Examining Folk Pedagogies of Science Exhibit Designers

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Abstract

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Science museum exhibits have the potential to positively impact science education, scientific literacy, public engagement with science and interest in the STEM fields. The personal exhibit design philosophies or “lay theories” of science exhibit designers impact how science exhibits are designed and, ultimately, what visitors gain from experiences them. In order to investigate the impact of science exhibit designers’ lay theories on science exhibit design, the self-reported practices of seven science exhibit designers are mapped onto best practices from the National Association for Museum Exhibition and cognitive science research summarized by the National Research Council. The results suggest that a more rigorous investigation of what resources science exhibit designers use and how they use them as well as the mitigating effects of institutional management may be important to understanding what research informs science exhibit design.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Figure Number Page

LIST OF TABLES

Table Number Page

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DEDICATION

To all of my family.

I. Introduction

Exhibits in science museums (including natural history museums, zoos, and aquariums) have the potential to positively impact science education, scientific literacy, public engagement with science and interest in the fields of science, technology, engineering, and math. Museum visitors can and do learn in exhibits – although this learning is difficult to measure (Hein and Alexander, 1998 and references therein). Visitors can come away from a single exhibit visit having learned something (Guichard, 1995). Recognition of this has spurred research into how to create the most pedagogically successful science exhibits possible.

The past 40 years have seen a dramatic increase in cognitive science research on how people learn science. Much of this research has focused on formal learning environments (e.g., National Research Council, 1999), but a wealth of research on learning science in informal environments, such as museum exhibits, also exists (e.g., Bell et al., 2009). In addition to the cognitive science research, there also exists an abundance of educational learning theories and best practices from the field of exhibit design itself that can inform the design of science exhibits (e.g., McLean & McEver, 2004).

However, research doesn't automatically translate into practice. Linda Black, from the Children's Museum of Indianapolis, notes that exhibit designers "need to reflect upon the differences between their practices and new research about learners, learning process, and specific subject matter fields" (Serrell & Association of Science-Technology Centers, 1990, p. 23). How often this occurs is part of the on-going discussion of professionalization in the field of museum exhibit design. Exhibit designers come from a variety of backgrounds – theater set design, architecture, and science to name a few. There is no standard curriculum to learn to be an exhibit designer and very few formal programs; as such, each exhibit designer brings a variety of skills, ideas, philosophies, and knowledge to their practice. This leads to a wide variety of approaches to exhibit design, resources used, and theories applied.

Linda Black from the Children's Museum of Indianapolis also noted, "every time we develop an exhibit, we are applying learning theories, even if it is only to exercise a personal assumption" (Serrell & Association of Science-Technology Centers, 1990, p. 23). Similarly, in *The Culture of*

Education, Jerome Bruner called for educators' intuitive pedagogical knowledge (which he called "lay theories" or "folk pedagogies") to be made explicit and examined (Bruner, 1996). This thesis explores the exhibit design practices of seven designers at science-based museums in Washington, Oregon, and California in light of cognitive science research and best practices from the field of exhibit design. It examines how they incorporate best practices, learning theories, and new cognitive science research into their designs, whether they use formal theories based on research or "lay theories" based on intuition and experience, or some combination. The results suggest that a more rigorous investigation of what resources science exhibit designers use and how they use them as well as the mitigating effects of institutional management may be important to understanding what and how research informs science exhibit design.

II. Literature Review

The last 40 years have been described as a cognitive science research revolution because of an "outpouring of scientific research on the mind and the brain" (Bell et al., 2009, p.2-2). The amount of research that can be found in books such as *Public Institutions for Private Learning* (Falk and Dierking, 1995) or *In Principle, In Practice* (Falk, Dierking & Foutz, 2009) and in journals such as *Science Education, Cognitive Science, Curator, Exhibitionist*, etc. is overwhelming. For this reason, several volumes published by the National Academies Press that compile and summarize current research are particularly helpful. These publications include *How People Learn* (National Research Council, 2000) and its companion volume *How People Learn: Bridging Research and Practice* (National Research Council, 1999), *Learning Science in Informal Environments* (Bell et al., 2009) and its companion volume *Surrounded by Science* (National Research Council, 2010). All are available for free as PDFs on the National Academies Press website (http://www.nap.edu/).

National Research Council Publications

The recommendations found in these reports are similar to each other. Some general ideas from these four publications that could inform science exhibit design include:

- Educators and designers should work with visitors' preexisting understandings and prior knowledge. This reflects an accumulation of research (e.g., Roschelle, 1995), reviewed and summarized in both *How People Learn* (National Research Council, 2000) and

Learning Science in Informal Environments (Bell et al., 2009), that new learning is filtered through what a learner knows, thinks they know, believes, and feels about a subject.

- Exhibits (and other informal science learning environments) should present a conceptual framework instead of just facts. Conceptual frameworks order and contextualize factual knowledge and make it "usable" – i.e. knowledge that a learner can apply rather than simply memorize and repeat for a test. For example, understanding that hair and producing milk for young are characteristics of mammals allows one to identify mammals from non-mammals without memorizing a list of known mammals.
- Exhibits should teach metacognitive skills. Metacognitive skills can help learners monitor, evaluate, and improve their own learning, but these skills are subject-specific and need to be taught. For example, an exhibit where visitors can build and race simple model cars might ask the visitor to predict which car will be the fastest. The act of making a prediction (which is a metacognitive skill, as opposed to a simple guess) causes the visitor to think about the factors involved each car's design and how they will impact speed.
- Exhibits and the exhibit design process should be "learner-centered" – i.e. design of educational experiences should take into account a "broader understanding" of learners, including their knowledge, skills, attitudes, and cultural differences; be wary of presenting intelligence as fixed. Avoid implying that there are people who are smart, people who are not smart, and that to be smart one should strive to have the "right" answers all the time.
- Exhibits should be designed using an iterative process. Designs should be reviewed, revised, and reviewed again to create exhibits that cater to clear exhibit goals.
- Exhibits should incorporate multiple ways for visitors to engage with the content. This could include, for example, interactive or multi-media elements that engage visitors' senses of sight and hearing as well as body movement.
- Exhibits should be designed in collaboration with community partners. For example, local educators who are familiar with fourth- and fifth-graders.

A brief summary of the four National Research Council publications that informed this thesis may be beneficial to the reader:

How People Learn & How People Learn: Bridging Research and Practice

The goal of *How People Learn* (National Research Council, 2000) was to "appraise the scientific knowledge dealing with human learning and its application to education" (p. 233). Its companion volume, *How People Learn: Bridging Research and Practice* (National Research Council, 1999), was written to help "link the findings of research on the science of learning to actual practice in the classroom" (p. vii).

How People Learn covers research in six areas its authors identified as "relevant to a deeper understanding of students' learning processes" (National Research Council, 2000). Four of these six areas are summarized and discussed briefly below. The remaining two are complex and the reader is referred to the publication:

(1) Research on the role of prior knowledge might be summed up by noting that learners – even very young children – are not blank slates; "teachers need to pay attention to the incomplete understandings, the false beliefs, and the naïve renditions of conceptions that learners bring with them to a given subject" (National Research Council, 2000, p.10). Failure to do so can lead to new learning being misconstrued, rejected, or memorized only to be forgotten later (Roschelle, 1995). (2) The concept of learning for understanding recognizes that a body of factual knowledge about a subject is important but that such factual knowledge needs to be organized in a conceptual framework if it is going to be useful to the learner, rather than existing as a list of disconnected facts. (3) Learning as an active process implies that learners are in control of their learning and can be taught metacognitive skills, which can improve learning by helping learners recognize when they understand and when they need more information. (4) Learning takes time.

How People Learn: Bridging Research and Practice discusses three key findings and their implications for teaching; these are: (1) students' preexisting understanding (also called prior knowledge, misconceptions, preconceptions, etc.) directly affect what and how students learn and teachers "must draw out and work with the preexisting understandings that their students bring with them" (National Research Council, 1999, p. 15); (2) students need a "deep foundation of factual knowledge" but also require a conceptual framework and organization of that factual knowledge such that it can be applied, therefore, "teachers must teach some subject matter in depth, providing many examples in which the same concept is at work and providing a firm foundation of factual knowledge" (National Research Council, 1999, p. 27); (3) metacognitive skills specific to subject areas can aid student learning and the teaching of metacognitive skills "should be integrated into the curriculum in a variety of subject areas" (National Research Council, 1999, p.27). The authors also discuss how research on learning is incorporated into teachers' practice and note that the influence of research on practice is mediated by public policy, educational materials, teacher training, and public opinion and, as a result, "the various mediating arenas that influence practice are often not aligned either with research findings or with each other" (National Research Council, 2000, p.1).

While *How People Learn* discussed learning in general, its companion volume focused on what has been labeled the "formal" learning environment – classrooms with teachers and students. The National Academies Press later released a report on learning science in informal environments – i.e. learning outside of classrooms, such as in museum exhibits, afterschool programs, camps, etc. This report, appropriately titled *Learning Science in Informal Environments* (Bell et al., 2009), is also accompanied by a companion volume (also referred to as the "practitioners' volume"), titled *Surrounded by Science* (National Research Council, 2010) as well as *Ready, Set, SCIENCE!* (National Research Council, 2007), designed to help teachers translate the recommendations of *Surrounded by Science* for elementary school classrooms.

Learning Science in Informal Environments & Surrounded by Science

Learning Science in Informal Environments was an effort to synthesize what's known and what remains to be understood regarding learning science in informal environments and to develop a common framework to guide research across the diverse fields that inform informal science education (Bell et al., 2009, p. 1-8). The report concluded that people do learn in informal learning environments and that museums, zoos, and aquariums can support science learning. The challenge, the report notes, is "developing clear and reasonable goals for learning science in informal environments" instead of expecting to see the same academic achievement outcomes as formal learning environments (i.e. school); however, the report also rejects purely subjective learning goals (Bell et al., 2009, p. ES-2).

The report offers six "strands" of science learning as reasonable outcomes for learning science in informal environments. According to these six strands, learners in informal environments: (Strand 1) "Experience excitement, interest, and motivation to learn about phenomena in the natural and physical worlds;" (Strand 2) "Come to generate, understand, remember, and use concepts, explanations, arguments, models and facts related to science;" (Strand 3) "Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world; (Strand 4) "Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena;" (Strand 5) "Participate in scientific activities and learning practices with others, using scientific language and tools;" (Strand 6) "Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science" (Bell et al., 2009, p. ES-3). The committee compared these strands to threads in woven fabric – each strand, when combined with the others, contributes to a whole that is greater than the sum of its parts. Not every science exhibit will include all of these strands, but each exhibit should include at least one.

The report includes a number of recommendations for exhibit and program designers: informal environments should "Be designed with specific learning goals in mind (e.g., the strands of science learning);" "Be interactive;" "Provide multiple ways for learners to engage with concepts, practices, and phenomena within a particular settings;" "Facilitate science learning across multiple settings;" "prompt and support participants to interpret their learning experiences in light of relevant prior knowledge, experiences, and interests;" and "Support and encourage learners to extend their learning over time" (Bell et al., 2009, p. ES-5). In addition, "informal environments for science learning should be developed through community-educator partnerships and whenever possible should be rooted in scientific problems and ideas that are consequential for community members" and "[e]ducational tools and materials should be developed through iterative processes involving learners, educators, designers, and experts in science, including the sciences of human learning and development" (Bell et al., 2009, p. ES-5). Like *How People Learn* (National Research Council, 2000), *Learning Science in Informal Environments* (Bell et al., 2009) was accompanied by a "practitioners' volume" with recommendations for applying the findings of the report. This volume, titled *Surrounded by Science* (National Research Council, 2010), repeats the six strands, discusses case studies and examples of informal science learning, and provides recommendations for educators and designers.

Exhibit Design Professionals' Best Practices

In an attempt to summarize the best practices of science exhibit design professionals, the National Science Foundation's Informal Science Education Program funded a conference and a book titled *Are We There Yet?* (McLean & McEver, 2004). This volume includes discussions and articles based on the findings of that conference and essays from conference participants on various topics informing best practices for science exhibition development. The editors distinguish exhibitions from exhibits: exhibitions are made up of exhibits, which may be described as individual elements such as an interactive element or a panel of text and an artifact. The editors stress that a "checklist" that guarantees a good exhibit not only doesn't exist, but that any list of "best practices" should be used with caution lest it stifle innovation. The editors provide a list of characteristics of good exhibition development, but noted that "most of the contributors to this list would probably disagree with at least one or two of the items on it" (McLean & McEver, 2004, p. 2).

According to McLean & McEver (2004), exhibit designers should:

- involve scientists, educators, community members, and others outside of the museum and the field of exhibit design. They not only have a different viewpoint, but are often stakeholders in an exhibit's outcomes.
- use a collaborative, rather than solo or siloed, development and design process.
- inform the entire process with evaluation (frontend, formative, summative, and remedial), including prototyping and iterative design.
- focus on what visitors want and need in an exhibit design and design for meaningful interactivity, e.g., interactive elements that contribute to engagement rather than adding some "flip-up flaps" as an interactive afterthought.
- use excellent visual and spatial design.
- develop and stick to clear exhibit goals and objectives.
- provide for secure access to sufficient resources, including time and money.
- have effective project management and institutional support.

- not neglect the maintenance and upgrading of the exhibit after it is installed.

The results of these best practices tend to include “memorable experiences; ongoing conversation and inquiry; wonder and excitement; personal relevance and meaning-making; accessible and comprehendible content” and “a comfortable and engaging environment” (McLean & McEver, 2004).

“Best” Practices

Publications authored by exhibit professionals (e.g., McLean & McEver, 2004) stress that there is no “right” way to make the “best” science exhibits. The National Research Council publications acknowledge this as well, but also state that they reject purely subjective approaches to exhibit design.

In addition to exhibit professionals’ best practices and standards and the National Research Council’s publications, many other resources can and do inform exhibit design practice. These include educational learning theory, psychology, and other theories ranging from discovery and inquiry to social marketing and “Brain Rules” (Medine, 2008). In addition, personal and professional experience accumulated over a professional’s lifetime also influence how exhibits and designed. It is this accumulation of ideas that Bruner addresses in *The Culture of Education* (1996) in his discussion of folk pedagogies.

In *The Culture of Education*, Bruner (1996) discusses the importance of “folk pedagogies” (or “lay theories”), which are personal theories of teaching that an individual develops. Folk pedagogies may include parts of formalized pedagogy but in general are constructed informally and have not been rigorously tested. This is not to imply that “lay theories” are inferior to formal theories; lay theories might best be described as theories that are developed from intuition and personal experience rather than formal experimentation and testing. However, lay theories "need to be made explicit and to be reexamined" (Bruner, 1996, p. 50). He writes, "in theorizing about the practice of education in the classroom (or any other setting, for that matter), you had better take into account the folk theories that those engaged in teaching and learning already have" because folk pedagogies influence how teacher (or exhibit designers) teach, which has a direct impact on how and what learners learn. (Bruner, 1996, p. 46).

III. Materials & Methods

For this study, I interviewed seven museum professionals from five different institutions accredited by the American Association of Museums (AAM) and/or Association of Zoos and Aquariums (AZA). All were, or are, involved in the exhibit design process at their institution. Participants were chosen from museums, zoos, and aquariums within driving distance from the Seattle area due to budget constraints. All participants who agreed to be interviewed were interviewed.

It should be noted that the views expressed by the interviewees do not necessarily reflect the views held by the institution or by their colleagues. This study differentiates between the terms “exhibit” and “exhibition,” and between “exhibit development” and “exhibit design” only where interviewees made the distinction themselves. Otherwise the term “exhibit” is used to refer to both “exhibits” and “exhibitions” and the term “exhibit design” is used to refer to both the development and design of exhibits. Participants who differentiated between the two noted that “exhibit development” referred to research, concepts, and content development whereas “exhibit design” referred to the visual, multi-media or interactive elements. Participants and publications that distinguish between an “exhibit” and an “exhibition” (notably McLean & McEver, 2004) use the word “exhibit” to refer to elements that make up one “exhibition,” which occupies a gallery (or similar area) in a museum.

Interviews were conducted in person and on-site, with one exception (participant ZD). Follow-up interviews were conducted via email, phone, or on-site with all participants. A list of potential topics and questions was used during these interviews, but the format was conversational, unconstrained, and unstructured. The interview protocol was not standardized; interviews were recorded when possible, along with written notes. See Appendix A for the list of questions and topics used.

Participants were asked to provide, if available and if allowed, institutional planning documents, interpretive plans, exhibit design philosophy statements, exhibit design plans, and similar “white” or “gray” papers. Interviewees were also asked to provide the names of authors or titles of books or papers that influenced their practice.

Transcripts of each interview were coded by tagging key words and phrases (such as "prototyping," "formative evaluation," "multiple intelligences," etc.). The set of codes used was not designed *a priori*; it emerged from the transcripts. Codes were then sorted into broad categories (such as "best practices" or "audience research").

Transcripts were scrubbed of identifying information to protect the privacy of participants, their colleagues, and institutions. Names of participants and their institutions were replaced with codes (see Table 1). Only female pronouns were used to refer to participants to further protect their anonymity.

This method had two primary limitations. First, it relied on self-reporting, which can often be problematic. Participants were very open and helpful, but one cannot expect an exhibit designer to describe in exhaustive detail their entire practice in a single interview – or even an interview plus follow-up questions. This relates directly to the second primary limitation of this method: transcripts were coded based on words or phrases. Therefore, my coding was unable to account for practices that participants did not specifically mention.

Table 1: Participants codes. Coded participants and the institution where they currently work.

Participant	Institution	Type of Institution
ZA	ZOO1	Zoo/Aquarium
ZB	ZOO1	Zoo/Aquarium
ZC	ZOO2	Zoo/Aquarium
ZD	ZOO2	Zoo/Aquarium
ZE	ZOO3	Zoo/Aquarium
SA	SCI1	Science/Natural History
SB	SCI2	Science/Natural History

IV. Results

Theories and strategies employed by exhibit design participants varied widely and many were mentioned by only one participant. Coded results that were categorized as theories or strategies (ideas that participants said they used to inform their exhibit design practice) are presented in Table 2 below. These theories and strategies include:

- "3P + trystorming," a theory from manufacturing that focuses on eliminating waste;
- "backwards by design," a method from the field of education of designing curriculum by setting goals first, then choosing activities and teaching content focused on those goals;
- "*Brain Rules*," used by one participant to refer to John Medina's 2008 book of that title as well as related brain science research;
- "CARE Standards," the professional standards of the AAM's Committee on Audience Research and Evaluation;
- one participant referred to "Maslow's hierarchy of needs" as a way of talking about attending to visitor comfort (such as providing places to sit);
- "multiple intelligences" was used to refer to the work of Bernice McCarthy and/or Howard Gardner;
- "naturalism" was a term used by one participant to refer to creating naturalistic environments for zoo animals that immerse visitors and encourage natural behavior from animals, thus blurring the boundary between visitor and animal and allowing visitors to learn by simply observing (See, for example, Bierlein 2003);
- "Planning for People" refers to various essays and books on visitor comfort (e.g., McLean 1993)
- "Sensory experiences" refers to providing exhibit elements that visitors can touch, hear, or otherwise use more than one sense
- social marketing, the idea of applying marketing theory to change others' behavior for a social good
- "Top down and bottom up" refers to starting both with end goals and working backward (much like backward design) as well as starting with experiences and linking them to goals.

Table 2: Theories, strategies, and ideas used by exhibit design participants.

Theory or Strategy	# Participants	# Institutions
“3P + trystorming”	2	1
AAM best practices	1	1
Add "human element"	1	1
Affective goals	3	2
Animals as ambassadors	1	1
Are We There Yet	1	1
AZA publications, best practices	2	1
Backwards by design	1	1
Brain Rules	1	1
CARE Standards	1	1
Cater to different age groups	1	1
Cue visitors for discovery	1	1
Don't need to read to learn	1	1
Don't worry about visitors who do come to learn	1	1
Evaluation	5	4
Experiences + concepts	1	1
Goal driven – conservation	1	1
Goal driven - knowledge, attitude, behavior change	1	1
Hopeful labels, compassion fatigue	2	2
Humor	1	1
Immersion	2	2
Inquiry	1	1
Interpret only what's there	1	1
Just by experience	2	2
Linked In®	1	1
Make it easy for parents to read exhibits to kids	1	1
Maslow’s hierarchy of needs	1	1
Misconceptions	1	1

Multiple intelligences	3	3
National Association Aquariums resources	1	1
National Research Council publications	2	2
Naturalism	1	1
Ocean Project research	1	1
Planning for People	1	1
Prior knowledge, preconceptions	1	1
Prototyping	4	3
Sensory experiences	2	2
Social marketing	1	1
Start with what we want people to know	1	1
Target school groups and programs	1	1
Team approach	6	5
Top down and bottom up	1	1
Trying to save habitat, not animal	1	1
Visitor Studies Association best practices	1	1

Where do science exhibit designers go to research or keep current with their field(s)? Participants identified a wide variety of resources that they use to inform their practice, from academic journals such as *Science Education* to email list-serves. Resources mentioned are presented in Table 3.

Table 3: Resources mentioned by participants.

Resource	# Participants	# Institutions
Academic Journals	4	3
Always seek more information	2	2
Are We There Yet? (McLean & McEver 2004)	1	1
ASTC Publications, resources	1	1
AZA Publications	1	1
Board members bring new ideas	1	1
Bring in relevant speakers	1	1

Colleagues	1	1
Environmental education research	1	1
Examples from other institutions	1	1
Exploratorium publications	1	1
John Falk publications	1	1
Legacy (National Park Service publication)	1	1
LinkedIn®	1	1
List Serves	2	2
Multi-institutional research	1	1
Multiple Intelligences research	3	3
National Research Council publications	1	1
Professional conferences, workshops	3	2
RoyalSociety.org podcasts	1	1

Five participants identified difficulties practicing exhibit design the way they would like; these are presented in Table 4.

Table 4: Difficulties encountered by participants.

Difficulty Encountered	**# Participants**	**# Institutions**
Best practices "squeezed out"	1	1
Dealing with controversy	1	1
Dealing with institutional board	1	1
Dealing with steering committee	1	1
Difficulty of applying theory to practice	2	2
Institutional amnesia	1	1
Institutional inertia	2	2
Intra-institutional disagreement	1	1
Lack of field-specific resources, journals	1	1
Lack of opportunities to share ideas, resources with peers	1	1
Lack of professional development opportunities	1	1
Lack of resources (time, money)	2	1

Loss of staff	1	1
Rely on curators who don't always have time to develop exhibits	1	1
Strategic planning not based on research	1	1

Four participants commented on aspects of institutional management that affected their exhibit design practice, either positively or negatively. The coded results of these comments are presented in Table 5.

Table 5: Aspects of management identified by participants as either helping or hindering their exhibit design practice.

Management Aspect	# Participants	# Institutions
Autonomy	1	1
Professional development support	2	1
Management values best practices	1	1
Need for supportive management	1	1

Theories that informed participants' approach to exhibit design varied widely, but can be mapped to some of the theories and best practices mentioned above. Coded results were mapped onto the best practices listed in Bell et al. 2009 and McLean & McEver 2004 (except those that were difficult to apply to individual designers: using excellent design, providing time and money, exhibit maintenance and project management).

These texts were chosen for several reasons. My pilot study indicated that these resources might be underutilized by science exhibit designers and my coded results could be easily mapped to the practices recommended in these texts (as opposed to harder-to-define practices, such as Falk's suggestion, in his 2009 book *Identity and the Museum Visitor Experience,* of catering to different museum visitor identities). In addition, the practices mentioned during interviews reflected "best practices" such as prototyping or involving scientists and educators. No participant – not even the one who mentioned reading Falk specifically – mentioned visitor identities or key phrases that suggested they were applying other (equally worthy) theories. The results of this mapping are presented in Table 6.

Table 6: Specific comments mapped to best practices.

Theory	**# Participants**
Adhere to a single best practice/theory	0
Recommendations from *Are We There Yet?*	
Involve scientists, educators	2
Cooperative team planning	5
Evaluation/Audience Research	5
Prototyping	4
Focus on visitors	not mentioned specifically
Clear exhibit goals	3
Institutional support	2
Visitor comfort	1
Recommendations from the National Research Council	
Iterative design process	4
Address prior knowledge	3
Use a conceptual framework	not mentioned specifically
Incorporate metacognitive skills	not mentioned specifically
Incorporate multiple ways to engage	3
Clear exhibit goals	3
Learner-centered	not mentioned specifically
Community and educator partnerships	2

V. Discussion

1. Resources

I began this exploratory study with the assumption that every science exhibit designer would have heard of, read, and make use of the National Research Council reports for the very reason that they do pull together, synthesize, and summarize 40 years of research on how people learn science. My original intent was to look at the strategies exhibit designers used to apply the theories and recommendations found within the reports to their practice. What I found instead was that only one participant used the report. No participant identified one single theory or set of best practices that they adhered to strictly. Each consulted a variety of theories, best practices, articles, and personal experiences to inform their individual approaches to exhibit design and development.

A lack of available sources for information was generally not the problem, although ZA identified a lack of field-specific journals as a difficulty. Several participants (ZA from ZOO1 and ZC from ZOO2 in particular) identified navigating the "flood" or "fire hose" of information as a challenge. Both seemed eager to seek out new research and professional standards or best practices. Although ZC comes from a resource-rich institution and ZA from a resource-poor institution, both had methods for navigating the "flood" of information. ZC relies on colleagues and professional groups, such as on LinkedIn®, to help navigate the information available. ZA recently attended an educational conference and learned about "community learning networks" – groups of colleagues who share resources, strategies, and experience – and is using them to prioritize relevant resources. However, ZA went on to talk at some length about the difficulty of making time to think about, incorporate, and otherwise effectively use the resources she gathered.

2. Theories, Strategies, or Ideas

Kathy McLean, in *Are We There Yet?* (McLean & McEver, 2004), stated that there is no checklist for good exhibit design practice. It is true that none of the exhibit design professionals interviewed used a checklist – neither from the National Science Foundation, the National Research Council, nor any professional group such as the Visitor Studies Association or National Association for Museum Exhibition. Instead, the science exhibit designers interviewed rely on their lay theories. They use a variety of resources, incorporating some philosophies and strategies into their own personal exhibit design philosophies – their lay theories.

However, some broad theories and best practices seem to have been more absorbed or relied on than others. The theory of "multiple intelligences" or "multiple modes of learning" was the most commonly cited influence on exhibit design, whether or not the interviewees specifically referenced Howard Gardner and/or Bernice McCarthy (see Gardner, 1993 and McCarthy & McCarthy, 2006). One designer (SB from SCI2) mentioned using National Research Council resources such as *Learning Science in Informal Environments* (Bell et al., 2009) and *Surrounded by Science* (National Research Council, 2010), but these were not her primary references. Mapping the coded results of the interview transcripts showed that some best practices of McLean & McEver (2004) and Bell et al. (2009) are included in the individual practices of some science exhibit designers even if they have not read these publications, as seen in Figures 1 and 2, respectively.

Figure 1: Practices of McLean & McEver (2004). Number of participants who specifically mentioned a practice recommended by McLean & McEver (2004).

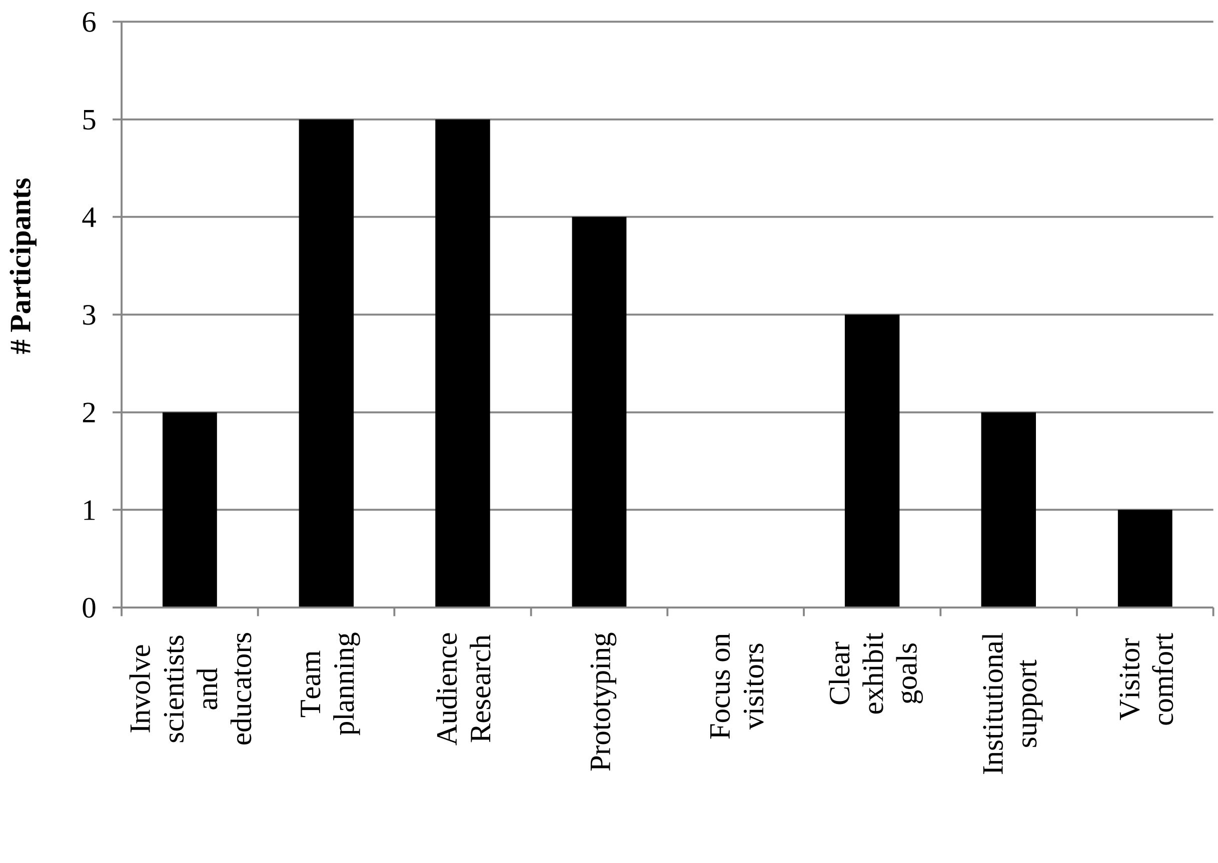
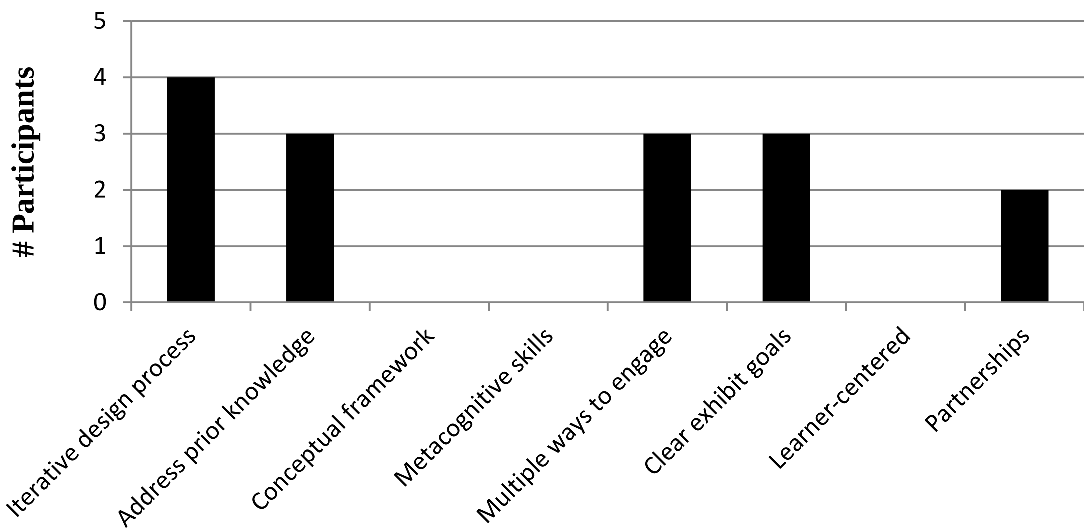


Figure 2: Practices of Bell et al. (2009). Number of participants who specifically mentioned a practice recommended by Bell et al. (2009).



Cooperative Team Planning

All of the participants described a "team approach" to exhibit design at their institution. SCI2 uses a "core team" comprised of an exhibit developer, exhibit researchers, and a project manager. Four advisory teams (made up of representatives from content development, education, the museum, and corporate partners) plus other individuals (such as developmental psychologists) are consulted at different stages during the exhibit development/design process. SA from SCI1 described her "working team" as a content lead plus representatives from public programs, marketing, fundraising, visitor studies, and the registrar. SCI1 relies on its curators to bring the exhibit content and development, but SA finds that the curators are often science-focused (as opposed to science education or exhibits focused) and don't always have time to be content leads. SA noted that her institution's lack of theoretical framework was a major shortcoming and that, in the past, outside exhibit design companies had brought museum exhibit theory to the museum's now-ten-year-old exhibits.

ZE described core teams at her institution as consisting of exhibit developers and exhibit designers who work in pairs with media specialists and the project manager. Representatives from other departments such as animal husbandry are consulted during projects. Projects are overseen by a steering committee, which is made up of the vice presidents of each department. Her institution makes use of audience research and best practices, particularly those from *Are We There Yet?* (McLean & McEver, 2004).

ZC and ZD described the exhibit development/design team at their institution as consisting of staff from exhibits, marketing, zoology/animal husbandry, and the graphic designer. ZC mentioned that representatives from facilities were present at meetings because a significant amount of exhibit building is done by them. Both mentioned several times the supportive upper management of their institution and the ample opportunities for professional development. ZC commented on the autonomy to meet deadlines and the trust her institution places in her and in research and evaluation as having a positive impact on her exhibit design practice.

Evaluation / Audience Research

Five participants mentioned using audience research to inform their practice. The Visitor Studies Group defines audience research as "the study of actual and potential audiences of an institution through the use of a variety of methods" (The Visitor Studies Group, n.d.). These methods include collecting demographic information on who does (or doesn't) come to the institution, administering surveys and questionnaires and other devices to assess visitor enjoyment, learning, affection, or behavior change. Evaluation, or audience research, is specifically mentioned by *Are We There Yet?* (McLean & McEver, 2004) as indicative of good exhibit design practice. Audience research allows an institution to take the visitors' perspective into account during exhibit design, and is also necessary for evaluating visitors' prior knowledge on a potential exhibit subject, for example.

A sixth participant mentioned that her institution would be conducting audience research in the near future. Of these five participants, four elaborated on the front end, formative, and summative evaluation they conducted and used to inform their practice. Two mentioned hiring professional outside evaluation consultants or firms. One mentioned using demographics and audience research to target certain audiences.

Multiple Ways to Engage

Three participants mentioned incorporating multiple ways for visitors to engage with exhibits. One of the three mentioned Howard Gardner's theory of multiple intelligences (see Gardner, 1993), one mentioned both Howard Gardner and Bernice McCarthy (see McCarthy & McCarthy, 2006), and one did not mention a specific author or study.

Prototyping

Four participants mentioned that their institution prototype exhibits. Prototyping involves creating mock-ups of exhibit elements and/or labels and testing them with visitors or focus groups. Prototypes inform an iterative design process; designers or institutions may use one or multiple rounds of prototyping. Two participants spoke at length about the integral role that prototyping and formative evaluation played on their exhibit design process. Visitors may be asked to try reading labels or to use an interactive element and give feedback. Formative evaluation may be used to systemically test the prototypes. Prototyping is identified as a best practice by both *Learning Science in Informal Environments* (Bell et al., 2009) and *Are We There Yet?* (McLean & McEver, 2004).

Involve Scientists & Educators / Partner with Community Members

Two participants specifically mentioned partnering with education specialists outside of the museum. SB relies on consultants such as education and child development specialists to make recommendations for the presentation of exhibit content that are in line with current cognitive science, psychology, and development. She commented that, while she is very interested in cognitive science and applying it to exhibit development/design at the museum, she feels that "a little bit of knowledge is a dangerous thing." SB is more comfortable consulting experts for the cognitive science aspects of exhibit design, saying that she knows a little bit about cognitive science but not enough to apply it to her practice. ZC relied on partner institutions to vet messaging in one exhibit because the animals involved were part of a conservation plan that relied not just on ZC's institution, but several outside institutions as well.

Addressing Prior Knowledge

Three participants specifically mentioned that they try to address visitors' prior knowledge. ZA described her institution's approach of trying to "disabuse" visitors of their misconceptions. Instead of "disabusing" visitors of misconceptions by simply presenting correct information, ZA would prefer to investigate how strongly held certain misconceptions are and attempt to address them accordingly. ZC and ZD, both from ZOO2, each mentioned using audience research to determine what visitors' prior knowledge is and using it to inform their exhibit design. ZE noted that her institution uses demographic information to target certain exhibits towards specific audiences, but did not specifically mention addressing visitors' prior knowledge.

Conceptual Frameworks, Metacognitive Skills

No participants specifically mentioned incorporating conceptual frameworks or metacognitive skills in their science exhibit design practice. These recommendations are stressed in the *Learning Science in Informal Environments* (Bell et al., 2009) and *Surrounded by Science* (National Research Council, 2010), but are not mentioned in *Are We There Yet?* (McLean & McEver, 2004).

Clear exhibit goals

Three participants mentioned that they develop clear goals for each exhibit that they design. Both McLean & McEver (2004) and Bell et al. (2009) identify developing clear goals as a best practice.

Visitor Comfort, Focusing on Visitors & Learner-Centered Design

One participant specifically mentioned attending to visitor comfort by referencing Maslow's hierarchy of needs, explaining that exhibits need to meet visitors' most basic needs (feeling safe, not being hungry or thirsty) before any learning or engagement can take place. Interviews with other participants gave the impression that they attend to visitor comfort, but because no specific word or phrase was uttered that could be coded, this is not reflected in my results. Similarly, no participant specifically mentioned designing "learner-centered" exhibits or "focusing on visitors."

Incorporate Metacognitive Skills

No participant mentioned incorporating metacognitive skills. Although this is a practice stressed in the National Research Council publications, those publications don't necessarily provide enough information on or examples of what incorporating metacognitive skills into an informal science learning environment such as a museum exhibit would look like.

Institutional Support

Institution support is not necessarily an aspect of exhibit design that practitioners have any control over, however, it is included here because it became evident that institutional support has a significant impact on the design of science exhibits. Two participants specifically mentioned and spoke at length about the excellent support they receive from their institution.

3. Difficulties Encountered

Difficulties mentioned by participants ranged from lacking time for prototyping their proposed exhibits to handling controversial exhibit content. For example, ZE remarked that her institution doesn't have a good method to handle potentially controversial exhibit content, such as whether or not to include an exhibit element commenting on the greenhouse gas emissions of the agricultural industry in a state with a powerful agricultural lobby.

SB noted that "institutional inertia" – an institutional reluctance to change – led them to view new developments in the field of exhibit design with an abundance of caution. SB described a wariness of "spending a lot of time and effort to turn the institutional ship in one direction" only to find out that it's the wrong direction.

Other difficulties can be attributed to a lack of time and/or money and management style. ZA and ZB, both from ZOO1, identified the limitation of time and money as a considerable challenge to their exhibit design practice. Shrinking budgets resulted in the loss of staff at ZOO1, some of whom ZA credited with bringing good exhibit design practices to the institution. The loss of staff also resulted in a lack of time for remaining staff to read, think about their practice, and keep up with new research. Less money also meant less professional development opportunities. In addition, ZA mentioned that one colleague used to facilitate intra-institutional sharing and reading of articles on best practices and relevant research; since the colleague's departure, the habit has disappeared.

In addition, ZA and ZB from ZOO1 identified "institutional amnesia" and "institutional memory failure" as challenges to their exhibit design practices. Turnover in staff, problems with communication, and/or a lack of a process to share knowledge, experience, and ideas within their institution led to failing to learn from past successes and mistakes, and much "reinvention of the wheel."

ZA's and ZB's comments illustrate that management style, in addition to time and money, has a significant impact on exhibit designers' practices. Supportive management does more than create a positive work environment and encourage exhibit designers; it can fund professional development, such as travel to national conferences, hire sufficient staff, and give exhibit designers enough autonomy to carry out their best work.

VI. Conclusions

There are probably as many approaches to science exhibit design as there are designers. No single set of best practices is held up as an "industry standard" by which all science exhibits or science exhibit design professionals are evaluated. This lack of standard criteria for assessing "excellence" in science exhibits presents a set of challenges beyond the scope of this exploratory research. However, efforts have been made to identify the best practices that science exhibit designers use and the cognitive science research that can best inform science exhibit design. Whether and how these resources are disseminated to practitioners and ultimately used remains unclear, although this thesis contributes to the groundwork needed for a larger and more systematic study.

Furthermore, this thesis points to several conclusions that may be of interest to the field at large. First, many resources exist that could inform science exhibit design, but fewer resources are available to help science exhibit designers navigate, understand, and utilize them. With so many articles and books to read and conferences to attend, how does a science exhibit designer prioritize which are worth her time? How does she even find the resources in which she is most interested among all the potentially helpful resources that exist? The fact that only one participant used McLean & McEver (2004) and one other used Bell et al. (2009) suggests that these resources may not be well disseminated in the field.

Second, time and money have a significant impact on how science exhibition designers are able to practice. This may seem obvious, but the effects of limited time and money reach beyond the ability to build a large, fancy, expensive exhibit. The availability of time and money impacts professional development opportunities, time to read and reflect on new information, opportunities to meet and exchange ideas with colleagues, time to prototype and modify designs, etc. Support for professional development and time to read and incorporate research, as well as time for introspection, seemed to be related to management style and organization of the institution. This was not something I had anticipated, and, consequently, information about management style and organization turned up in a haphazard fashion during interviews. However, it does seem that good management and sufficient time and money ultimately affect how exhibit designers are able to make use of the informational resources they find.

A more thorough investigation of science exhibit designers' lay theories could be fruitful, but institutional organization, management, and networks should also be investigated to provide a complete picture of what best practices and research influence science exhibit design. It is important to describe the personal theories or pedagogies of exhibit designers because they do impact what and how visitors learn from the resulting exhibits. However, no (or very few) exhibit designers work alone, and no one works in a vacuum. Management style and organization seem to impact science exhibit design practice and is a major mitigating force in how best practices, theories, and research are eventually realized in exhibits. Investigating the role of management style and institutional organization on exhibit design may be necessary to understanding how exhibits are ultimately designed.

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Appendix A: List of Questions/Topics

Best Practices

- Do you use a set or sets of "best practices" or recommendations? Which one(s)? NAME Standards? LSIE? Surrounded by Science?
- Do you have an institutional "best practices" or "conceptual framework"?
- What learning theories do you use or try to incorporate in your exhibit design process? (e.g., "multiple intelligences")
- What are some of the key ideas you keep in mind when designing exhibits?
- Do you have any favorite books, papers, or ideas that you heard elsewhere (one a listserv or at a conference) that you use or consult when designing an exhibit? (e.g., Planning for People, Are We There Yet, Lord & Lord)
- How do you apply theory to practice? Do you find these best practices/recommendations helpful? Useful? Practical?
- Does your institution or exhibit team follow developments in cognitive research, informal science education, etc? (If so, in what ways?) How do you keep current? Conferences? Journals? Newsletters? Blogs? Which ones?
- What resources do you turn to when developing/designing an exhibit?
- What have you found that works? What have you found doesn't work?
- Do you share your experience and expertise with colleagues at other institutions? Do you get ideas and help from them? Who/where and how?
- How often do practitioners or institutions reflect upon the differences between their practices and new research about learners, learning process, and specific subject matter fields? (ASTC)

Exhibit Development/Design Process

- How are projects started/managed?
- How is the topic, theme, "big idea" or "main message" decided?

- How are the space, budget, or other constraints decided?
- Who is involved in the development and design process? (In house staff? Contractors? Board members? Designers? Educators? Community representatives?)
- How did this group or team work together?
- How were decisions regarding content and design made?
- Who has ultimate say or "veto power"?
- How do others involved in the exhibit design process (educators, directors, board members, fabricators, graphic designers) react to your best practices (e.g., suggest there isn't time and money to prototype, or, enthusiastically endorse prototyping)?
- Do you prototype? (And if so, how? Do you test for usability, visitor comprehension, visitor enjoyment, etc.?) Do you test prototypes on visitors?
- Do you use audience research (front-end/formative?)

Specific Recommendations

- Do you address prior knowledge in your exhibits? How?
- Do you try to present visitors with a conceptual framework that individual facts fit in?
- Do you teach metacognitive skills in your exhibits?
- Do you consider cultural differences?
- Do you involve local communities in exhibit development/design?
- Do you design with specific learning goals in mind? (LSIE)
- Do you include intractives? (LSIE)
- Do you include multiple ways for people to engage with the content? (LSIE)
- Do you "support and encourage readers to extend their learning over time"?
- Do you use an iterative process?
- Do you consult scientists/science experts?
- Do you consult education/cognitive science experts?