Literature Review for the *Sweet House* at Garfield Park Conservatory

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OVERVIEW

Garfield Park Conservatory is currently developing the *Sweet House* exhibition, which is designed as an experiential environment where visitors will learn about photosynthesis. Specifically, the exhibition will focus on four major components of photosynthesis: air, water, light, and sugar. As part of the early development of the exhibition, we conducted a brief literature review on people's understandings of photosynthesis as related to the above-mentioned topics. In addition, since the exhibition will rely on an immersive environment, we also searched the literature for research about creating successful immersive exhibitions. Following is a summary of our findings.

PEOPLE'S UNDERSTANDING OF PHOTOSYNTHESIS AND RELATED TOPICS

Research suggests that people's understandings vary relative to the four major components of the exhibit: Air, Water, Light, and Sugar. Almost all the research we found has been conducted with children, but Borun *et al.* (1993) note that "a common misconception about misconceptions is that they are held by children and replaced by formal instruction….However, our findings indicate that naïve notions are widespread among adults."

In general children have critical misconceptions about how plants get their food, and these misconceptions often persist despite instruction (Roth, 1985). Although many children seem to have developed at least a partial understanding of the needs of plants, they are often confused about key concepts related to photosynthesis. For instance, most fifth graders in a Michigan classroom identified sun, water, and soil as the basic needs of plants, but few seemed to know about plants' need for air. Also, most of these students considered the soil to be the source of the plants' food (Smith & Wesley, 2000).

What follows is a more detailed look at people's—especially children's—ideas about the four concepts that will serve as the basis for the exhibit.

Air

Simpson & Arnold (1982a) found that most 11- and 12-year-old children could use the word "gas" in conversation and give examples of one or more true gases (68% named oxygen and 45% named carbon dioxide)

Here are some alternative understandings held by large numbers of children in one or more studies:

- **Which substances are gases?** In one series of studies, many children classified both carbon and carbohydrate as gases (Simpson & Arnold, 1982 a and b).

- **How do plants use air?** Most primary and many secondary children stated that either plants do not use air *or* that plants use air in opposite ways from animals (Simpson & Arnold, 1982b, their italics).

- **Do plants respire?** Many children stated that plants do not respire, or do so only in the dark (Simpson & Arnold, 1982b). Barrass (1984) implicates teachers and textbooks in perpetuating this misunderstanding.

- **How does gas enter plants?** Many children stated that the gas used in photosynthesis enters the plant through the roots or stem (Simpson & Arnold, 1982b).

- **Which gas does what?** Haslam & Treagust (1987) found that younger secondary students, in particular, were easily confused about the roles various gases play in photosynthesis. For instance, about a quarter of the younger students agreed that more carbon dioxide was given off by plants in sunlight, and almost equal numbers agreed that oxygen was used to make food.

- **"Carbon dioxide *can't* be a building block of sugar!"** Why? Because carbon dioxide is a gas, and gases don't weigh anything! According to Fisher & Moody (2000, p. 58), "A great many people believe that gases have no weight because we cannot feel the air around us." Given that belief, it makes perfect sense to deny that carbon dioxide could contribute carbon to make sugar, because sugar does have weight.

This last "alternative understanding" demonstrates an important point: People's alternative frameworks often make perfect sense given their limited experience of the world, and basic scientific ideas are often counterintuitive (Fisher & Moody, 2000). Overall, the research cited here suggests that there are several basic—and very important—concepts about air that should be clearly and convincingly explained in this section of the exhibit: Plants *do* need air, the air needed for photosynthesis enters through the leaves, and one part of the air really *does* contribute to the weight of sugar. Exhibit developers and designers will have to decide the best strategies to deal with these concepts, and the effectiveness of their strategies will have to be tested during formative evaluation.

Developers and designers will also have to decide how to deal with the concept of respiration in plants—comparisons between "breathing" in people and plants may ultimately prove confusing (since green plants *both* photosynthesize *and* respire).

Water

As noted earlier, most children seem to understand that plants need water. However, they often misunderstand the role that water plays in the growth of plants.

- **Water is food**. Many children describe water as food for plants, sucked up by the roots (Smith & Anderson, 1984). Many authors have noted ways in which this belief parallels discredited scientific theories, such as Van Helmont's theory that water is food for plants (Eisen & Stavy, 1992; Wandersee, 1986).

- **Ideas persist**. Boyes & Stanisstreet (1991) found that more than a quarter of first-year undergraduates thought that plants got their energy from soil and/or water.

These results suggest that the exhibit's interpretation will have to explain very clearly that water is one of the ingredients for making sugar, but not in itself a source of energy for plants. We're also curious about what visitors understand about wilting, and how they relate that to plants' production of food (if at all). We will continue to look for research on this subject.

Light

Simpson & Arnold (1982a) found that only a few 11- and 12-year-old children spontaneously described the sun as a source of energy, and that even this understanding was somewhat tenuous. "Of those few who asserted that the sun or a light bulb gave out energy and that this was a combination of heat and light, half immediately then *denied* that heat and light were, in fact, energy" (Simpson & Arnold, 1982a, p. 70).

In many ways, a child's understanding of energy is limited to the way the term is used in everyday language:

- **Function of sunlight**. Students interviewed by Bell (1985) appeared to have little understanding of the function of the energy obtained from sunlight. They knew sunlight was a requirement, but they didn't know why.

- **Energy is for movement**. For many children, the use of energy was associated exclusively with movement. These children are using the term "energy" in an everyday sense of being energetic (Bell, 1985). Children with this partial understanding may fail to consider that plants (and animals) must use energy just to stay alive (e.g., for metabolic processes) (Simpson & Arnold, 1982b).

- **Sun desirable, not necessary.** Incomplete experiences can lead to misunderstandings about the role the sun plays in plant growth. As a result of an experiment where grass seeds were grown in the dark, most members of a fifth grade class concluded that plants don't need light to survive, although light does help make plants healthier. These conclusions were based on the observations that the seeds did grow in the dark—they even grew taller—but were an unhealthy, yellowish color (Smith & Anderson, 1984).

It's clear that children have a limited understanding of the role that light plays in the lives of plants—and that they often misinterpret the demonstrations traditionally used in schools to explain these ideas. It seems likely that the Light section of the exhibit will require both creative exhibit development and intensive formative evaluation. It also seems clear that the intersection of the four areas—focused on the sun—will have to build basic understandings about energy as well as interpret the overall process of photosynthesis.

Sugar

We were interested to find that most of the research papers we read talked about plants producing either food or carbohydrates—children's understandings of *sugar* production was not a major focus of this research. We found one warning in the work of Barker & Carr (1989a). They described the results of experiments where students tested leaves for starch under various conditions, and concluded that:

> *Pupils found the anticipated conclusion, that plants contain starch and/or sugar, difficult to reconcile with their everyday experiences….(Except for nectar and sugar-cane) plants patently do not taste sweet* (Barker & Carr, 1989a, p. 42).

Although there has been little research about what children know about sugar, it's clear that many of the problems with children's understandings about photosynthesis may be traced to the everyday understandings of related terms, such as "food," "producer," and so forth. Many children expressed these sorts of beliefs:

- **Food from the soil**. Most primary and many secondary students stated that the food stored and used by green plants was obtained from the soil, through the roots (Simpson & Arnold, 1982b). The food, in this case, might be considered either water, fertilizer—plant food—or anything else taken in from the outside, including air (Bell, 1985).

  Many authors have noted ways in which this belief parallels discredited scientific theories, such as Aristotle's theory that plants get their food from the soil (Eisen & Stavy, 1992; Wandersee, 1986). These ideas seem to persist over time. Boyes & Stanisstreet (1991) found that more than a quarter of first-year undergraduates thought that plants got their energy from soil and/or water.

- ***Only* producers**. Children who have a tentative understanding of terms like "producer" and "consumer" tended to think of green plants as *only* producers—they don't seem to realize that plants also consume food (Simpson & Arnold, 1982b).

- **What substances are gasses**? As noted previously, many children in Simpson & Arnold's studies classified carbohydrate as a gas (Simpson & Arnold, 1982 a and b).

It’s interesting to speculate that, by focusing on *sugar* as a product of photosynthesis, the proposed exhibit may avoid some of the problems inherent in the use of terms like “food” and “carbohydrate.” This speculation will have to be tested through formative evaluation. Developers will also have to decide how they want to use the term “food” in the exhibition. If visitors are going to develop scientifically correct understandings of photosynthesis, they will eventually have to confront any alternative ideas they have about plants and food.

- **Building blocks and products**. Simpson & Arnold (1982a) and Bell (1985) speculate that children may have difficulties learning the scientific concept of photosynthesis because they misunderstand basic concepts about the building blocks and products of photosynthesis, not because the overall idea of photosynthesis is too abstract. If this is true, helping visitors better understand the components of photosynthesis—air, water, sun, and sugar—may eventually aid their understanding of the complete concept in ways that won’t be apparent until long after their visit.

Academic Science and Everyday Experience

Some difficulties in understanding photosynthesis can be traced to what happens when academic science and everyday experience overlap. The studies we read pointed to a number of dualities in children’s lives which may interfere with their understandings of scientific concepts.

- **Two meanings**. Many misunderstandings occur because key words like “energy,” “food,” and “respiration” mean different things in academic and everyday contexts. Children can not distinguish between the two uses (e.g., Solomon, 1983, on energy; Simpson & Arnold, 1982b, p. 179, on food; and Barrass, 1984, on respiration).

- **Two worlds.** Some authors, like Lijnse (1990), take the distinction between academic and everyday even further. Lijnse writes about the two very different worlds in which physics students must think: Their life-world and the World of Physics. In their life-worlds, students can function quite well with their “natural thinking about energy,” which “is characterized by its strongly anthropomorphic, material (substance-like), causal, and nonmathematical character.” Such thinking works pretty well in everyday life, but it fails miserably in the world of physics.

- **Two theories**. Simpson & Arnold (1982b) point out that children’s own theories may coexist with the theories they were taught in science class. However, when children make no meaningful links between the two, the scientific theory may be merely rote learning. They found that when children believe that plants take food from the soil, they can still learn the scientific theory—but they often abandon scientific thinking when their everyday reasoning seems to work (Simpson & Arnold, 1982b, p. 181).

What Do Adults Understand About Photosynthesis?

Although all the research discussed in this report was conducted with children, we'll repeat the earlier quote from Borun *et al.* (1993): "Our findings indicate that naïve notions are widespread among adults."

A number of studies have been conducted with college students. Although they show that many older students have developed scientifically correct understandings of photosynthesis, some students still maintain their alternative views despite what they have learned about the science. For instance, in surveys of first-year British undergraduates, Boyes & Stanisstreet (1991) found that 93% said that they were sure plants got their energy from the sun. However, respondents were allowed to choose more than one energy source: 31% of these same students *also* agreed that plants got energy from the soil, 28% thought plants got energy from water, and 20% thought plants got energy from air. We will need to find out more about adult understandings of photosynthesis during the next stage of front-end evaluation.

Why does this matter? As Simpson & Arnold (1982b, p. 174) point out, "it is not merely the *absence* of appropriate mental operations, concepts or skills which inhibits learning; the *presence* of previously acquired theories, information or skills which may be incorrect or inappropriately applied may actively interfere with the acquisition of new material" (Simpson & Arnold, 1982b, p. 174, their italics).

Smith & Anderson (1984) present a fascinating case study of how children's alternative conceptions of plant growth and nutrition can interfere with their understanding of photosynthesis—and how things only get worse when teachers fail to recognize the effects of their differing beliefs.

Approaches to Teaching Photosynthesis

Researchers have tested a number of approaches to improving students' understanding of photosynthesis. Some approaches have met with more success than others.

- **Guided discovery**. In their analysis of school texts and classroom observations, Barker & Carr (1989a and c) found that the guided discovery approach was the most common approach to teaching children about photosynthesis. This approach used experiments (e.g., testing leaves for starch and iodine under various conditions) to inspire children to "invent" a process by which carbon dioxide and water are converted into carbohydrates and oxygen in the presence of sunlight and chlorophyll. Barker and Carr (1989c) argue that this approach is relatively ineffective, in part because the sense students make of the experiments may be radically different from what the teacher expects. The case study by Smith & Anderson (1984) might best be termed a guided discovery approach, and it described a similar mismatch between students' conclusions and the teacher's expectations.

- **Generative learning**. Barker and Carr (1989a and c) describe a unit they developed, called *Where Does the Wood Come From?* This unit used a constructivist approach that they termed a "generative learning strategy," which involved generating links between learners' existing ideas and "sense information." Students were encouraged to discuss their out-of-school ideas about plant "breathing," "drinking," wood production, soil, minerals, and leaves. Instructors then assisted them in linking appropriate ideas together to form an explanation of the origin of plant materials. The authors claimed that 71% of their 14-year-old students acquired a view of photosynthesis as a carbohydrate-producing practice (Barker & Carr, 1989c).

- **Peer collaboration**. Working with high school students, Lumpe & Staver (1995) found that "students working in peer collaborative groups developed more scientifically correct conceptions of photosynthesis than did students working alone," although individual members of the group did not always internalize the concepts generated by the group.

- **Material cycles in nature**. Working with junior high students, Eisen & Stavy (1992 and 1993) developed a unit that they hoped would change pre-existing misconceptions—and prevent the formation of new ones—by ignoring details and avoiding information overload. They focused on the role of plants in moving materials (like carbon, hydrogen, and oxygen) cyclically through the ecosystem. In post-tests, their experimental group did significantly better than the controls in concepts related to ecosystems and respiration, but did not do much better with concepts related to chemistry and autotrophic feeding.

While the specifics of these various approaches may not be useful to the exhibit portion of this project, they may be more useful as program developers consider the production of supporting materials for school groups. These studies also suggest four important points that we will have to consider during development and testing of the exhibit units:

- **Visitors' understandings of natural phenomena will likely be very different from our understandings.** This is the lesson from Barker and Carr (1989a, b, c) and from Smith & Anderson (1984).

- **We will need to draw clear links between visitors' current understandings and the "sense information" in the exhibit.** This is another lesson from Barker and Carr (1989a, b, c).

- **We need to think of visitors as traveling in "peer collaborative groups."** This lesson uses the language of Lumpe & Staver (1995). There is mounting evidence that much of what visitors learn in museums is learned through social interactions—as much or more than from one-on-one interactions with the exhibits (Borun *et al*., 1996; Diamond, 1986; McManus, 1987; McManus, 1988; Perry, 1989). When visitors talk about what they are engaged in, research suggests that:

  - Their learning of verbal concepts is enhanced
  - The content becomes more available to other group members
  - There are increased opportunities for reflecting on and discussing the shared experiences after leaving the museum.

- **The apparent "simplicity" of the exhibit concept—three building blocks and one product—may help visitors avoid information overload.** This approach is concurrent with the overall thrust of the work of Eisen & Stavy (1992 and 1993).

"Alternative Understandings" and Informal Education

Researchers have developed perspectives on the role of "alternative understandings" in informal education. As Borun *et al.* (1993) point out, educators have developed many terms to describe the ways that laypeople's understandings of the world differ from those of scientists. These include: "naïve notions," "alternative frameworks," "preconceptions," and "misconceptions." They also discuss the shift in the way that many educators think about learning toward a more constructivist approach.

A review by Roschelle (1995) provided a constructivist commentary on learning in informal settings. He discussed how visitors must construct their new knowledge from what they already know, resulting in the "paradox of continuity." How can people construct knowledge from their existing concepts if their existing concepts are flawed (Roschelle, 1995, p. 38)? He listed three implications for exhibit designers:

- Designers should seek to **refine prior knowledge**, rather than attempt to replace it with their own (Roschelle, 1995, p. 40). "Prior knowledge is properly understood not as the cause of errors or success but as the raw material that conditions all learning" (Roschelle, 1995, p. 41).

- Designers should **anticipate a long-term learning process**, of which the short-term exhibit experience will form an incremental part (Roschelle, 1995, p. 40).

- Designers must remember that **learning depends on social interaction**, and that conversations will shape the form and content that learners construct (Roschelle, 1995, p. 40).

Finally, he stressed that, "When learning experiences are more concrete, related to familiar situations, and interactive, so-called 'resistance' [to conceptual change] often disappears and students construct new concepts quickly" (Roschelle, 1995, p. 42).

Research and evaluation studies suggest that visitors *can* alter their understandings by interacting with informal science exhibitions. Despite concerns like those expressed in Roschelle (1995), it seems possible to develop exhibits that successfully address visitors' misconceptions about science topics, at least for the short term. Two examples of projects that did just that are:

- ***Global Gamble* at the Franklin Institute.** This exhibit used a game show format on a video wall to present basic science information about global climate change, and then allowed visitors to select from a variety of strategies that might slow down the process of global warming (Mintz, 1995, p. 10-11).

- ***Naïve Knowledge Study* at the Franklin Institute.** Borun *et al.* (1993) described a three-and-a-half year study that first researched visitors' understandings about gravity and then prototyped and tested exhibits that addressed two major misconceptions: The idea that air causes gravity or that air is necessary for gravity to work, and the idea that gravity is caused by the Earth's rotation.

Based on these studies, there seem to be two keys to success for exhibits addressing misconceptions:

- **Formative evaluation is critical.** As iterative prototyping-and-evaluation proceeded, visitor learning improved dramatically in both studies (Borun *et al.*, 1993; Mintz, 1995).

- **Labels, as well as the prototype exhibits, must be tested iteratively.** Seemingly small details in the wording of a label can be important. Borun *et al.* (1993) concluded that, "(1) we cannot simply tell people a naïve idea is not so, (2) negative statements are easily misread or misinterpreted, and (3) formative evaluation of labels is necessary to find out if they are effective in explaining an exhibit."

Conclusions

This review suggests that children will be coming to the *Sweet House* exhibition with a number of partially formed ideas and, most likely, some misunderstandings about building blocks, products, and overall process of photosynthesis. We suspect many adults will also hold alternative views on one or more aspects of the process, but we need to investigate adult understandings through front-end evaluation.

Our findings also suggest that the overall approach to the exhibit—four areas focused on the building blocks and product of photosynthesis and a central area focused on the Sun's energy—should prove to be effective ways to present this topic to middle-school-aged children and their families, because many children (and probably adults) need to develop scientific ways of thinking about the building blocks and products of photosynthesis.

Even if they don't tie all the concepts together within the exhibit, they will still have developed a firmer foundation for later learning about the subject.

Photosynthesis: Recommendations for the *Sweet House* Team

Based on this review, we make the following recommendations for the exhibit team:

- **Think hard about what the *Sweet House* exhibition is trying to accomplish relative to visitors' current concepts about plant nutrition**. It seems likely that the most appropriate approach will be to build on what visitors already know, but the team must decide the best ways to do that.

- **Try out several theories of conceptual change during prototyping to test how well each applies in a museum setting**. Given what we know about visitor groups, we may want to start with theories that view learning as a social process.

- **Conduct iterative development, design, and testing of both exhibit prototypes and labels**. This will be the key to a successful exhibition—and the best way to find out what visitors are taking away from the prototype exhibits.

Photosynthesis: Recommendations for the *Sweet House* Evaluation

Based on the literature review, we can make some very specific recommendations about how to proceed with front-end and formative evaluations.

Front-end evaluation. The most critical thing to investigate during front-end evaluation will be how *adult* visitors think about photosynthesis. Research has revealed that much of the learning that takes place in informal settings happens as visitors talk about the contents of the exhibit. In the *Sweet House* exhibition, will conversations between adults and children reinforce the exhibit's messages, or will they instead guide children away from a scientific understanding of the components and overall process of photosynthesis? Will conversations among adults tend to rehearse and reinforce their alternative conceptions, or will more knowledgeable adults be able to guide their companions towards a more scientific understanding? More specifically, we need to find out:

- What do adults understand about the roles played by the three building blocks of photosynthesis—air, light, and water—and about the products of synthesis—sugar and starch? How do they talk about these components individually, as visitors will first encounter them in the *Sweet House* exhibition?

- Do adult visitors to the Conservatory seem to hold the sorts of alternative frameworks about the overall process of photosynthesis that have been described in this review? Do they think that plants get their food from the soil, and that plant food is anything that plants can suck up from the soil? If they hold a more scientific view, do they still have difficulty with some of the details?

We will answer these questions through depth interviews of adults and through group interviews, where we encourage group members to discuss these topics among themselves and come to a consensus. Many of the tools we will use during these interviews—including specific questions and techniques for mapping concepts and delving into visitors' understanding of graphics—can be drawn from existing studies of children's understandings about photosynthesis.

Formative evaluation. During formative evaluation, we will—as is typical for such studies—investigate how well each prototype seems to communicate its messages. We will pursue these investigations within the framework of what we have learned about how people think about photosynthesis and how they feel about their immersive experiences within the Conservatory. Specific questions that we will need to answer about each prototype include:

- In what ways do individual visitors understand or misunderstand the message of each prototype, and how do these understandings relate to their prior understandings of the components and overall process of photosynthesis? Does the prototype build on or conflict with visitors' prior understandings of the photosynthesis? How do visitors *feel* about the ways in which the prototype may challenge what they already know?

- How do visitors talk about each prototype with other members of their groups? Do the labels guide parents towards appropriate explanations for younger children? Do the labels guide the conversations among same-age groups (older children or adult) towards a more scientific understanding of the components and overall process of photosynthesis? How do group members *feel* about the ways in which these conversations may challenge what they already know?

- How does each prototype exhibit feel to visitors when they encounter it within the context of the Conservatory? Does it seem to fit within the Conservatory environment or does it tend to disrupt visitors' immersive experiences?

Because the formative evaluation will be part of an iterative approach to design, prototyping, and testing, we will use the answers to these questions to guide the next round of prototyping.

IMMERSION EXHIBITS

Developers of the *Sweet House* exhibition refer to the proposed exhibit as an immersion exhibit. The term "immersion" is used in different ways by different authors and some otherwise knowledgeable museum professionals don't recognize the term (Gilbert, 2000). A number of published and unpublished reports have examined the theory, research, and practice behind immersive exhibits.

Terminology

Professionals use the term "immersion" to mean different things. Bitgood (1990b) defined "simulated immersion" as "the degree to which an exhibit effectively involves, absorbs, engrosses, or creates for visitors the experience of a particular time and place." Examples of this type of experience include walk-through caves in museums (Koran *et al.*, 1983), historical recreations in Greenfield Village in Michigan (Bitgood, 1990b), and the "landscape immersion" exhibits created in many zoos over the last few decades (Hyson, 2001). Bitgood (1990b) states that when visitors are immersed in an exhibit, they report that the exhibit accomplishes one or more of the following things:

- involves or absorbs you
- creates an exciting experience
- creates the feeling of being in a particular time and place
- is realistic and natural
- makes the subject matter come to life
- focuses your attention
- is memorable

Many museum professionals use the term "immersion" to cover a broader range of experiences than "the experience of a particular time and place." Based on surveys and interviews with museum professionals, Gilbert (2000) recognized two distinctive types of immersive exhibits:

- **Immersive environments**: Re-created realistic settings intended to make visitors feel as if they are visiting a particular time or place.

- **Immersive experiences**: Creating a situation and experience distinct from merely the physical re-creation of the environment.

Many of the respondents in Gilbert's survey were either not aware of the range on meanings of the word "immersion" or used the word in a more restricted sense. Also, some educational professionals use the term for experiences that go beyond physical immersion, including experiences like virtual reality (VR). Psotka (1995) describes immersion as the key added value of VR. Psotka (1995) asserts that the challenge, interactivity, realism, and fantasy of immersive VR result in motivation and mindful engagement, which in turn opens many new paths for learning.

In a few cases, developers appear to have pushed the meaning of immersion beyond reasonable limits. We found a text-based Web site that claimed to be an immersion exhibit. It "'immerses visitors within a naturalistic setting" by allowing them to read the field notes of an "imaginary world traveler" <http://beyond.org/immersion/immerse_index.html >.

It's important that developers of the *Sweet House* be very clear what *they* mean when they use the term "immersion." Otherwise, readers of the proposals and other documents may misconstrue their meaning.

"Natural" means different things to different people. The *Sweet House* exhibition has also been discussed as a natural or naturalistic exhibit. Just as there are different meanings for the term "immersion," "natural" also means different things to different folks. Hyson (2001) points out that the sorts of zoo exhibits that professionals and visitors recognize as "natural" has changed over the last century, and Spirn (1997) makes a similar point for gardens and landscapes. It also seems that "landscape architects and the general public often hold markedly different ideas about what 'natural' is" (Hyson, 2001, p. 31).

Therefore, it's also important that developers of the *Sweet House* exhibition define what they mean when they use the term "natural"—and that the front-end and formative evaluations investigates how visitors will perceive a "natural" experience within the Conservatory environment.

What Makes an Immersive Environment?

Many features combine to make an exhibit "feel immersive." Bitgood (1990b) gives the following list of factors that may contribute to simulated immersion when used in various combinations:

- use of physical space
- provision of environmental feedback
- inclusion of multi-sensory stimulation
- use of authenticity or object realism
- use of "real time" or "dramatic time"
- social involvement
- use of text to prompt mental imagery to encourage visitors to feel immersed
- artistic portrayal
- lighting effects

Bitgood (1990b) goes on to describe the theory of, and research on, each of these factors.

Harvey *et al.* (1998) investigated visitors' experiences of immersion and psychological flow in a newly renovated exhibit of large mounted mammals at what was then called the Denver Museum of Natural History. Their analysis demonstrated that the factors most responsible for visitors' feelings of flow and immersion were the interactive components, multisensory stimulation, and dynamic displays (e.g., videos of animals in action.).

Jones & Wageman (2000) found that a number of factors influenced visitors' recognition of and immersion in exhibits that simulate particular human-built places, such as a microchip "clean room" and an operating room. Environmental features, such as flooring and lighting, helped visitors recognize these areas as different from the rest of the exhibit hall. The inclusion of real environmental elements from the actual places and authentic details helped create feelings of immersion. Including interpretive materials in these exhibits seemed to have a minimal impact on visitors' feelings of immersion, although including exhibit cases did seem to disrupt the experience (Jones & Wageman, 2000).

Psotka (1995) analyzed how the feeling of immersion can be produced in synthetic environments:

> *Immersion seems to be facilitated by the ability to control attention and focus on the new VR to the exclusion of the real world. Being able to see parts of one's own body, even in cartoon form, adds to the experience. It also depends on the use of good visual imagination. There is a great range of individual differences in the experience of immersion in VR environments. The technological limitations are largely responsible, but temperamental differences among individuals result in different reactions to these limitations.* (Psotka, 1995, p. 409)

Some of these ideas—control of attention, exclusion of the real world, the roles of imagination and individual differences—may also be applicable to understanding immersion in a Conservatory environment.

Immersive exhibits can have unintended consequences for visitors. In some cases, these unintended consequences can have negative effects for the visitor. Here are two examples:

- Schaefer *et al*. (2002) found that in an immersive walk-through exhibit about soil, children five-and-under were often so frightened by the dark tunnels and hundred-times life-sized animals that it disrupted the entire family's experience.

- Coe (no date) points out that the zoo-visiting public complains that animals in landscape immersion exhibits are too distant and too inactive.

The *Sugar House* team and evaluators must be aware of the possibility of unintended consequences and be prepared to ameliorate them during both the prototyping and remediation phases of exhibit development.

The evaluators will continue to investigate the published and unpublished literature on factors that contribute to the immersive experience. The exhibit team and evaluators should work together to investigate visitors' immersive experiences within the conservatory during front-end and formative evaluation.

Interpretation and Immersive Exhibitions

Type and placement of interpretation can be important in immersive exhibits. A preliminary examination of the research and evaluation studies on interpretation has revealed two published studies that look at interpretation before, during, and after immersion experiences.

- Birney (1990) investigated visitor use of a large, laminated, four-page guide sheet in Brookfield Zoo's *Tropic World*, an immersive exhibit of living primates, which was at that point devoid of fixed graphic interpretation. About half the visitor groups picked up a guide. All types of visitor groups picked up the guide, including large groups and groups with children. Visitors were able to use the guide to identify animals that they saw in the exhibit, although they had more difficulty using the guide to locate animals within the exhibit.

- Koran *et al.* (1983) investigated the educational effects of attending to interpretive panels before and after an immersive experience. In an experiment using a relatively small number of middle-school-aged students visiting a walk-through cave exhibit, they found that attending to either the "before" or "after" panel increased learning over the control experience, and the "before" panel had a slightly greater, but not statistically significant, effect (Koran *et al.*, 1983).

Although it seems unlikely that many middle-school students would attend to such exhibit panels during an actual museum experience, the overall concept—providing attention-directing experiences before and/or after the immersion experience—will be a useful one for *Sweet House* developers to consider

The evaluators are continuing to investigate the published and unpublished literature on interpretation. The exhibit team and evaluators should work together to should make this a major priority during formative evaluation.

What Do Visitors Learn in Immersive Exhibits?

Although we still have much to learn about immersion exhibits, many professionals point to evidence of their effectiveness. Gilbert's survey of museum exhibit directors asked if they considered immersive exhibits to be effective. Of the 23 respondents who answered this question, 65% gave an unequivocal yes, and another 30% stated that they can be effective in some circumstances. These respondents stated that immersion exhibits were successful because they created new experiences for visitors, set up a context where visitors can explore a range of content, and created memorable experiences that aided long-term retention of knowledge (Gilbert, 2000).

Some points about learning in immersive exhibits:

- Bitgood (1990b) points out that "learning associated with immersion is more experience-driven than it is information-driven. Instead of emphasizing the acquisition of facts, concepts, etc., a more pervasive understanding of the subject is sought—one that includes the feelings of experiencing another time and/or place, curiosity, excitement, etc" (Bitgood, 1990b, p. 5).

- Stoinski *et al.* (no date) discuss evidence that naturalistic zoo exhibits can affect visitors' attitudes about conservation and understanding of the need for habitat preservation.

- Based on an analysis of 400 stories that museum professionals told about "significant, memorable, pivotal museum learning experiences," Perry (2002) defined a type of learning termed "wrap-around learning." "Wrap-around learning is learning that you feel with your whole body and via all your senses; learning that you can wrap your arms around" (p. 24). This sort of learning was also characterized as "gut-level understanding" that develops through the senses in immersive exhibits such as walk-though caves, walk-through hearts, and dioramas.

The evaluators are continuing to investigate the published and unpublished literature on the effectiveness of immersive environments for learning. The exhibit team and evaluators should make the investigation of learning a major priority for formative evaluation.

Immersion: Recommendations for the Exhibit Team

Based on this review, we suggest that the exhibit team do the following:

- **Clearly define the term "immersion."** Professionals don't share a single meaning for the term, and the team should recognize that fact in the grant proposal and other documents that describe the exhibit.

- **Consider what "natural" means within a conservatory environment.** Define this term clearly in exhibit-related documents.

- **Be prepared for unintended consequences**. The team should be open to the possible need to modify ideas they hold dear based on the public's reaction to them, and the budget must be flexible enough to make needed changes during both the prototyping and remediation phases.

Immersion: Recommendations for the Front-end and Formative Evaluations

Based on this review, we suggest that the front-end and formative evaluations investigate the experience of immersion among Conservatory visitors.

Front-end evaluation. We suspect that from the moment they enter the Palm House, visitors find themselves engaged in an immersive experience—and that the immersive aspects of the experience are very important to them. The *Sweet House* will rely on visitors recognizing differences among four different immersive environments, and we need to understand how sensitive visitors will be to these differences. Selinda Research Associates will continue to investigate the literature on immersive experience, particularly the unpublished evaluation literature. In addition, we will talk with visitors about their immersive experiences in the Conservatory.

Questions we will want to investigate with visitors during front-end evaluation include:

- What terms do visitors use to describe their experience of the overall Conservatory environment?

- Do they use terms like "natural" or "naturalistic"? If so, what do these terms mean to them?

- Which aspects of the experience seem most critical for maintaining the feeling of immersion?

- What sorts of things can disrupt the feeling of immersion for visitors, and why?

- How sensitive are visitors to changes as they move from one house to another within the Conservatory? Which environmental cues do they seem most sensitive to? How do they feel about the changes they experience from one house to another? Do any of the changes leave them feeling uncomfortable?

We will be able to learn these things through depth interviews of adults and through group interviews where we encourage group members to discuss these topics among themselves. Many of the tools we use during these interviews—including specific questions—can be drawn from existing studies.

Formative evaluation. It may be possible to prototype the environmental changes that visitors will experience as they move from one section of the *Sweet House* to another. If so, we will want to find out how sensitive visitors are to these changes.

- Which environmental cues do they seem most sensitive to?

- How do they describe and interpret these changes?

- Do any of the changes leave them feeling uncomfortable?

We can use the results of these studies to improve the overall experience of immersion for Conservatory visitors.

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