Science Education for Diversity and Informal Learning

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Importance of Informal Environments for Learning Science

Museums, science centers, zoos, and aquariums often serve as the "face" of science in the community where they operate. They are an important place for diverse communities to learn about and be excited by science and, subsequently, are in a position to serve as facilitators of communication, cooperation, engagement, and activism among the public, K-12 school science authorities, and science research institutions (both public and private). Informal science education institutions that adopt a sociocultural stance towards science and science education can provide an entrée to science for traditionally underrepresented communities by identifying science as a way of knowing along with other socially and culturally constructed paths to knowledge. The scientific community is beginning to recognize the importance of informal experiences to the development of appreciation for and interest in science in children and adults alike.

Dierking and Falk (2010) point out that scientific research and education communities are both interested in advancing the public's understanding of science. And they point out that people assume that children do most of their learning in school. In reality, children spend less than five percent of their life in formal classroom settings. Furthermore, people's knowledge and interest in science and the environment are shaped by everyday experiences.

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A report published by the National Academies, *Learning Science in Informal Environments: People, Places and Pursuits* (Bell 2009), indicates that everyday experiences contribute to people's knowledge and interest in science. The report notes that experiences in informal settings can significantly improve science learning outcomes for individuals from groups that are historically underrepresented in science, such as women and minorities. Evaluations of museum-based and after school programs indicate academic gains for children and youth from underrepresented groups. In addition, Bell (2009) indicates that, "Learning is broader than schooling, and informal science environments and experiences play a crucial role. These experiences can kick-start and sustain long-term interests that involve sophisticated learning" (p. 14). Falk and Needham (2011) have demonstrated that visits to a science center have long-lasting impacts on science and technology understanding, attitudes, and behaviors. They found that some of the strongest beliefs of impact were expressed by minority and low-income individuals. Simpson and Parsons (2009) point out that minority parents' decision to participate in informal science education hinges on their perception of the curriculum as culturally congruent.

These findings illustrate both the important role of informal education for engaging children in science but also the importance of considering diverse groups and cultures when designing and researching science learning in informal environments. Learning science in informal contexts is a complex process that involves the prior knowledge of the learners; guidance from others through conversation, text, and symbols; multiple perspectives about what is to be learned and the learning process; and reflection over time about what was learned. The conceptual framework for science learning used determines "what counts" as learning. According to the informal literature reviewed, learning in informal contexts such as science centers and zoos also occurs through visitors' interactions with exhibits. Learning also occurs through visitors' interactions and reflections with informal learning staff. The conceptual framework chosen by researchers allows them to examine these characteristics. Ways of viewing science learning determine how researchers and educators define and measure learning. Considering diverse ways of viewing science learning allows for the design and study of learning contexts that engage diverse cultures.

This chapter presents current sociocultural science education research about how best to design environments that support free-choice/informal learning for diverse audiences and applies this knowledge, presenting several examples of best practices. The chapter will also identify important features of informal learning in the context of diversity and equity issues. The chapter proceeds by, first, identifying key features of science learning in informal environments; second, describing the framework used by educators and researchers in designing and studying learning in informal environments; third, providing three vignettes illustrating the key features of science learning in informal environments; and, fourth, making recommendations for creating successful informal learning experiences for diverse groups.

Key Features of Science Learning in Informal Environments

In the last 20 years, research about science learning in informal contexts such as museums, science centers, zoos, and aquariums has proliferated. Researchers have examined learning in informal contexts such as science centers, museums, zoos, and aquariums; informal learning organizations have focused on family groups, individuals, and school groups and have asked diverse questions about science learning. This work has been situated in multiple research paradigms and traditions each of which approaches the concepts of learning and research from a different perspective.

The research studies below illustrate key features of successful science learning experiences in informal settings. Foundational to successful learning is the activation of visitors' prior knowledge. One of the most common strategies for this activation is through scaffolding provided by text, symbols, or interpreters. However, research also points to the importance of designing informal learning experiences that value the diverse array of knowledge and experiences of traditionally underrepresented groups. This can be achieved by designing experiences that acknowledge the multiple perspectives that visitors bring to an experience and through encouraging learners to reflect on their own experiences, knowledge, and values.

Activation of Prior Knowledge

Gilbert and Priest (1997) studied a school group's (8- and 9-year-olds) visit to the London Science Museum. They focused on locating critical incidents in learners' discourse that played an important role in the (re)construction of students' mental models. They found that recognition by the learners of a familiar object or action—something that they had previously observed or experienced in their lives—initiated discourse among the learners. They found that unexpected experiences with an invitation to explore further also initiated discourse. The initial surprise attracted learners' attention after which the learners eagerly offered comparisons and contrasts with familiar objects and actions. Guiding questions were also found to focus learners' attention and promote discourse among the group.

Gilbert and Priest (1997) also located critical incidents that allowed for the continuation of a line of discourse building more complex models about a concept. This occurred when learners were able to link a particular activity or object at the science center to broader experience—linking the particular to the general—and when experiences with different objects or actions inside the science center were linked by the learners. Alfonso and Gilbert (2007) have built on this result and note that these connections need to be made explicitly through text or other symbols in order for a meaningful link to be made to prior knowledge. Discourse was halted when the exhibit's prompts were not available to the learners—either because of their placement, their inappropriate content, or because they were missing (Afonso and Gilbert 2007).

Brody and colleagues (2002) discuss the role of prior knowledge in learning at Yellowstone National Park. They identified prior knowledge that was common to many visitors that served as "anchors" or "bridges" for their learning during and after their visit to the park (p. 1136). This prior knowledge tended to be knowledge about science concepts but was also related to the values that visitors associated with these concepts. For example, many visitors associated deep ocean thermal vents with unique and interesting life forms—after text linked Yellowstone National Park in the United States with deep ocean thermal vents, they valued the park differently.

Bamberger and Tal (2006) have also explored the influence of past personal experiences on learning in natural history museums and mechanisms through which visitors activate these experiences. They have found that moderately structured activities (where learners had choices, but textual information and prompts were provided for them) allowed for the most connection to prior knowledge and the most complex discourse when compared with completely free-choice activities or activities where learners had no choice.

Botelho and Morais (2006) have studied the characteristics of science center exhibits and learner-exhibit interaction and determined that links to prior knowledge are best made directly. That is, none of the linking process should be left to learners' imaginations. Exhibits that serve as models for physical phenomenon should be linked explicitly through symbols or text.

Hohenstein and Tran (2007) also emphasize the importance of textual, scaffolding prompts for informal science learning. They examined the effects of guiding questions on the conversations of visitors at a science center. Their research suggests that broad, guiding questions stimulate learner discourse but that the physical nature of the exhibit is also important—it determines how much attention learners pay to the prompts provided for them. It is important to provide these prompts for learning experiences, because, as Tunnicliffe (2000) has found, they create a storyline for visitors to follow at an exhibit.

Acknowledging and Valuing Multiple Perspectives

Ash (2004) identified characteristics to determine the mechanics that allow visitors to construct meaning using exhibit features. She recommends that exhibits have multiple "entry points," or multiple ways to understand what is essentially the same concept. She suggests that one way to accomplish this is to create thematic exhibits or exhibit clusters that focus on the big picture of science. She gives one interesting example: an exhibit or cluster that addresses the question, "When is something alive?" from multiple perspectives. The exhibits would provide simple prompts at multiple levels that promote discussion among learners of all backgrounds.

Zimmerman and colleagues (2010) examined the importance of diverse perspectives in the informal science learning of families. They analyzed the interconnectedness of individual cognitive resources, situated activities, and cultural resources that support learning and processes and found that families use a wide variety of knowledge to make sense of exhibit content in the area of biology by transferring cultural resources from prior experiences and two types of scientific epistemic resources to make sense of biological exhibits.

Falk et al. (2008) have developed typologies of visitor identities, which could be described as the visitor's motivations and role in a group (or individual) visit. Falk describes that through the analysis of visitor interviews and observation, he and other researchers found that learning outcomes of the visit are strongly linked to the visitor identity. He also notes that only one or two of the visitor identity types are strongly linked to the acquisition of science content knowledge. Visitors' identities determine how they will interact with the exhibit and their social group and determine what criteria will be used to determine the relevance and power of the information and experiences offered at the exhibit. This underscores the findings discussed above that visitors come to an informal science learning context with diverse motivations, knowledge, and experiences. Valuing these diverse perspectives is critical for creating and studying successful learning experiences.

Thus, the literature review shows that learning science in informal contexts is a complex process which at its foundation relies on the activation of learners' prior knowledge or experiences. Achievement of this for diverse populations involves careful scaffolding of visitor discourse and the acknowledgement and valuing of visitors' perspectives which are culturally situated. Both designers and researchers of informal science learning environments have recognized this strong connection to culture and have applied sociocultural frameworks in their work.

Sociocultural Frameworks for Informal Science Learning

Science education researchers have defined learning in several different ways. Foremost in each of the frameworks for learning developed in the research literature are the goals for learning science. These goals determine what "counts" as meaningful science learning in each framework and are essential to studying and designing learning contexts in which learners of diverse backgrounds, cultures, and interests can thrive. Because sociocultural theory emphasizes understanding the variability, as well as commonalities of the learning process, it is particularly well suited to understanding learning in informal contexts (Schauble et al. 1997). However, two types of sociocultural views of learning have dominated research and exploration of learning that occurs in informal environments. Each values a different outcome of science learning, searches for learning at different levels, and, hence, focuses on different units of analysis. The first is the social constructivist framework.

Sociocultural Approach with Individual Science Learning Goals: Social Constructivism

The social constructivist view focuses on changes to individuals' cognitive structures, but recognizes that those changes are created by both social and individual processes. This learning framework is commonly used in formal and informal science education research and represents a shift away from viewing "learning as individual cognitive growth to learning as individual cognitive growth in social settings" (Carlsen 2007, p. 58).

Learning takes place in the mind, but it is not simply an individual process; it involves dialogue with our environment—people, places, history, and culture. Glynn and Duit (1995) state that learning science meaningfully and being scientifically literate involves socially constructing and applying "valid scientific models" of the world.

The creation of a mental model requires the use of symbolic forms—a language with which to shape the representation. Therefore, language and learning cannot be separated from one another in the social cognitive framework. As Vygosky would argue, language and learning develop together (1978). Language is a social construction. It allows us to share our mental models with others. It is rooted in culture, history, and place because it originates with our mental models of the world. Therefore, both language *and* learning are social enterprises. This way of looking at learning has important implications for answering the question: How does one learn?

If learning is the construction of a symbolic mental model, then language must mediate this construction. Learning is a product of social interaction. Vygotsky (1978) described it this way: "Every function in the child's cultural development appears twice: first, on the social level and, later on, on the individual level; first, between people (interpsychological) and then inside the child (intrapsychological)" (p. 57). This process of learning has been termed social constructivism. Learning involves interpreting our perceptions of the world and organizing them into a mental model. But perceiving and organizing are mediated by language and social interaction. Social interaction directs our perception by focusing our attention, sharing pieces of mental models, and modeling the manipulation of physical objects.

Science learning with acquisition goals through social construction emphasizes opportunities for all learners to discover scientific principles through direct experimentation, discussion, and scaffolding from members of the learner's social group or through accompanying text. The process of experimentation would be the same for all learners—because through a combination of experience and guidance from their social group or another resource, they will be able to discover and acquire the same scientific principle. Questions posed are intended to create dialogue among learners and to guide them towards a particular change in their mental models. Together the learners and guide work towards building a consensus model that resembles the scientific conceptual model. It represents a shift away from viewing "learning as individual cognitive growth to learning as individual cognitive growth in social settings" (Carlsen 2007, p. 58).

The goal of science education according to this framework is the construction of scientifically valid mental models. It views scientific literacy as property of the individual. Learning is a social process that is internalized by the individual and becomes property or part of that individual. Informal science education institutions have adopted these goals for science education and used them to develop programs, exhibits, and fieldtrip experiences (Yager and Falk 2008).

This framework may not best capture the complexity of science learning at museums, science centers, zoos, and aquariums. Unlike school science classes, the visitor determines the goals and agenda for experiences at informal science institutions, and often learning scientifically valid models of the world is not a primary goal of their visit. This does not mean, however, that visitors to informal learning institutions do not or cannot learn science during their visits. The conceptualization of science learning as change, through individual or social means, is not fruitful for research about what and how visitors learn in these contexts. As Minda Borun (2002, p. 245) explains, "The learning unit . . . is not the individual, as in a classroom setting, but the small group." Learners visiting the zoo or other institutions are not visiting with the intention of demonstrating their knowledge in an exam or other individual assessment. The science learning that occurs is the result of contributions from individuals with diverse backgrounds and prior knowledge. Thus, science learning in the context of science centers, zoos, museums, and aquariums must be examined as a product of this social interaction and be examined on the group level, rather than the individual level.

Sociocultural Approach with Community Learning Goals: Collective Praxis

Learning frameworks with participation goals for science learning represent a much broader view of learning than the acquisition view. Learning is larger than the uptake of scientific concepts and processes or the participation in a model scientific community. They focus on more than individual mastery or accomplishments and view science learning as a collective enterprise that is more than the sum of its parts. Roth and Lee (2002) describe this framework as "collective praxis." They place science learning entirely in the social realm. Scientific knowledge is greater than the individuals who collectively create it; it cannot be reduced to characteristics of individuals.

This way of viewing science learning and scientific literacy does "not have boundaries coincident with formal education" (p. 33) and can accommodate the diverse forms that science takes as it is situated in everyday lives (Jenkins 2002; Roth and Lee 2004). This framework for science learning deemphasizes the science of scientists, such as the valid scientific models and concepts discussed in the previous framework, and focuses instead on how groups of people make use of and act upon their knowledge of science and science resources (Roth and McGinn 1997).

The process of communicating, locating, and acting upon scientific knowledge requires the use of language but also broader modes of communication (Jewitt et al. 2001).

Science learning as collective praxis provides opportunities for all learners to engage science in a context that is meaningful for their group or community. There are no set procedures or steps to follow. The group negotiates meaning by drawing upon the resources at hand and is encouraged to find and utilize new resources. Questions posed are reflective in nature—intended to assist the group in making decisions about what is important in their particular learning situation.

Science learning in an informal context represents a much broader view than the uptake of scientific concepts and processes or the participation in a model scientific community. It must focus on more than individual mastery or accomplishments and view science learning as a collective enterprise that is more than the sum of its parts. Science learning in informal contexts occurs socially, but the knowledge created is greater than the individuals who collectively created it. This way of viewing science learning and scientific literacy does “not have boundaries coincident with formal education” (p. 33) and can accommodate the diverse forms that science takes as it is situated in everyday lives (Jenkins 2002; Roth and Lee 2004).

In the real lives of visitors to informal science learning institutions, science cannot be separated from other forms of knowing—it is integrated with values, morals, subjectivities, tradition, and beauty. As Feyerabend (1975) contends, there are no criteria with which to demarcate science from other ways of knowing.

This way of viewing learning has also been described in other contexts as socially situated learning (Lave and Wenger 1991). Rather than being the creation of a mental model of the world through individual or social processes, science learning is the act of participation in a community. Members of the community have different levels of experience and prior knowledge. It is the distribution of prior experiences and knowledge that allow members to collaborate and create knowledge. The process of working together to create knowledge is where learning resides—it is not located in any single individual.

Science learning in informal learning contexts has been studied using participatory conceptual frameworks. Ash (2002) has also developed an explicitly participatory conceptual framework for learning science in informal contexts. Her framework for science learning is based upon Vygotsky’s (1979) zone of proximal development. This is the space where collaboration and meaning making occur between individuals with distributed expertise (Ash 2002, p. 359). “Purposefully collaborative family conversations are both process and product, and are set within a larger activity system that has multiple purposes, such as having fun and learning new ideas” (Ash 2002, p. 361). Ash has used this participatory framework for science learning and used it to examine how family groups make meaning during experiences at science centers and museums.

She reports (2003) that families visiting the Exploratorium in San Francisco emphasized a wide variety of inquiry skills including observation, questioning, comparison, explanation, interpretation, reflection, and analogical modeling. Ash (2004) has also found that families at a natural history museum used questions to create organizational patterns in which to situate their new knowledge, to invite all members of the family to co-construct meaning, and to sustain ongoing content themes deemed important for learning by the family. Thus, having multiple access points or multiple ways to understand the same concept has the ability to promote dialogue and diverse perspectives.

The Practice of Informal Science Education for Diversity

Bell and colleagues (2009) provide several recommendations to education developers in informal science learning institutions. Two of those recommendations are to "provide multiple ways for learners to engage with concepts, practices and phenomena within a particular setting" and to support learners in interpreting "their learning experiences in light of relevant prior knowledge, experience and interests" (p. 6). They reiterate that science learning for diverse audiences, and ultimately all audiences, hinges on the collaboration of a learner and a guide (adult or more advanced peer). Hence, providing space for these collaborative dialogues to take place is essential for informal science learning institutions.

What follows are three research examples of such collaborative science learning events in informal institutions conducted by Parker (2009). Each highlights the roles that the design of the environment and the social interactions among the learners play in creating such collaborative environments.

Examples of the Impact of Exhibit Design on Collaborative Talk

The family in Example 1 uses exhibit text in two related ways: to frame the exhibit and direct their observations, as a source of new vocabulary with which to describe their observations.

Example 1

Mom: Did you guys look at this thing over here where it says domesticated or wild? Do you wanna read that?
Mom: Let's go over and read the sign.
. . .
Sam: (reading) A transformation nomadic hunting and gathering lifestyles to farming took place around 10,000 to 12,000 years ago in the middle east.
Mom: mmhmmm
Gabby: (reading sign) Imagine what your life would be like without dom-domesticated plants or animals.
Mom: Is autumn domesticated?
Sam: Yeah
Mom: Yeah

12 Mom: Is Gus domesticated?
13 Sam: Yeah
14 Mom: Yeah
15 Mom: Elsie?
16 Sam: Yeah
17 Mom: How ‘bout um, Grandma’s things that she has in her garden?
18 Gabby: Yeah
19 Mom: Plants can be domesticated too
20 Gabby: Yeah, there it says from weeds. (points to sign)

The mother in this family approaches the zoo learning experience as a guide with the intention of directing her daughters’ attention and the conversation so that they notice how a scientific concept such as domestication applies to their daily lives. Mom also uses the text at the exhibits to focus her observations and guide the girls as they create explanations.

The family in Example 2 often shared control of the science learning discourse in ways that allowed multiple family members to contribute ideas and practice using science terms, prior science knowledge, and observations to justify their ideas and explanations. The next example displays how the family uses a collaborative discourse to build explanations.

Example 2

1 Dad: Did you see what he did?
2 Scott: Yeah, he sticked his tail out.
3 Dad: He grabbed something with his tail–he used it to grab somethin’.
4 Scott: Mulch, I think.
5 Dad: Mulch? That’s what it looked like.
6 Scott: A spider monkey, these are spider monkeys (looking at sign).
7 Dad: Is that what they are?
8 Scott: Yeah, it says right there. Spider Monkey.
9 Dad: Look at his tail . . .
10 Dad: Look at the end of his tail. Look at the end of it.
11 Scott: Ohh
12 Dad: On the underneath side. There’s no hair, you see it?
13 Scott: Oh yeah
14 Dad: It kinda looks like a really long gorilla finger or somethin’ doesn’t it?
15 Scott: Yeah
. . .
16 Scott: Dad, it says um the grasping tail that works like a fifth hand. Its tail it
17 works like a fifth hand.

In Example 2 Dad and Scott use observations and the exhibit text to learn how monkeys use their long, agile tails. In lines 1–5, Dad and Scott describe their observations of the monkey’s behavior (using its tail to retrieve a piece of mulch located beyond the barrier of its enclosure). Dad makes additional observations about the characteristics of the monkey's tail (line 10). Scott seeks out and retrieves relevant information from the exhibit text that explains their observations and reports it to the group (line 16). Both Dad and Scott contribute to the building of the explanation using observations and available text.

In Example 3, Dad, Scott, Mom, and Maggie were able to fully integrate the exhibit text into their collaborative explanations. For example, when discussing an eagle's nest size (lines 21–25), Dad and Mom refer to the model to elaborate on their understanding of the actual nest size question asked by Maggie.

Example 3

Maggie: Look at that.
Dad: That's the eagles' nest.
Scott: Wow.
Dad: Wanna set in it? Wanna be a baby eagle?
Maggie: Nnn (shakes head)
Scott: I will
Mom: No?
Maggie: I'll be a mother.
Dad: You'll be a mother eagle?
Dad: That's a pretty big eagles' nest huh?
Scott: Yeah. So this is what an eagles' nest looks like?
Maggie: (inaudible)
Dad: Yeah, what is that called, aerie? aerie?
Scott: I think
Dad: That one–
Scott: I don't know. I thought it was really an um teepee thing that's in there (moves to wingspan painting).
Dad: I saw the teepee thing in there.
Dad: Called an aerie (looking at sign and reading aloud) one of the largest birds' nests in the world.
Mom: Is that the actual size?
Dad: I think it–(goes back to sign)
Scott: My arms—(moves from wingspan painting to model nest)
Dad: (reads sign aloud) Two feet deep and five feet wide.
Dad: Yes, that's the actual size.
Mom: Ohhhh.
Scott: That's an–
Dad: (reading sign aloud) Bald eagle uses the same nest year after year continually adding materials to the nest, aeries have been found that are at large as 20 feet deep with a weight of more than two tons.
Mom: My goodness
Scott: Whoa
Scott: Alright now–
Dad: 20 feet deep, my land, that's a house.

Example 3 illustrates how text is consulted as a supplement to the collaboration and in the context of Mom's (line 21) and Sam's (line 11) questions about the model's relation to a real Bald Eagle nest. During collaborative explanations, the text is consulted as a resource in the context of the group inquiry, rather than as a frame through which to view the exhibit. A science learning event at the Bald Eagle Exhibit illustrates how the design of this exhibit allowed them to access the information using multiple approaches including role-play.

Leinhardt and Knutson (2006) have shown that learners' roles change throughout their experience at museums, science centers, and zoos. They studied grandparent-grandchild groups at a natural history museum to explore the roles and identities that members of the group displayed during the visit. They can become learner, teacher, modeler, storyteller, historian, scientist, and mediator within the same visit. The exhibit itself can provide structure for these multiple and changing roles through prompts and scaffolding that support multiple roles and perspectives. Members of these families played different roles during science learning events. Parents acted as guides in parent-directed explanation—a role similar to "teacher" as described by Leinhardt and Knutson (2006). But they enacted other roles during collaborative explanation: Dad in Example 1 described one of his roles as "devil's advocate."

Text at exhibits can create a frame for interpreting observations. However, easy access to scientific vocabulary and explanations can encourage parents to use this text to "teach" the group in a directed manner and can limit the ability for the group to contribute their own interpretations and culturally relevant knowledge.

Gilbert and Priest (1997) also found that successful consultation of the exhibit text helped the groups to continue their discourse at the exhibit. They describe this consultation occurring after the group has initiated interaction and conversation at the exhibit. They then consulted the text to assist them in thinking about or explaining their initial observations.

How social groups understand or approach learning in informal environments is also a factor in how they construct explanations during their science learning events. Tunnicliffe (2000) has found that exhibit text creates a storyline for an exhibit. She studied learner conversations at a robotic dinosaur exhibit cluster at London's Natural History Museum. All facets of the exhibit related back to a primary, broad storyline (in this case, that dinosaurs had very diverse diets), and this scaffolding helped keep learners' discourse focused towards the exploration of a big picture or theme. The storyline is not meant to convey a certain set of facts (although some facts are present), but to encourage and sustain the sharing of ideas on a broad subject.

Gilbert and Priest (1997) reported that when experiences with different objects or actions inside the science center were linked by the learners, meaning-making discourse was initiated and sustained by the group. Their study focused on an exhibition in a science center that had a clear theme that was known to the visitors because it was the title of the exhibition.

In studying a video-based exhibit, Stevens and Hall (1997) found evidence that creating records of experiences at a science center allowed learners to reflect on their experience at that exhibit but also provide a catalog of learner experiences for the next learner to view and model or utilize in some way—effectively broadening the social interaction from which learning is constructed. This reflection process also allowed visitors to treat learning as a continual process that continues after the actual experience at the exhibit has ended. Creating a space for reflection over learning at each exhibit and during the visit as a whole could improve visitors' ability to connect exhibits to each other and encourage visitors to view science learning as a process rather than a collection of facts.

Getting family visitors to focus upon and discuss the "big ideas" of science during and after their visits assists informal learning centers, including zoos, in achieving their stated educational objectives. Emphasizing broad themes rather than disconnected concepts also assists visitors in recognizing science as more than isolated explanations of observations and support a view of science as one of many ways to understand and interact with their environment.

Anne Lorimer's (2007) exploration of a "hands-on" exhibit on commercial aviation at the Chicago Museum of Science and Industry raises important questions about how we approach teaching and learning science at informal education institutions. How should we portray science and technology? How are science and technology perceived by visitors? Lorimer's study showed that visitors do learn, reflect, and make connections with their own lives about science and technology during their time at museums and science centers. She explored one case where the connection made was emotional and deeply personal—a reminder of unrealized adolescent aspirations. For others the visit reinforced their broader feelings of alienation from science and technology.

The museum's goal was an admirable one: to create a sense of excitement, wonder, and infinite possibility in young visitors and their families. The visitors, however, took those feelings of wonder and connected them with their personal experiences with science and technology—associating the wonder and awe felt during the visit with something that was unattainable. They were constructing or reconstructing knowledge about science and technology that placed a boundary between science and technology and themselves. The exhibit developers did not intend for visitors to interpret their exhibit in this way. As informal educators, we cannot control the meaning that visitors construct at museums and science centers, but we can help to shape that meaning by providing the necessary context and resources to visitors and our community.

Lorimer's study is a wake-up call for informal educators. It shows that even with the best of intentions, our exhibits can have results that are opposite of those that we expect. Visitors do make deep, personal connections at the museum and science center, but simply providing them with objects to manipulate is not enough to help guide their meaning making. Science and technology presented without the context or resources that visitors need to integrate new knowledge in a positive way may end up reinforcing previous understandings of science and technology as something unattainable. Placing science on a pedestal reinforces visitors' views of science as "other," as separate from themselves. Museums and centers that focus on science and technology must change their approach—away from contextless exhibits focused on very narrow concepts, towards broad themes in science and technology that touch everyone's lives.

Involving Diverse Groups in Development of Programs and Exhibits

One way to change this is to better integrate science museums and centers into the community. Involve community groups in development and discussion about programs and exhibits. Help visitors personally connect with exhibits by basing the exhibits on local concerns, interests, and resources. Most importantly, reach out to community groups who are not typically associated with science centers. Fight the alienation from science and technology that Lorimer describes by purposefully including a diverse array of groups and interests from the community.

AAAS (1993) has suggested that the best way to promote "science for all" is to emphasize the nature of science rather than individual science concepts. Part of learning about the nature of science is thinking about the human, personal, social aspects of science and technology–connecting science and technology to our lives, our society, our history, and our culture and giving context back to science and technology. The research indicates that surrounding science and technology with context that assists visitors with connecting it to their own lives and promotes learning dialogue among visitors, their families, and friends is the way to create a meaningful informal learning experience.

What follows is a series of practical steps that informal science institutions can take to involve community groups in the development of exhibit content and programs:

- Step 1: Make connections with representatives of community groups.
- Step 2: Compare suggestions and interests from the community with a theme.
- Step 3: Research other informal learning centers for the physical context.
- Step 4: Develop learning objectives for the exhibits.
- Step 5: Draft the exhibit design and text.
- Step 6: Construct the exhibits and conduct pilot visits with the community.

To elaborate on each step, we have included specific recommendations for involving diverse groups in the development of programs and exhibits.

Step 1

Make connections with representatives of community groups—especially those not typically associated with the science and technology center (civil rights groups, church groups, cultural groups, neighborhood associations, etc.). Hold a town meeting to present the theme for the future program and solicit input from the community. Connecting with community groups that have not previously been associated with the center may take extra time and effort.

Step 2

Compare suggestions and interests from the community with the theme, the nature of science, and determine how they could be integrated into the theme. For example, suggestions might include questions about how scientists do their work such as, “Do all scientists follow the same procedures or method?” Another community group may be interested in the history of science as an accepted way of understanding the world. Both of these interests could be integrated with the issues that comprise the nature of science. Part of the program could focus on scientific inquiry and explore issues of how something is “known” in science. Another part of the program could focus on the history of science and its position in society. Ideas for portions of the programs should be created from the community suggestions then the final ideas that will become exhibits in the program will be selected by science and technology center staff. The final ideas for exhibits should be easily connected so that exhibits have continuity and so that exhibit ideas echo the representation of the nature of science in Science for All Americans, Chapter 1 published by AAAS (1990).

Step 3

Science and technology center staff and volunteers should research the development of other exhibits focusing on the nature of science at other informal learning centers to gather possibilities for the physical contexts of the exhibits. Pedretti (2002) reviews several recent examples of exhibits focusing on the nature of science: *A Question of Truth* at the Ontario Science Center which focused on science as a human endeavor, the history of prejudice in science, and science’s interaction with the local community; *Science in American Life* at the Smithsonian explored the history of science and technology’s positions and roles in society; *Birth and Breeding* at the Wellcome Institute for the History of Medicine in London explored the role of biology, medicine, and social sciences shaped the perception of motherhood in the current culture; and *Mine Games* at Science World in Vancouver focused on engaging visitors in open discussion about the costs and benefits of mining science and technology to society. The physical contexts of each of these programs should be examined and a list compiled of possible ways to approach the exhibits (hands-on, interactive, visitor forums, dioramas, etc.). The choice of physical context for the exhibits should focus on what selection of approaches would allow for access by the visitors with the widest range of physical and academic abilities, allow for flexibility/choice by the visitor so that each experience can relate to their personal background and interest, and allow for the simplest access to resource information (supplemental text, discussion questions, prompts, pictures, etc.) by visitors. For example, an exhibit focused on the methods used by scientists might include a hands-on section where geology/paleontology is compared with experimental biology, an interactive area where visitors construct and receive feedback on their own “scientific method” using computer technology and a video area showing biographies of scientists who approached science in diverse ways—Darwin and Rachel Carson, for example. An exhibit focusing on the history of science as a way of knowing might include an interactive timeline (which responds to touch) which discusses ways of knowing in various cultures from Ancient Egyptians, through the present day, a hands-on mystery box that lets visitors experiment with how they "know" what's inside, and a daily visitor forum that discusses the role of science and scientists in current society.

Step 4

After the exhibit ideas and approaches have been finalized, science and technology center staff should develop learning objectives for the exhibits. These objectives should echo the basic concepts of the nature of science developed by AAAS (1990). For example, a learning objective for an exhibit about scientific methods that corresponds with AAAS' description of the nature of science: Learners should be able to discuss the diverse ways that scientists interact with their world including passive observation, description and collection, active probing and experimenting. An exhibit that focuses on the history of science's role in society could have the following learning objective: Learners should value science as an important way of understanding the world, but recognize that it does not have special authority as the only way to understand the world.

Step 5

Draft the exhibit design and text. Share the exhibit drafts with the same community groups that provided suggestions at the beginning of the process and incorporate their feedback wherever possible. Be sure to consult with disability advocates to check the accessibility of the exhibit designs.

Step 6

Construct the exhibits and conduct pilot visits with the community. Use the information gathered from these pilot visits to fine-tune the design and text at each exhibit. Specifically, collect observations and data to determine if the exhibits meet objectives 1a and 1b. Use this opportunity to prepare the science and technology center staff, management, donors, volunteers, and educators for the full implementation. By involving the community in the development of the program, hopefully they will be familiar with the program's theme and objectives. The center's staff, volunteers, management, and donors will also have had the opportunity to take part in the development of the program so they should also be familiar with the program's goals and objectives. Extra preparation should be given to docents and educators who will interact with visitors at the exhibits. Familiarize them with the concepts involved in the nature of science by giving them copies of

Science for All Americans. Provide them with training on good question asking (wait time, open questions)—inform them that they will be facilitators of dialogue and not sources of information. Allow them to practice these skills during the pilot program.

In Conclusion

It is clear from the literature and from the studies conducted that informal science education via museums, science centers, zoos, aquariums, etc. can play a positive role in not only learning science, but also in providing opportunities for diverse populations. The examples provided from the literature and our own research point out the importance of multiple ways of meeting the diverse needs of informal education visitors in order to help them achieve their goals. As our examples show, the visitor has multiple opportunities to utilize exhibit information in order to answer their own questions. Visitors treasure their direct experiences and value opportunities to inquire into informal education. Visitors also need to recognize that they bring diverse and cultural experiences with them to the informal setting. Text, observations, interactions, direct experiences, and the use of artifacts and models all contribute to the opportunity to provide diverse experiences for successful informal education experiences.

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