration and research. We wonder about the impact of this research methodology, in which the families were cued extensively and at various stages prior to their experience in the exhibits. Would a more naturalistic observation technique such as the use of hidden cameras have yielded different behaviors and possibly different results? It would be interesting to see whether parents engage with their children at the same level of interaction and for the same length of time with the zoetrope if they were not made aware that the exhibit was part of the study. Would they have made as much of an effort to understand the *Map Your Head* exhibit? Unobtrusive research such as that undertaken by Leichter, Hensel, and Larsen (1989) has revealed many fascinating behaviors, and those techniques may offer us even greater insight into how collaborative learning actually works in museum settings.

Another important question arises from the authors' statement that "a collaborative model of learning focuses the researcher on analyzing family interactions." While the family unit may be the obvious place to begin an examination of collaborative learning, we are curious about whether the types of interaction observed here could be duplicated in situations where the principal adults were not family members, but museum presenters, docents, or youth explainers. It is worth noting that the Getty Museum has offered enhanced tours in which staff facilitate collaborative learning about the paintings on display, and the participants—school classes as well as casual adult visitors—explore together how they think, feel, and learn about art. Intrafamily interaction offers something very special. Family stories are often shared and relationships strengthened. Parents are usually attuned to their children's unique learning styles and interests. But learning interaction in the family sphere has the potential to be negative as well. It is not uncommon to hear parents offering their children incorrect information about an exhibit, for example. The strong emotional connection among family members has the potential for positive and negative outcomes. If family dynamics are not good, the child may leave the museum environment with a very poor disposition toward future museum experiences. What changes in the learning, both for the better and for the worse, might be observed when collaborative learning takes place among nonfamily members? These questions are especially significant to history museums such as our own, since the "points of entry" for historical content are often based in family memories and because we tend to have interpreters or docents as part of our core staff.

Our final comment is to urge greater attention to something treated lightly in the article. As an aside, in discussing modes of learning, the authors state how difficult and rare it is to measure reliably "affective variables" of "curiosity, fun, or interest," and they seem almost to dismiss the possibility. We feel strongly that the need to assess (not the same thing as to measure) and understand these factors is central to museums' work. One of the negative impacts of our increasing educational ambitions is that sometimes we act as if the validity of our learning environments is solely dependent on what people learn at our site. We should know better. Much of the educational value of museums is our ability to encourage learning as a way of life, to provide experiences that help people grow their delight, satisfaction, and skill in making use of the museum of the world. When we genuinely embrace these affective and motivational aspects of learning, learn all we can about them, and then assess our work by these new standards, we will unlock new and important power in our work.

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COMMENTARY

Shared Lessons and Self-Discoveries: What Research Has Taught Children's Discovery Museum

SALLY OSBERG

Sally Osberg is executive director of Children's Discovery Museum of San Jose in San Jose, California, a position she has held since 1985. In that capacity, she works with a deeply committed staff and volunteer board to live the museum's mission and advance its vision: to provide learning experiences for children of diverse backgrounds and ages and for the adults who live and work with them—experiences that range from the joyous and engaging, if fleeting, single museum encounter to sustained interactions that deepen appreciation and understanding of the self, other people, and the physical world.

In their focus on children—in fact, children's museums describe themselves as "client-centered" rather than discipline based, singling out the criterion that most differentiates them from other museums—institutions like ours have had a blind spot when it comes to connecting with adults. At Children's Discovery Museum of San Jose, we came to the realization that while the child is indeed our client, the adult is our customer: the person who chooses to visit the museum, who drives, who pays, and who decides ultimately the value of the experience. The revelation is deceptive in its simplicity. Of course! But making this link launched Children's Discovery Museum in a new direction, one that acknowledged the absolute necessity of including grown-ups in the exhibit experiences we design.

Happily, this new strategic direction for the museum dovetailed with the opportunity to work with a team of developmental psychologists from the University of California at Santa Cruz (UCSC). As the museum's director, I particularly welcomed this chance. I was familiar with Barbara Rogoff's work on the sociocultural context for learning, and I knew that she and her colleagues were genuinely intrigued by the work we were doing with interactive exhibits. In addition, I was increasingly frustrated by standard exhibit evaluation rubrics and findings. Our previous efforts to assess exhibits for their effectiveness had not been particularly illuminating. We had called upon professional evaluators, each of whom approached the challenge as a communication issue: What do you as museum developers want your child visitors to "get" as a result of their interactions? This emphasis on cognitive grasp is fairly commonplace in the field, and the practice of formative evaluation depends upon it. At its best—and the evaluation firms and folks who worked with us were first-rate—formative evaluation is ethnographic in its methodologies: one pays lots of attention to what's going on. But even naturalistic observation funnels findings into a transactional learning model: the exhibit somehow possesses and communicates information, the visitor somehow extracts and understands the intended message. The exhibit developer is left to tinker with variables in order to clarify his or her intention.

Adding to our discomfort with this approach was our exhibit development framework. Our own culture and preferred mode of exhibit development was itself pretty constructivist. Developers at Children's Discovery Museum have had free rein to generate ideas and translate them into exhibits without submitting to more customary "team" processes. Our point of departure has always been fueled by an exhibit developer's own interest. One of our developers, for example, tackled the tricky business of rendering the microprocessor intelligible out of his remembered fascination with the clock relays governing the traffic signals of his youth. We were ourselves most comfortable building from our own individual experiences, following our own personal lights. Small wonder that we fell into the same theoretical model for our visitors.

Because we gave ourselves so much latitude in the exploration process, we were generous with our visitors. We attuned ourselves to children's insights, interpretations, and actions. When one professional evaluator reported to us that children were not "getting" the theme of rhythm underlying a series of exhibits on that subject, we pointed to evidence of children dancing. When our series of Rube Goldberg–style ATMs failed to show much sign of visitors' interpreting the system in terms of banking deposits and withdrawals, we noted children hoarding tennis ball currency—which we translated into their intuitive grasp of the concept of value. Recognizing that we were on slippery terrain, I adopted Seymour Papert's mildly revisionist term "constructionist" to describe our visitors' experiences:

> The word with the "v" expresses the theory that knowledge is built by the learner, not supplied by the teacher. The word with the "n" expresses the further idea that this happens especially felicitously when the learner is engaged in the construction of something external or at least shareable . . . a sandcastle, a machine, a computer program, a book. This leads us to a model using a cycle of internalization of what is outside, then externalization of what is inside, and so on. (Papert 1990, 3)

Papert's use of the word "shareable" is revealing, and yet, caught as we were in the paradigm of what Kevin Crowley and Maureen Callanan call "child-directed constructivist models" and wed ourselves to the "romantic notion" of individual discovery, we missed it at first. It took the pragmatic realization that adults were crucial to our business and our fortuitous partnership with the UCSC team to get us truly started on the quest to integrate adults into our learning milieu.

Our work with Crowley, Callanan, and their student research associates has itself been collaborative, becoming an exceptionally close and rewarding partnership—a benefit we had not anticipated. With their support, we have clarified our understanding of what an informal science learning environment is best suited to contribute, emphasizing the process of inquiry over the communication of facts and information. We have become better versed in general issues of child development, scientific thinking, and parent-child learning. And we found able and willing partners seeking to unravel some of the vexing questions of thinking, behaving, theory making, and learning. On the spectrum of collaboration—with "marriage of convenience" at one end and partnership at the other—we are true partners: expert in our own domains, trusting and respectful of one another, and genuinely curious about the rich and complex process of learning.

Other benefits have emerged from our partnership as well. Crowley and Callanan's carefully developed human subject protocol for studying adults and children in the museum involved gaining permission from visitors. Greeting our visitors, student researchers explained the study process and project and then secured written permissions from parents. In doing so, they communicated metamessages: that the museum is a place of learning, a site for important research about how children and parents learn, and a partner with a major university. What better way to set the tone for a value-added experience—something no "pay for play" franchise would ever offer!

Even more important, Crowley and Callanan's work provided a forum in which to discuss our effectiveness—always a dicey proposition when a group tries to critique itself or one of its member's creative offspring. Prior to integrating the UCSC team's research into our exhibit development work, we had struggled as a museum staff to share impressions about the way visitors used exhibits, our conversations consistently bogged down by deference and defense; wearily, we wrote off both behaviors as subjective. The research work, with its rigorous protocol and coding techniques, earned our regard. Here at last was a sufficient base of data, gathered in response to our questions, specific and general (How is this prototype working? What are people doing and thinking with it?), submitted to scientific analysis, and rendered back to us in terms we valued. To exhibit developers who spend hours on the floor watching visitors, the research findings often confirmed an intuition, while to other staff members, such feedback was illuminating, provocative, and useful. In effect, research took the element of judgment and critique out of our discussions, giving us the space and permission to focus on scientifically valid findings rather than personal impressions. Thus we were far more free to think and probe, released from the fear of hurting a developer's feelings, betraying personal bias, or missing some nuance of visitor experience.

In some wonderful ways, our own organizational learning has mirrored that of our visitors. Crowley and Callanan have served as Vygotskian-style mediators, helping us conceive exhibits that include rather than exclude adults. Even more important, they have helped us discover that the essence of constructing knowledge is as much in its being "shareable," in the process of co-construction, as in any intrinsic transfer of meaning between single exhibit and solo learner. Just as parent participation deepens children's engagement with the exhibit, so too have our research partners enhanced and expanded Children's Discovery Museum's learning about learning.

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