CLARIFYING THE ROLE OF AUTHENTICITY AS AN ELEMENT OF SCIENCE EXHIBIT DESIGN

A Dissertation

by

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ABSTRACT

When the doors of a science center open, so do opportunities to step into oversized bubbles or unearth fossils in a dig site the size of a football field. Are those experiences educationally meaningful or merely novel? To address this question, I gathered evidence and interpretations in three separate yet connected studies on the design features of a quality science exhibit in three separate studies.

In the first study, I conducted a literature review on exhibit design features that had a moderating effect on learning.. Each of the 19 studies in the sample was an empirical investigation. I used the findings from this review to (a) generate a research-based exhibit design resource and (b) highlight exhibit elements that need clarification.

In study two, I interviewed six veteran exhibit designers from nationally recognized institutions to clarify the role of authenticity in the exhibit design process. Findings from a constant comparative analysis of their interview data indicated that science exhibits needed to be authentic to the (a) institution, (b) learner, and (c) science as a field of study. "Scale" and "role-play" were two unique factors that shaped immersive environments in informal science education institutions.

My focus on the exhibit as a learning environment predicated the need to investigate how *authenticity* is expressed across a larger sample of exhibits. In the third study, I used four expressions of *authenticity* as pre-determined categories for a content analysis on 106 exhibit descriptions from summative evaluations in the Building Informal Science Education network database. The findings from this study affirmed the

effect of an institution's priorities on the presence of authentic artifacts (e.g., natural history museums) over hands-on experiences (e.g., science centers). Where visitors' opportunities to interact with authentic artifacts might have been limited by the type of institution, visitors' opportunities to explore with their senses were not.

DEDICATION

This dissertation is dedicated to the many professionals who make learning science exciting all around the world. I am indebted to their willingness to share their passion and be engaged in the successful growth of the informal science education landscape.

Let love be authentic – Romans 12:9

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NOMENCLATURE

AISL	Advancement of Informal STEM Learning
BISEnet	Building Informal Science Education network
CAISE	Center for the Advancement of Informal Science Education
EEF	Exhibit Element Framework
ISE	Informal Science Education
IMLS	Institute of Museum and Library Services
NRC	National Research Council
NSF	National Science Foundation

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CHAPTER I

INTRODUCTION

When you enter a science classroom, research lab, or science center, you become part of a larger story of how people engage science learning in their community. In traditional classrooms, students are led through a variety of learning experiences by a professional educator in the social context of peer groups. Likewise, novice researchers explore and grow in their understanding of specific strands of science in research labs directed by a team of experts through an apprenticeship model.

This series of studies considered how science learning experiences are shaped in informal environments. Fenichel and Schweingruber (2010) described learning experiences in Informal Science Education (ISE) as (1) being physically, emotionally, and cognitively engaging; (2) providing direct or technologically-mediated interactions with authentic scientific phenomena; and (3) being learner-directed experiences. These shared attributes provide learners with active and accurate representations of the complex nature of science (Fenichel & Schweingruber, 2010, p.5). Additionally, Fenichel and Schweingruber (2010) characterize informal learning environments as uniquely providing learners a distinctive sense of autonomy or control over a typically open-ended experience.

Learners exercise a considerably unique level of autonomy over their choices about where, with what, and how much they will participate in informal science learning experiences (Fenichel & Schweingruber, 2010). Learners initiate conversations or pursue experiences as their interests are piqued or their schedules provide opportunity. For example, learners might navigate through the halls of a science center considering which experiences will make the best use of their time and agenda. Once they find an exhibit or experience that piques their interest, visitors interact with it in ways that compliment their learning style and level of comfort and disengage at their convenience (Falk & Storksdieck, 2010). They determine their personal path to learning in an experience as they focus their time and energy on a given part of the experience. One learner may walk away with a new experience with an unfamiliar tool while another may leave with new terms to describe an observation or phenomenon and a third may depart feeling satisfied by an entertaining experience. As the learner determines the extent and direction of her experience in each scenario, the learner's experienced benefit may be more personally meaningful than traditionally structured experiences in a classroom or laboratory (Falk, Moussouri, & Coulson, 1998).

Learning in Informal Science Environments

These experiences are not limited to a science center. Informal science learning environments include numerous activities ranging from conversations in a family garden, to participation in an astronomy club, or to trips to a local science center. Bell, Lewenstein, Shouse, and Feder (2009) organized how people learn science in informal environments into three categories: (1) everyday experiences, (2) programs, and (3) designed environments. Everyday experiences can include scientific observations about patterns in Nature on the way to school or conversations that weave scientific ideas into normal discussion around a family meal, community garden, or road trip through a new environment. Programs include organized groups that share a common interest like a gardening program or an afterschool astronomy club. Designed environments include those places that exhibit and organize scientific phenomena for the public's view and comprehension. Designed environments are growing as a category of ISE experiences. They can include traditional science centers and museums as well as emerging spaces like science festivals, cafes or traveling science shows. This dissertation focuses on understanding the learning experiences in the third category: designed environments.

Designed Environments

Fenichel and Schweingruber (2010) defined designed environments as "places where artifacts, media, signage, and interpretation by staff or volunteers are primarily used to guide the learner's experience" (p.3). This definition's focus on the interaction between people and objects is broad enough to include both traditional sites (e.g., museums and science centers) and emerging places (e.g., science cafes, science festivals). My interest in science education research in designed environments hinges on two features unique to how people learn science in these spaces: accessibility and autonomy.

Accessibility. One important feature of designed learning environments in informal science education is its accessibility. Access to learning experiences in classrooms and research labs are limited to specific audiences. Learning experiences in classrooms are limited to students enrolled in a specific course. Learning experiences in designed environments do not share this limitation—they typically engage a variety of participants. Individuals, families, groups of friends, and even strangers can socially, emotionally, and physically interact with the artifacts, stories, and cognitive challenges in designed learning environments.

Autonomy. Whereas a teacher or curriculum directs a learner's experience in a classroom, the learner's choice and autonomy characterize the learner's experience in a museum or science center. In a classroom setting, teachers organize the learning materials, choose the activities, and modify the arrangement of the classroom furniture with the purpose of creating a learning experience that is meaningful to their students. Behind-the-scenes professionals from the ISE community are similar to classroom teachers. Their strategic planning and day-to-day effort shape visitors' experiences through a series of planned interactions in a variety of learning environments.

Stakeholders in the Design of Informal Science Experiences

Effective learning environments are purposefully designed. Teams of people have a stake in creating those learning spaces. It is an oversimplification to assume that classroom teachers create learning environments in their classrooms in isolation. Architects were involved in the design of the room's orientation and features. Administrators assigned teachers to classrooms based on a larger organization by content, grade level, or access to specialized equipment. Curriculum specialists guided decisions on materials and resources that frame the educational messages with a guiding standard. Similar stakeholders exist who make up the behind-the-scenes professionals in the ISE community. Among these professionals are ISE researchers, exhibit developers, and evaluators.

Researchers. Researchers in the ISE field investigate how learning happens in designed environments. ISE researchers can be embedded in an institution like Sue Allen and Joshua Gutwill at the Exploratorium, or they can be associated with a cooperating university like Kevin Crowley at the University of Pittsburgh or John Falk at Oregon State University. Researchers' methods vary but the quality of their work is consistent with professionals across the social sciences.

Practitioners. Practitioners, such as exhibit developers, can also be internal or external stakeholders. Exhibit designers and developers may not have consistent access to current research. Their methods are typically very collaborative and success is found at the institutional level. Many exhibit developers work with content experts, learning scientists, and funders to shape a set of learning goals for each exhibition. While their discoveries may not make the pages of peer-reviewed journals, they clearly shaped the decisions and quality of subsequent projects.

Evaluators. Finally, evaluators are a segment of stakeholders who share similarities to both researchers and practitioners. Like researchers, evaluators follow common guidelines to select data collection methods and analyze visitor behaviors and descriptions. Evaluators' focus is broad and can include any number of aspects of the ISE experience (e.g., visitor satisfaction, cleanliness of the facility). Like practitioners, evaluators collaborate with floor staff, administration, and internal decision makers to design their evaluations. Evaluators' findings typically have limited distribution to internal stakeholders. Exceptions to this practice include government or external funders, which may require sharing results with the public.

While each of these three categories of stakeholders contribute to how learning environments are shaped across the ISE community, it is important to acknowledge that the boundaries that separate these positions are not as defined or impermeable as they may seem. In fact, many evaluators were once researchers or practitioners or both before a change in focus on evaluation. Additionally, many researchers serve as external evaluators in tandem to their research and teaching commitments at their respective institution. As such, these overlapping experiences and interconnected interests might have colored their contribution to the research process.

Statement of the Problem

Highly successful ISE institutions use research and evaluation for strategic planning and responsiveness to their changing communities. Evaluators capture snapshots of visitor experiences and make recommendations to improve what works, given their institution's specific context, mission, and vision. Responsive ISE institutions transform these snapshots into barometers of both their institutions' and their community stakeholders' assets and opportunities for growth. However, access to these resources is not evenly distributed across the ISE landscape.

Smaller, regional ISE institutions fill the countryside, but their limited access to resources restricts their ability to shape clear and meaningful strategic plans (Blackwell & Scaife, 2006). Because of their limited capacity and resources, small and regional museums, zoos, and science centers cannot commit to the same process standards for exhibit design as larger and more resource-rich ISE institutions. As ISE professionals' experience with the processes and language of research and evaluation expand, their abilities to collaborate with external partners improve (Pontin, 2006). Many institutions rely on contracting exhibit design services or donations from outsiders to fill their museum floors. Relying on donations from benefactors like universities, businesses, and individuals intensify the need for ISE institutions to be able to communicate effective exhibit design principles. Regular access to quality and timely research-based findings can support museum leadership's ability to communicate design criteria and constraints with external exhibit designers and donors. Subsequently, access to these resources can also improve the life of an exhibit and extending its initial investment (McLean & McLean, 2004; Pontin, 2006). Small or rural institutions' access to best practices in the field varies, but their lack of experience of conducting routine evaluations limits their ability to communicate well with outside consultants and exhibit designers (Winterbotham, 2006).

By comparison, relatively few ISE institutions have the capacity to make research-informed priorities and communicate them well with external consultants and exhibit designers. In many cases, geographic proximity limits visitor access to resource-rich institutions to a handful of urban centers across the U.S. As such, smaller and regional ISE institutions as well as the communities they support could greatly benefit from sharing in the benefits of the experiences and process-knowledge from resource and experience-rich institutions. I purposed this series of studies to bridge that gap between resource-rich and resource-poor institutions by defining and describing evidence of research-based design principles.

Statement of Purpose

My purpose in conducting this series of investigations is to narrow the gap between high quality informal science learning experiences and the capacity of informal science institutions. To accomplish this purpose, I gathered evidence and interpretations from researchers, practitioners, and evaluators on what *authenticity* looked like in a high quality experience with a science exhibit. I synthesized three different stakeholders' interpretations of exhibit design features that have empirical and practical moderating effects on visitor learning behaviors. I organized exhibit design attributes and characteristics into a resource for making and communicating design choices. Additionally, the resources I developed in this line of inquiry provided a common framework to profile comparable features of exhibits in future research. The findings from these studies have the potential to distribute meaningful research to the larger landscape of small, regional ISE institutions. This revival is not in competition or to the detriment of understanding visitors and their agendas, but is a complement for better understanding of the informal science learning experience.

Theoretical Framework

I share the contemporary constructivist perspective of how people learn science—namely, through an iterative progression of model-building experiences—however, for the purposes of this series of studies I focus not on the learning behaviors of the individual, but on their interactions with the artifacts and materials in a science exhibit. My experience as a science educator and as a teacher educator has shaped my value of the role social, physical, and cultural influences have on a learner's experience. Bandura's (1986) Social Cognitive Theory provides a framework for interpreting the interactions among a learner's thinking processes, interactions with their environment, and their manifest behaviors. In this series of studies, I interpreted the design features of science exhibits as one vertex of Bandura's model—namely the environmental factors vertex. In Bandura's model, the environmental factors vertex has an interdependent relationship with the learner's internal processing and with the learner's expressed behaviors—both are part of the learning experience (Harlen, 2001).

Research Questions

The overarching research question for this inquiry was: What are the moderating effects of exhibit design characteristics on visitor learning behaviors? I conducted three studies to answer the main research question. In my first study, I addressed the overarching research question in depth through a literature review of empirical studies. This review highlighted exhibit design features with moderating effects on visitor learning behaviors. I then narrowed the subsequent investigations to *authenticity* as one specific exhibit design characteristic that impacted visitor learning behaviors. In order to define *authenticity* appropriately, I investigated how different stakeholders experienced the phenomenon. I selected three different perspectives to investigate: the researcher, the practitioner, and the evaluator. By synthesizing these three perspectives, I was able to make a stronger claim about the moderating effect of exhibit design characteristics on visitor learning behaviors.

In the first study, I investigated the researcher perspective of the moderating effect of exhibit design features on visitor learning behaviors in designed environments. The research question I posed in this study was: What effects on learning behavior do researchers attribute to exhibit elements? I reviewed the literature to gather methods and findings from empirical studies on visitor learning behaviors in designed environments. This analytic process yielded eight exhibit elements that had a moderating effect on visitor learning behaviors. I organized these exhibit elements into a two-tier exhibit design framework—the Exhibit Element Framework (EEF). Researchers' divergent interpretations of these design features highlighted a need to clarify and validate broadly or ill-defined features further. I selected *authenticity* as one exhibit design feature to clarify in the subsequent investigations.

For the second study, I investigated the practitioners' interpretations of *authenticity* as an exhibit design feature. I focused the semi-structured interviews on the role of *authenticity* in the exhibit design process. The following research question guided the data collection in this study: What descriptions do practitioners use to illustrate the role of *authenticity* in the exhibit design process?

For this study, I interviewed a group of expert practitioners. I selected my interviewees purposively to represent perspectives associated with different stages of an exhibit design process: the strategic planning of the exhibit, the development of the exhibit, and the evaluation of the exhibit. I used a constant comparative method to analyze the interview data for themes shared between these expert practitioners, as well as areas where their perspectives on the role of authenticity differed. By analyzing the themes from each interview, I was able to describe attributes of an exhibit and its design process that can be used to measure authenticity.

In the third study, I investigated the evaluator perspective by conducting a content analysis of relevant summative evaluations included in the NSF-funded BISEnet database. The research question for this study was: To what extent and in what ways are aspects of *authenticity* characterized in the descriptions of science exhibits included in the BISEnet evaluation data? I systematically compared exhibit descriptions from a high quality sample of the summative evaluations included in the BISEnet database. I treated each exhibit within the summative evaluations as individual cases. I used descriptions of the exhibits as the content whereby I coded the level of *authenticity* across four designed attributes: *artifacts, sensory experience, presentation of the phenomenon,* and *environment*.

In the concluding chapter I highlight lessons learned across the three studies and summarize the benefits of the findings to the field as a whole. I critically reflected on the findings from each of the three studies. I also make recommendations for policy, practice, and future research.

Significance of the Study

Science education research in informal learning environments has provided important insights on how people learn science outside the traditional structures of lock-step K-16 educational models. Highlights in this series of studies emphasize the role *authenticity* can have on improving both formal and informal science learning environments. The products of this study can give smaller museums an opportunity to clearly communicate their desired design attributes and constraints to exhibit designers and manufacturers. Smaller ISE institutions can shape their design constraints to better predict desired outcomes consistent with their institution's vision and mission. Finally, the products of this line of inquiry can support all ISE institutions by expanding the transferability of highly engaging exhibit design principles across the landscape of informal science learning environments and perhaps into the realms of formal K-16 education.

Limitations of the Study

This research is predicated on the perspective that some elements within an exhibit can have an effect that can be generalizable to other science exhibits and settings. A common thread existed among the expert practitioners interviewed in Chapter III. Their perspective was that every exhibit is a custom-designed series of experiences that begin from the ground up in a design process. Many expressed a belief that no single characteristic or combination of exhibit characteristics has any greater influence than the sum of their parts. They describe the exhibit design process as an artistic, holistic expression of the designer's response to the constraints of the strategic goals of their institution. The perspective that holistic exhibit design is an artistic expression can condemn resource-poor institutions. Without the advantages and results from internal research, design, and evaluation teams or the language and strategies that stem from high quality experiences, these smaller institutions will continue to struggle to develop high quality experiences in their institutions.

Organization of the Study

This dissertation was organized in such a way as to address three different stakeholder perspectives on *authenticity* as an exhibit design feature. This is a three article dissertation. In each of the three articles, I present my findings of independent studies of investigating researcher, practitioner, and evaluator perspectives of the moderating effects of exhibit design characteristics on visitor learning behaviors, respectively.

Chapter I was the introduction to the three studies discussed in this document. Chapter II is the first study—a literature review on exhibit design features and visitor learning behaviors. Chapter III is a multiple case study focused in on *authenticity* as an exhibit design feature. Chapter IV is a content analysis that investigates how *authenticity* was expressed through the design features of a larger sample of exhibit descriptions. In Chapter V, the findings from the three studies are summarized. Final conclusions and implications of my research findings are also discussed.

CHAPTER II

EXHIBIT DESIGN AND VISITOR LEARNING RESEARCH:

AN EMERGING FRAMEWORK

Your family has been navigating a series of experiences at a local children's museum. Your goal was to get everyone out of the house and have fun on a rainy day. Somewhere between *Newton's Third Law of Motion* and *Build-Your-Own Bucky Ball*, you see a young girl quietly working at what appears to be a small factory line. Sets of large blue three dimensional geometric foam shapes are rotating around a circular conveyer belt. The shapes and belt are accessible from all around the exhibit. On four points of the conveyor belt, raised sensor pads with a green light and a red light above them, wait to provide instantaneous feedback to the museum's visitors. No signs to attract or direct a visitor's experience, but the six-year-old girl's curiosity led her to one sensor.

The girl quietly places one object after another on the sensor, watching the LED lights carefully for affirmation of a job well done. She continues to check different objects from the conveyor belt, unaware of the older boy who has taken his place at the sensor to her left. His hasty attempts to use his pad sensor draw the little girl's attention away from her sensor. She reveals an as-of-yet unspoken discovery: "If you put the square face of the objects on your pad, it should turn green," she shares—unconventionally stepping out of her shy cocoon for a moment. The boy seems intrigued and places the square face of a blue foam cube on his sensor. Much to the young girl's shock, a red light appears. The young girl and older boy start to work together, making suggestions and testing hypotheses until they figure out how his sensor works. It is time for the little girl to move on through the rest of the museum with her family but the boy goes to the third sensor to start the exploratory process again.

I know this girl well—she is my oldest daughter. Of all my children, she is by far the most introverted. I watched as the peculiarity of a simple interactive science exhibit drew down her guard and opened a door of opportunity to: (1) share her learning and (2) help another child explore his own. As a classroom science teacher, I was intrigued by the interaction. In less than ten minutes, my daughter explored a system independently, tested multiple hypotheses, repeated her test to validate her results, communicated her findings with a peer, and co-investigated a similar phenomenon with a total stranger. All of this happened without an adult facilitating the interaction.

Landscape for Science Education

Across the U.S., curriculum specialists meet and organize formal standards into a progressive series of grouped learning objectives. Each state has a choice of adopting national standards or developing their own. Most of the decisions about scope and sequence happen at the school district level—some happen at the state level. In either case, these learning outcomes shape the classroom and laboratory experiences of science students in communities across the landscape of formal science education. As rich as these experiences are, Falk and Dierking (2010) propose that classroom experiences account for only 5% of a person's life. Learning science is not limited to this small fraction. Many ways exist for people to engage in science learning outside of the classroom. These experiences are broadly grouped under the umbrella of Informal Science Education (ISE).

In an early attempt to map delivery vehicles across the ISE landscape, Falk, Randol, and Dierking (2011) conducted interviews with representatives in ISE contexts and produced a two-dimensional snapshot of the institutions and organizations that provided out-of-school science learning experiences. Their map included traditional settings such as natural history museums and science centers and emerging contexts such as science cafes and science media. By qualitatively analyzing the interview data, these authors were able to plot and compare each unique context by the level of informal education of the institution and the level of public STEM understanding linked to the institution's broader impacts. As extensive as the landscape was, there is room to improve ISE member representation by including science festivals, citizen science portals, and other innovative environments for engaging the public with science.

Bell, Lewenstein, Shouse, and Feder (2009) organized this growing landscape into three larger categories. These appear in the National Research Council (NRC) handbook for understanding and shaping learning research in the ISE landscape, *Learning Science in Informal Environments*. The three categories were (1) everyday experiences, (2) afterschool organizations and activities, and (3) designed environments. Everyday experiences in ISE range from managing a family garden to conversations around the dinner table. Afterschool organization and activities include Boys and Girls club activities, and school-sponsored astronomy clubs. The third category, designed environments, includes the category that is the focus of this review.

Learning Science In Designed Environments

Designed environments include, but are not limited to, science centers, planetariums, zoos, aquariums, botanical gardens, and a host of different types of museums (e.g., children's museums, natural history museums). Each site may organize their learning experiences differently, but some common delivery mechanisms exist. The two most common delivery systems are programs and exhibitions. Most designed environments host a mixture of programs and exhibitions to meet the needs of their specific audience.

Programs are docent-led experiences or modeled demonstrations that vary depending on time of day or season of the year. Exhibitions are permanent or semi-permanent features of designed environments that include different combinations of exhibit components. Exhibit components can range from static displays and dioramas to open-ended experiences using advanced sensor instruments. Many designed environments will offer educational programs to complement exhibitions on their site.

Measuring Learning Around Exhibits

Learning around exhibits has been measured by analyzing observable behaviors, visitor discourse, and explicitly recalled data from surveys or interviews. Each method has been used individually and in varied combinations to achieve different levels of understanding about the visitor's learning experiences.

Observable behaviors. Observable behaviors are usually expressed in terms of attraction power, holding power, number of stops and return visits to single exhibits along a learning path (Atkins, Velez, Goudy, & Dunbar, 2008; Guler, 2015), and a progression of observable interactions from limited observing and touching of exhibit elements to the full appropriate use of an exhibit according to a designer's intention (e.g., Alfonso & Gilbert, 2007; Alt & Shaw, 1984; Boisvert & Slez, 1995; McManus, 1987; Sandifer, 1997; Sanford, 2010; Yalowitz & Brennenkant, 2009). While these passive measures are simplest to incorporate into the public learning environments without interfering with the visitors' overall experience, these measures also make the largest assumptions related to the visitors' learning. An observation that a child remained at an exhibit for statistically longer than another is difficult to interpret. Was the longer period of time due to a deeper learning experience or was it because their parent told the child to wait there? Conversely, the child might have merely enjoyed the novelty of a specific aspect of the exhibit.

Visitor discourse. Researchers have different terms they typically use to categorize discourse around exhibit spaces. Some researchers count the length of conversation or number of "educational messages" as a comparable feature (Pattison & Dierking, 2012), whereas others use categorical and hierarchical taxonomies to measure the quality of the conversations (e.g., Allen, 2002; Crowley & Jacobs, 2002). Discourse taxonomies in informal learning environments typically cover five broad categories of discourse: strategic, perceptual, relational to experience, relational to knowledge, and evaluative speech (Allen, 2002; Crowley & Jacob, 2002; Geerdts, Van de Walle, & LoBue, 2015; Silverman, 1990).

Explicit recall. The method of explicitly questioning visitors through interviews, focus groups, or surveys—also known as explicit recall—is the only indirect method for operationalizing learning that routinely appears in visitor studies. This method is used in pre-visit and post-visit interviews, surveys, or pre- and post-visit personal meaning maps (Falk, Moussouri, & Coulson, 1998; Falk & Storksdieck, 2010). In each type, the method is employed beyond the scope of the respondent's actual experience with the exhibit. With a survey, for example, findings can be difficult to link to learning. In one instance, Stevenson (1991) used a nine-question survey administered six months after the visit to an exhibition. By using this survey, Stevenson expressed an assumption that exhibits that make a long-lasting positive memory have a more educational value than exhibits failing to leave a positive memory.

Limitations. Our understanding of visitors' learning experiences is limited by the use of only one source of data collection. Each data collection has its merit and challenges. Explicit recall can be an intrusive data collection method and the presence of researchers conducting systematic observations may influence visitors' behaviors as they enter an exhibit space. Additionally, over-reliance on self-reported visitor data can make it difficult to distinguish the difference between the visitors' real experiences and reported perceptions. Many researchers have found that multiple points of data collection have improved their ability to interpret visitor learning behaviors around exhibits (Allen, 2004; Sanford, 2010). Through the use of multiple data collection methods, researchers can improve their ability to interpret findings and extend or broaden legitimacy to the field.

Purpose

The purpose of this study was to organize a breadth of empirical findings from current research on exhibit design and visitor learning behaviors into a meaningful framework. I believe this purpose will ultimately broaden the reach of high quality experiences in science learning environments. Potential beneficiaries of this type of research are smaller or rural institutions that do not have access to, or the resources for engaging, current research on a regular basis. Smaller or rural institutions can use this evidence-based framework to shape design considerations for future exhibits and strategic planning, thus expanding the impact to more communities and more people. Finally, although the empirical data are focused on a single type of science learning environment, informal science institutions, the framework generated from this review can also inform the design considerations for other science learning environments also.

Research Question

As an emerging researcher, I walked away from the observation of my daughter's interaction with the sorting sensors with several questions: What was it about this exhibit that created the conditions for this social interaction? Was this event just an isolated moment in time or does this happen consistently around certain types of exhibits? These and similar questions prompted me to focus my literature review on the empirical and theoretical connections between exhibit elements and evidence of learning in informal science learning environments. The research question that guided this literature review was: What effects on visitor learning behaviors do researchers associate with exhibit elements?

Methods

This review was the product of a multiple phase search process, a rigorous set of inclusion criteria, and the application of a theory-based coding scheme. This process narrowed the review to focus on 19 empirical studies that illustrated an empirical relationship between exhibit design features and visitor learning behaviors.

Search Strategy

I began the search and selection processes with a review of the National Research Council's *Learning Science in Informal Environments* (Bell et al., 2009). This book represented the most current comprehensive review of learning theories in the field. There were three rounds in this search process. Each round contributed to a larger sample of potential articles for inclusion in this review.

Round one. In round one, I outlined relevant sections of the book including the introduction, theoretical assumptions in the field, and assessing learning, as well as the specific chapter focused on learning in designed environments (e.g., science centers and museums.) I mapped the content and references for each section and conducted a preliminary analysis of their sources by author and publishing journal.

Table 2.1.

Key Authors and Journals from Select Chapters of Bell et al.'s (2009) Learning Science in Informal Environments.

Authors		Journals	
Name	Citations (n)	Name	Citations (n)
John Falk	23	Curator Journal	30
Lynn Dierking	18	Science Education*	27
Kevin Crowley	11	Journal of Research in Science Teaching*	18
Gaea Leinhardt	10	Visitor Studies	14
Kirsten Ellenbogen	9	Public Understanding of Science*	12
Philip Bell	7	International Journal of Science Education*	10
Leonie Rennie	6	Journal of Museum Education	9
Sue Allen	4	Journal of the Learning Sciences*	6
Stephen Bitgood	3	Studies in Science Education*	5
Joshua Gutwill	2	Museum Management and Curatorship	3

Note. * Indicates journals that publish relevant special issues on learning in ISE institutions.

Round two. From the compiled list of citations, I selected ten authors and four museum practitioner journals for the second round of the search process (Table 2.1). I compiled each author's published works from ERIC, EBSCO, and Pro-Quest. I reviewed the titles of publications within each author's openly available curriculum vitae for work related to visitor learning and exhibit design. I also reviewed the titles of articles published in *Curator, Visitor Studies, Museum Management and Curatorship,* and the *Journal of Museum Education* for evidence of visitor learning and exhibit design. I reviewed each journal retrospectively for a 30-year period where applicable; as not all journals had a 30-year history. I searched the introductions and literature review sections of each article for additional sources for a third round of the search processes.

Round three. Searching for the references cited in the introductions and literature review sections of the papers reinforced the importance of the identified names, articles, and journals from round one of the search processes and expanded the cumulative list to include additional authors, articles, and journals. Articles identified in each round of the selection process were read and evaluated based on a series of inclusion criteria.

Inclusion Criteria

I selected studies for inclusion in this review based on the following three criteria: (a) the study had to be an empirical study of visitor behaviors; (b) the study had to include references to exhibit characteristics or features; and (c) the setting of the study had to include a designed environment (e.g., museum, science center, zoo, planetarium, aquarium). Based on these criteria, I reduced the identified works to a focused sample of 19 articles from 11 journals.

Coding and Synthesis

I used Bandura's (1986) *Social Cognitive Theory* as a theoretical framework for coding the studies included in this literature review. In its most primitive form, Bandura's theory considers how three moderating variables interact with one another to shape a learning experience. These three moderating variables appear as vertices of an interconnected triangle: (1) personal variables, (2) environmental variables, and (3) actions. While still fundamentally behaviorist in nature, Bandura's model incorporates the interactions of a learner and features of their environment. This extends the traditional behaviorist paradigm by emphasizing that learning is not a one-to-one relationship between incentive and action. In fact, Bandura's model includes the use of double-sided arrows to express the interdependent relationships among each of the three moderating variables.

The double-sided arrows in Bandura's SCT model illustrate the perspective that a learner's internal processing shapes, and is shaped by, their learning environment as are their manifest behaviors and vice versa. Fenichel and Schweingruber (2010) emphasize the need for additional research on these same variables; namely the learning processes within individual minds as it complements interactions with environmental features such as language, artifacts, and others (p.13-14). Because my focus on this literature review is the connection between visitor learning behaviors and exhibit design features as elements of the learning environment, Bandura's model provides a framework for analyzing and interpreting evidence in each category across a series of studies. Therefore, I extracted data that mirrored Bandura's three vertices but in the context of how visitors learn around science exhibits. Figure 2.1 is an example of how I used Bandura's SCT model to organize data from Alfonso and Gilbert's (2007) study on the effect of different presentations of sound on visitors to the Pavilion of Knowledge in Lisbon, Portugal.

In Figure 2.1, Alfonso and Gilbert (2007) measured the visitor participants' appropriate use around two basic types of exhibits that communicated the science of sound with their visitors. The emphasis of the research design was on the exhibit features as they related to the authenticity of the experience. These authors operationalized learning by associating it with time spent, appropriate use, and completion rates of designed activities around the exhibits. Alfonso and Gilbert (2007) determined the appropriateness of visitors' uses of the exhibit to the exhibit designers' original intention. Alfonso and Gilbert conducted follow up interviews to profile a level of understanding by asking questions about the visitors' perceived benefits, value, and learning from the experience. Figure 2.1 organizes each of those attributes into graphic representation based on Bandura's (1986) SCT graphic.

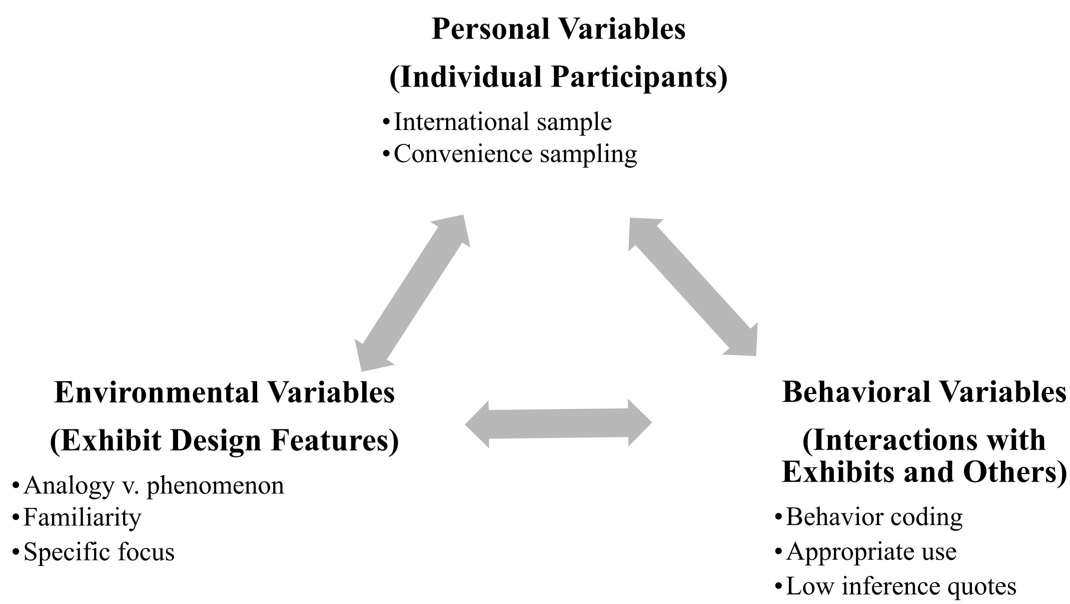

Figure 2.1. Sample Coding of Personal, Environmental and Behavior Variables of Alfonso & Gilbert (2007)

Table 2.2.

Personal, Environmental, and Behavioral Variables by Included Study

	Personal Variables			Environmental Variables			Behavioral Variable
Author (year)	Unit of Analysis	Sample (n)	Demographic Features	Nature of Site	Exhibits (n)	Exhibit Design Feature	Visitor Learning Behavior Measure
Alfonso & Gilbert (2007)	Individuals	125	Convenience	Science Center	7	Presentation, Context, Authenticity, Facilitation, Text, Participation, Physical Interactivity	Observable behaviors; explicit recall
Alt & Shaw (1984)	Individuals	2,000	Convenience, over age of 16	History Museum	45	Participation, Accessibility, Physical Interactivity	Observable behaviors; explicit recall
Atkins, Velez, Goudy, & Dunbar (2008)	Individuals	557	Focused on four family groups as representatives of visitor behaviors	Science Museum	1	Facilitation, Text, Participation, Physical Interactivity	Observable behaviors, discourse
Boisvert & Slez (1995)	Individuals	154	Systematically targeted visitors by age, gender	Science Museum	5	Content, Complexity, Participation, Physical Interactivity	Observable behaviors
Braswell (2012)	Family group	33	Groups included 1 parent, 1 child	Children Museum	2	Content, Familiarity	Observable behaviors
Crowley, Callanan, Tenenbaum, & Allen (2001)	Family group	298	Mixed family groups by gender and role	Children Museum	18	Content, Complexity	Observable behaviors; discourse

Table 2.2 continued

	Personal Variables			Environmental Variables			Behavioral Variable
Author (year)	Unit of Analysis	Sample (n)	Demographic Features	Nature of Site	Exhibits (n)	Exhibit Design Feature	Visitor Learning Behavior Measure
Geerdts, Van de Walle, & LoBue (2015)	Family group	26	Family groups included at least 1 child age 4-6	Science Museum, Zoo	2	Content, Familiarity, Presentation, Context	Discourse
Henderlong & Paris (1996)	Individuals	120	Targeted field trip group	Children Museum, Science Museum	2	Participation, Physical Interactivity	Observable behavior; explicit recall
Hohenstein & Tran (2007)	Individual interactions	464	Convenience	Science Museum	3	Facilitation, Text	Observable behaviors; discourse
Lewalter, Geyer, & Neubauer (2014)	Individuals	522	Convenience, Mean age 29, 56% female, 44% male	Science Center	2	Presentation, Authenticity, Facilitation	Explicit recall
McManus (1987)	Individuals, dyads, small groups	28	Mixed group composition by gender	History Museum	5	Facilitation, Text, Docents	Observable behaviors, discourse
Mortensen (2011)	Individuals	136	Convenience	Science Centers (2)		Presentation, Authenticity, Participation, Physical Interactivity	Explicit recall, Observable behaviors
Pattison & Dierking (2012)	Interactions	63	Staff, volunteer with families	Science Museum		Facilitation, Docents	Explicit recall, discourse

Table 2.2 continued

Author (year)	Personal Variables			Environmental Variables			Behavioral Variable
	Unit of Analysis	Sample (n)	Demographic Features	Nature of Site	Exhibits (n)	Exhibit Design Feature	Visitor Learning Behavior Measure
Sanford (2010)	Family group	493	Convenience	Children Museum	25	Content, Familiarity, Participation, Physical Interactivity	Observable behaviors, discourse
Smith, Smith, Arcand, Smith, & Bookbinder (2015)	Individuals	167	Convenience	Planetarium, Science Museum	1	Facilitation, Text	Explicit recall
Weiler & Smith (2009)	Individuals	288	Questionnaire respondents	Zoo	5	Facilitation, Docents	Explicit recall
Yoon, Elinich, Wang, Van Schooneveld, & Anderson (2013)	Individuals	307	6th graders, field trip	Science Center	1	Facilitation, Text	Observable behaviors; explicit recall
Zimmerman, Reeve, & Bell (2010)	Family group	15	Active member, participation in specific program	Science Center		Facilitation, Text, Participation, Accessibility	Observable behaviors; discourse

For the purposes of transferability to other learning environments, I focused this review on the empirical findings related to designed environment features and learning behaviors, extracting relevant data based on the points framed in the graphical representation of Bandura's (1986) SCT model. Then, I consolidated the extracted data from each models into a single model to capture a broad picture of the investigated design attributes and how the authors operationalized learning.

Results

This review yielded 19 empirical studies of visitor learning behaviors linked to designed characteristics of exhibits in designed environments (Table 2.2). The studies varied in their measures of learning behaviors, exhibit characteristics, and setting. Of the nineteen articles in the review, eleven studies used the individual as the unit of analysis, seven studies used a dyad or family group as the unit of analysis, and the remaining article used individual interactions as the unit of analysis. Additionally, sixteen studies in the final sample were set in institutions in the U.S.; the remaining six were set in the U.K., Portugal, Australia or an unspecified set of European ISE institutions involved in the Nano-to-Touch project. The studies were conducted at eleven science centers, three history museums, eight science museums, six children's museums, two zoos, one planetarium and one art museum. The measures of learning varied among the studies. Fifteen studies used data collected through observable behaviors; twelve studies used collected discourse for analysis; ten studies used data collected directly from visitors via explicit recall; and fourteen studies used a mixture of data collection methods for analysis. The publication dates of the articles ranged from 1984-2015, with a mean publication year of 2005.

Exhibit Element Framework

A framework emerged as I organized the findings from each study into broader categories. Initially, I started with eight categories: *complexity, familiarity, context, authenticity, text, docents, accessibility,* and *physical interactivity.* I banded each of these categories into four larger constructs: *content, presentation, facilitation,* and *participation*. *Complexity* and *familiarity* reflected the exhibit designer's selection and refinement of the content or educational message of an exhibit. *Context* and *authenticity* were most associated with the exhibit designer's presentation of the exhibit's content. *Text* and *docents* demonstrate a facilitating effect on visitors' experiences with an exhibit. Finally, *accessibility* and *physical interactivity* were most associated with a visitor's ability to participate with an exhibit's features. The four larger constructs of the *Exhibit Element Framework* were: *content, presentation, facilitation,* and *participation.*

Content. Two primary categories exist in regard to the organization of content: (1) the complexity of the topic and (2) the familiarity of the topic. The complexity of a topic can range from how concrete or abstract an idea is, to how simple or complex it is. On one extreme, an exhibit could be presenting a single idea (e.g., an animal's diet or basic facts about a planet). On the other extreme, an exhibit could present the animal's diet as part of a complex ocean ecosystem, bringing in food chains and webs, shared habitats, and symbiotic relationships.

Complexity. In investigating the role gender differences played in family learning behaviors, Crowley, Callanan, Tenenbaum, and Allen (2001) found parents or guardians were three times more likely to explain complex concepts to boys than to girls. Their study analyzed 258 different family's video-recorded physical and verbal interactions around 18 science exhibits at the Children's Museum of San Jose. Crowley et al.'s (2001) study found no significant differences between the two sexes as far as initiation or interaction behaviors or in conversations related to observable evidence or procedures. The complexity of the science presented in the exhibit did trigger different learning behaviors for family conversations—specifically regarding parent-child explanations. Considering evidence that parents initiate and dominate family learning conversations, an increase in the complexity of a science concept might have been a leverage point for increasing the number of explanatory conversations, even if limited to young male audiences in parent-child visiting groups.

Boisvert and Slez (1995) found simple and concrete concepts increased exhibits' holding power and level of engagement. This finding was based on the learning behaviors of 154 visitors around 80 different exhibits in the Human Body Discovery Space of the Boston Museum of Science. The visitors' learning behaviors included attraction, length of stay (holding power), and physical interactions such as reading labels, touching elements, and completing designed tasks. Although this learning behavior might have been limited to human anatomy and biological sciences exhibits, the systematic participant selection process was appropriate and sufficiently thorough enough to generalize the findings to multiple age and gender populations. Boisvert and

Slez's paired findings were consistent with Allen's (2004) experiences at the Exploratorium: an exhibit's content should be immediately comprehensible both in concept and clarity in presentation to be an effective learning experience.

Familiarity. New innovations in science have made their way to the walls of a science center or museum much faster than to a textbook or a school district's scope and sequence. Some innovative ideas or discoveries have quickly become familiar topics of conversation. The familiarity of an exhibit's content to the intended audiences plays an important role in the learning behaviors of visitors. Popular movies such as Dreamworks' *Penguin's of Madagascar* and Ridley Scott's *The Martian* have brought a sense of familiarity to audiences that could have shaped their experiences in informal learning environments such as science centers, zoos and museums.

In their study of parent-child conversations around familiar and novel live animal exhibits, Geerdts, Van de Walle, and LoBue (2015) found that while parents predictably generate most of the conversations around live animals exhibits, parents were more likely to use perceptual and connecting talk around unfamiliar topics such as the stick and leaf bug exhibit than the more familiar content and behaviors in the penguin coast exhibit. In their discussion, the authors inferred that the familiarity and popularity of penguins in contemporary culture and media fundamentally changed the nature of parent-child conversations around penguin exhibits in informal science environments. This study also used empirical data to affirm earlier studies (e.g., Crowley et al., 2001) that found parents as a dominant voice; particularly noting a relationship between the age and nature of the type of conversation parents have around live animal exhibits.

Braswell (2012) also found a similar pattern in comparing a familiar grocery store exhibit and a more novel water table exhibit at the Children's Discovery Museum in Normal, Illinois. Braswell's validated hypothesis was that the level of familiarity of an exhibit's context would have a positive correlation with visitors' engagement. The length of learning conversations between adults and children, as well as between children, were significantly lower at the familiar grocery store exhibit compare against the more abstract, novel water table experience. Although this study could have benefited from some level of discourse analysis to clarify directionality and intent within the learning conversations (e.g., Sanford, 2010), the connection between volume of conversation and familiarity of the content does affirm Geerdts et al.'s (2015) findings with familiar and unfamiliar live animal exhibits.

Allen's (2004) working definition of *immediate comprehensibility* included both the level of complexity or abstraction and the familiarity of the topic. The perceived need for parents to make and share explicit observations and connections with their children around unfamiliar exhibits can be used as a leverage point to spark learning conversations in future exhibits. These findings validate Allen's anecdotal experiences related to high-learning potential science exhibits and warrant this element's inclusion in the EEF.

Presentation. Exhibits communicate science content through a series of experiences that make up the exhibit's context. In the same way that an exhibit might have been based on a simple or complex concept, the exhibit's presentation of that content could have had a similar effect on shaping a visitor's learning experience. For this review, I have organized the research associated with presentation into two categories: context and authenticity.

Context. Some researchers focus on a single concept across multiple exhibitions such as the *Human Body Discovery Space* at Boston's Museum of Science or the *Frogs* exhibition at the Exploratorium. Other researchers analyze learning experiences across different exhibits with different contexts. Across the 20 empirical studies included in this review, nine were life science-specific and eight were physical science specific. The life science-specific studies focused on topics such as ecosystems and physiology in humans and animals like frogs, lions and penguins. The physical science-specific studies stemmed from applied physics and chemistry and included exhibits and exhibitions on sound, fluid dynamics, electrical circuits, thermal imaging, and astronomy. The remaining studies focused on math (n=1) or technology applications (n=2) or a mixture of different contexts similar to Crowley et al.'s (2001) research at the Children's Museum of San Jose. Crowley et al.'s study examined learning behaviors across 18 exhibits from a variety of different disciplines: life sciences, physical sciences, psychology, geography, and engineering design challenges. Alfonso and Gilbert (2007) found visitors preferred experiences that connected to life science even in physical science-dominant exhibits. Alfonso and Gilbert used this preference to shape their exhibit selection process.

Live animals. One category of science exhibit context that has a unique impact on learning experiences is the presence and use of live animals to engage visitor audiences. By analyzing 26 families' learning behaviors around live animal exhibits in two different environments, Geerdts et al. (2015) found that learning around live animals was a phenomenon that consistently elicited more conversation across multiple settings. The stick and leaf bug exhibit was part of a larger adaptations and survival exhibition in a regional science center and the penguin coast exhibit was a fixed part of a regional zoo. In both settings parents used more conceptual, biological, and socially-connected statements with their younger children (ages 4-6) than with older children. Additionally, no significant differences existed in either setting on the nature or volume of conversation generated by the children. Both of these findings indicated some generalizability of the effect of live animals as an isolated design feature that impacts visitor learning experiences.

Authenticity. In additional to the domain context of an exhibit, the level of authenticity of the artifacts, phenomena presentation, designed environment, and science all play a unique part in shaping the learning experience of a visitor to a science center.

Artifacts. As part of an NSF-funded Museum Learning Collaborative, Crowley and Jacobs (2002) investigated family conversations, interests and experiences around a table of authentic and replica fossil artifacts at the Children's Museum of Pittsburgh. Using an open-coding scheme to analyze video-recorded family interactions around the staged exhibit, Crowley and Jacobs identified four main conversation themes: explicit label references, observable properties, explanations and level of value or authenticity. In exit interviews, Crowley and Jacobs found that the level of authenticity of a paleontology exhibit and its elements affected the visitor's perceived value of their learning experience. In addition to Crowley and Jacobs study, Schwan, Grajal, and

Lewalter (2014) identified additional instances where visitors preferred authentic artifacts and tools to computer simulations and representative models in engineering design, botanical science, and nature of science exhibit contexts. The more a person values any learning experience, the more likely the person will return or share the experience with others. This makes the level of authenticity of artifacts an important consideration for shaping positive learning experiences in the future.

Phenomena presentation. Alfonso and Gilbert's (2007) identified five exhibit design features that supported a visitor's transition from an entertainment centered agenda to a learning opportunity. Their findings were based on the analyses of 125 visitors' learning behaviors and interview data related to five science-of-sound exhibits at the Pavilion of Knowledge in Lisbon, Portugal. Alfonso and Gilbert found that visitors experience improved when the exhibits were authentic exemplars of phenomena connected to real life experiences and utilizing sensory feedback over a detecting instrument. This finding points to both an authentic experience with the phenomena through presentation and authentic participation through sensory observations as leverage points for learning around science exhibits. Other design recommendations affirmed previously described findings such as avoiding the selection of content that is unfamiliar or hyper-focused on only one aspect of a bigger content theme. Additionally, providing explicit text to support making connections in an exhibit and using similar structures for exhibits within a specific topic to support visitors making inter-exhibit connections were also found to be helpful.

Environment. Mortensen (2011) analyzed visitor learning behaviors around a traveling exhibit that situated the content in an authentic immersive environment at both the Experimentarium in Copenhagen and the Royal Belgian Institute of Natural Sciences in Brussels. Mortensen found that staged authenticity through immersive environments such as entering a dark cave to learn about cave life had a positive effect on learning, but came with inherent challenges such as fear, hesitation, and an unwillingness to be immersed in the role play that may limit visitor participation. Schwan et al. (2014) also found that immersive environments were one part of stagecraft that helped guide visitors' agendas and confer value of the content being presented. Other parts of stagecraft included the use of lighting, recreated scenes, and narrative storytelling.

Science and scientists. Lewalter et al. (2014) explored the role of authenticity on learning as it related to connecting visitors to research scientists. Their research followed two traveling nanotechnology exhibits across five science centers and four European countries. The traveling exhibits were the Open Nano Lab, a small group experience with scientists and science communicators around a nanotechnology lab and the Nano Researcher Live Events, a large group presentation and question and answer session with active and emergent nanotechnology scientists. By analyzing 522 visitors' responses to a series of questions related to perceived knowledge acquisition and the perceived benefits of nanotechnology research, Lewalter et al. (2014) found that both experiences with real nanotechnology scientists had a positive effect on both perceived learning and value of nanotechnology research, with the smaller group structure of the Open Nano Lab being linked to higher gains in learning.

Facilitation. Two exhibit features support the idea of facilitation. The first is through the use of text to guide a visitor's experience. The second is through a person acting as a facilitator for the experience. This docent could take the form of a parent or teacher intentionally guiding a child's experience, or it could be interacting with a floor staff member or getting a behind-the-scenes tour of a live animal exhibit with the animals' trainer(s).

Text. Labels are one of the most direct ways an exhibit designer can communicate explicit science content or participatory expectations to a visitor. Labels have been the focus of a large body of empirical research. Investigating visitor learning behaviors linked to labels has included experimental studies that add or remove labels, modify labels by adding questions or simplifying language, or by positioning labels at different points on an exhibit. Each study highlighted a different perspective on the role labels played independently and in conjunction with other exhibit features to support or shape visitors' learning experiences. Some of the facilitating purposes of labels include: making connections, contributing to a narrative storytelling style across exhibits, and inspiring curiosity. There are also a series of unexpected or unintended outcomes associated with the use of labels in exhibit design and learning research.

Making connections. Alfonso and Gilbert (2007) found that explicit text on labels supported visitor ability to make connections between sound presented through analogies and real life applications. Not all researchers in the field of informal science education share this finding. Research-based findings on labels, their placement, and content have varied. Both McManus (1987) and Zimmerman et al. (2010) found that parents who wanted to facilitate a learning experience with their child found the labels to be of little help because they did not close the gap between their child's high interest and their parents limited background knowledge. In all three studies, connections were not verbalized because both the child and adult could not have accessed the information they needed at an appropriate level and purpose. These findings point to the importance of having scaffolded text on labels accessible to all participants with the express purpose of supporting visitor connections.

Narrative storytelling. Not only are labels useful in supporting visitors' abilities to make connections between a phenomenon and its application, but they can also be useful in connecting experiences within a single visit to a museum. As mentioned previously, Schwan et al. (2014) conducted a review of the literature in the field on environmental design features of exhibits and found that the narrative storytelling process was an important part of the stagecraft used in making meaningful visitor experiences. They found that labels as well as common design elements (frames, textures, shapes or spacing) were essential parts of the successful narrative storytelling process around successful exhibits.

Inspiring curiosity. Through the analysis of an open-ended survey of 167 visitors to a traveling exhibit at the Adler Planetarium, Smithsonian's National Air and Space Museum, Denver Museum of Nature and Science and the Boston Museum of Science, Smith et al. (2015) found that awe and wonder accounted for over 20% of the variability between guests' perceptions of the value of labels and visualizations of deep space images. Magnitude and scale, bewilderment, and aesthetic appeal were the other factors, but they only contributed to 5-8% of the variance. Smith et al. found no significant difference in visitor preferences among labels that included either a question and answer, fun fact or an exhibit's original label. Their study, although limited by sample size and by the use of perceived value alone, did point to an important role that both text and visualization play in shaping a visitor's affective outcomes of an exhibit.

Unintended outcomes. Some research on labels pointed to counter-intuitive or unexpected outcomes. Yoon, Elinich, Wang, Van Schooneveld, and Anderson (2013) initially found that scaffolding through activity guides and knowledge prompts on labels and signs had a positive effect on learning in school groups. Yoon et al. analyzed 307 sixth grade students learning behaviors around the Be the Path exhibit on electrical circuits at the Boston Museum of Science. Through observation, artifacts and interviews, Yoon et al. were able link positive gains to six different types of scaffolds: (a) digital augmentation, (b) collaborative working groups, (c) guided response sheets, (d) collaborative activity guides, (e) embedded knowledge building prompts and (f) a collection of possible findings. Each scaffold produced significant positive gains and the effect was multiplied with layering of multiple scaffolds. Yoon et al., ultimately discovered that the overuse of labels and support documentation recreated a formal learning experience in an informal setting and sacrificed the affective rich gains possible with informal science experiences..

Atkins, Velez, Goudy, and Dunbar (2008) found that by providing insulating mittens and an explanatory label, visitors interacted less with a thermal imaging camera exhibit than had nothing been provided at all. Further investigation into this counterintuitive finding revealed that while labels and artifacts had an overall negative effect on level of open-ended interactivity, these same features had a positive effect on visitors frequency of interacting with the exhibition according to the exhibit's intended learning outcome: to understand the role thermal insulators play in thermal energy transfer. Without the label to guide their observation or the insulating mittens to test the role of insulators specifically, the visitors were more apt to participate in broader scientific processes. Visitors without the guiding label or insulating mittens typically created their own unique data sets with their bodies and personal items, exploring the phenomenon created through the thermal imaging camera.

Atkins et al. (2008) highlighted two important considerations in designing and evaluating learning experiences around an interactive exhibit. First, quantitative behaviorist measures including attraction power, holding power, and level of physical interaction alone are insufficient for understanding the learning processes that are happening around exhibits. Triangulating visitor behavior and discourse are essential to make sense of the counterintuitive findings. The second important consideration relates to the nature of the exhibit's intended goals. How you frame learning and value within an exhibit can have a dramatic effect the overall success of an exhibit. The learning objectives for the thermal sensor exhibit were focused on the role of insulators on thermal energy transfer. In order to engage visitors in this specific learning objective, there was a need for additional facilitation. A variety of objects such as mittens and supplemental guiding labels provided the necessary facilitation. Had the learning objective been more focused on the practice of scientific processes of data collection, exploration and analysis of the labels and insulating mittens would have a negative effect on the visitors' interest in exploring their own questions.

Hohenstein and Tran (2007) conducted an experimental study at the Science Museum in London where they changed the signage and labels around three different exhibits to see the effect of adding questions and simplifying text on learning. They found each condition (i.e., original label, added question, and simplified text with a question) produced different results in three different exhibits. For example, Hohenstein and Tran (2007) found a significant positive effect on adding a question to the current label of the sectioned and exploded view of a Mini Cooper static exhibit, but there were no significant differences on the same condition at the porcelain bowl from Hiroshima static exhibit. This divergent finding may point to labels as having a layered effect with another exhibit element, likely from the content or presentation of an exhibit. Sanford (2010) found evidence of a similar layered effect with labels in her study. She found no explicit outcomes directly related to the presence or lack of a label; however, in conjunction with other exhibit characteristics, labels were found to have a range of outcomes from high interactivity and low learning talk to low stay time and high learning talk and everything in between.

Docents. Whether you call them docents, floor staff, educators, volunteers, or explainers, the use of people to guide a visitors experience is a rich way to promote learning and increase a visitor's engagement in an exhibition. This exhibit feature can be challenging for typically nonprofit organizations to provide for all exhibits. Therefore, understanding the efficient use of docents is an important consideration in designing learning experiences around new exhibits or reorganizing personnel around a science centers.

Staff-facilitated experiences. An analysis of survey data collected on visitors to the *Lions on the Edge* exhibits at the Werribee Open Range Zoo outside Melbourne, Australia, revealed positive effects on visitor cognitive, affective, and behavioral gains across five different staff-facilitated experiences (Weiler & Smith, 2009). Staff facilitation ranged from casual conversations around exhibits with floor staff, attending shows, and conducting behind-the-scenes tours of lion exhibits. Weiler and Smith (2009) found no one type of facilitation had significantly higher gain than any other; however, these experiences produced consistently higher cognitive, affective and behavioral gains when in conjunction with one another. The more facilitated experiences a visitor had within a single visit to the zoo, the higher their gains were across all three measures.

Parents as gatekeepers. McManus (1987), Zimmerman et al. (2010) and Pattison and Dierking (2012) found parents were gatekeepers to the agenda and learning opportunities for their children. As such, supports for parents need to be in place for both aspects of facilitation: the use of labels and the initiation, transition, and extension activities of science center staff facilitators. Crowley et al. (2001) reinforced this shared role of facilitation between parents and docents. They found parents contributed most of the conversation around exhibit spaces, sometimes at the expense of one population over another (e.g., parents were three times more likely to explain a challenging or difficult concept to boys than girls). Not all experiences were shaped by this gender dichotomy; some experiences were enhanced differently by age. Crowley and Jacobs (2002) found that although parent mediation had a positive effect on all children's ability to correctly identify plant and animal fossils, it had a considerably larger effect on children between the ages of four and six than children age seven to twelve.

Other facilitating factors. McManus (1987) found evidence that the presence of a female adult in a visitor group of adults had a positive effect on the group's level of participation with an exhibit and all its features. This finding pointed to women serving as an unintended facilitator for the learning experience. This finding stemmed from the passive observation of 28 visitor groups across five exhibits at the British Museum of Natural History. Although this is not necessarily a feature that any informal science experience provider could control, it might have been a moderating effect that is important to be familiar with when investigating visitors' learning behaviors.

Participation. Every exhibit is designed to provide an experience for a visitor, but not all experiences are designed to promote visitor participation. These designed characteristics can be organized under two umbrellas: accessibility and physical interactivity.

Accessibility. *Accessibility* includes several different elements such as (a) direct access to signs, artifacts or interfaces, (b) ease of use and (c) versatility by age and ability of visitors. Alt and Shaw (1984) conducted a large scale study (n=1980) on biological exhibits at the British Museum of Natural History, drawing out seven exhibit design features they termed as "morphological characteristics" of exhibits. Of the seven exhibit design features they identified, four could have been categorized under the umbrella of *accessibility*. These four were *noticeability, clarity, ease of use,* and *versatility*. Each of these four morphological characteristics related to accessibility by their application. They were noticeable by all audiences, understandable regardless of age, easy to use regardless of ability, and versatile for multiple visitor demographics. The other three characteristics were subject matter, required visitor responses and visually memorable effects. These three characteristics are reflected in the EEF under content, participation, and presentation.

Later, Zimmerman et al. (2010) found that children with higher interest in the content and activities associated with an exhibit could not have accessed additional information or extension activities because they were only accessible from a higher adult positioned sign. Zimmerman et al. saw a pattern of parents with limited interest or background knowledge unintentionally becoming a barrier to their children's further exploration. A young child had an extensive knowledge and interest in the subject of an exhibit. She found the resources she could access unchallenging. Her father had limited knowledge on the same subject and the labels at his access point seemed for too complex to translate to his child. This incongruity between the girl's interest and access impeded the girl's learning experience at the exhibit.

Physical interactivity. Baradaran Rahimi (2014) described the process of engaging a visitor to participate in a learning experience as "actuation." In a Delphi study of experts across three fields related to the design, use and evaluation of exhibit spaces, Baradaran Rahimi found that actuation was one of three elements that had the highest impact on the learning potential of exhibits. The other two elements were context and motivation. Considering that two of the three elements were directly influenced by the design of an exhibit, it warrants an understanding of what worked and did not work in engaging visitors to actively participate in a designed experience.

Actively interacting with exhibits can be defined in a variety of ways; however, physically interactive exhibits typically involve the presence of hands on artifacts or manipulable features and can include a number of other characteristics. Alt and Shaw (1984) found that requiring visitor participation was a predictor of positive visitor experiences at 45 biological exhibits at the British Museum of Natural History. Sanford (2010) added to the required visitor response to visitor control over variables and multiple outcomes, as well as the ability of multiple visitors to simultaneously interact with an exhibit as leading to higher staying power and increased levels of engagement at 25 different exhibits at the Children's Museum of Pittsburgh.

Artifact characteristics. The presence of physically interactive features or artifacts alone might or might not have an effect on visitor learning behaviors; it is important to understand how they were presented and how they related to different contexts. Henderlong and Paris (1996) used an experimental study on a group of 120 elementary students on a field trip to the Ann Arbor Hands-on Museum and Children's Museum of Elgin to investigate the best way to present puzzles as a museum exhibit. In their experiment they set out a series of tangram puzzles that were fully complete or incomplete as well as partially complete to see how students would interact with the different conditions. The students' motivation, stay time, and completion rates for partially completed puzzles were consistently higher than those where the puzzles were fully unassembled or completed prior to the students approaching. The researchers inferred that the disequilibrium of a partially completed puzzle was an effective leveraging point for actuating a positive learning experience in their sample.

Additionally, the choice to use a detecting instrument can elicit a variety of outcomes dependent on several other aspects of the designed experience. Atkins et al. (2008) found thermal imaging cameras to be effective tools for getting visitors to interact with an invisible phenomenon (e.g., the properties of thermal energy and heat transfer) and to practice the scientific processes of generating data and testing variables. As mentioned earlier, Atkins et al. reported that hands on objects such as mittens and other insulators could reduce the level of open-ended interactions around a thermal imaging exhibit. Atkins et al. concluded that by providing the hands on objects, they were able to target specific learning outcomes not naturally explored by visitors in an open-ended context.

Whereas Atkins et al. (2008) found the detecting instrument useful, Alfonso and Gilbert (2007) found that the use of sensory data to participate in an exhibit experience led to a higher level of engagement than the use of detecting instruments. Additionally, Schwan et al. (2014) found that visitors' preferences for the nature of their participation were dependent on the content and context of the exhibit. For instance, authentic hands on artifacts were the preferred medium for engineering design exhibits, botanical studies, and Nature of Science exhibits whereas virtual environments and computer-mediated interactions were preferred in other contexts. Sanford (2010) explained this phenomenon in that she found that props or artifacts were rarely an isolated feature, but a part of a total experience of other exhibit characteristics (e.g., ease of use, labels, multiple simultaneous users, and high versatility by age) that can lead to lengthened stay times and higher engagement behaviors but little to no learning talk.

Benefits and unintended outcomes. Boisvert and Slez (1995) conducted a study at the Boston Museum of Science's Human Body Discovery Space. They found that if the overall interactivity of an exhibit was high, then the attraction and holding power were also high. Boisvert and Slez's measures of physical interactivity progressed from reading a label, to touching exhibit features, to completing a designed experience. Although these measures were simple and might not have accurately represented a progressive set of learning behaviors, the systematic sampling procedures the researchers used to collect data did provide some validity to the emergent patterns identified in the study's findings.

In using a staged table activity with authentic and replica fossils, Crowley and Jacobs (2002) were able to engage visitors in a hands on experience in a paleontological exhibit. They found that the hands on elements spurred family conversations about the scale and function of the organisms the fossils represented. Additionally, family groups who read labels aloud, described observable properties of the fossils, and compared anatomy of multiple fossil samples were more likely to infer function. These correlations between specific behaviors and conversation codes reinforce the idea that some exhibit elements, characteristics, and features are not isolated variables, but have a layered effect on learning outcomes in informal science environments.

Not all interactive experiences produce the same benefit. As mentioned earlier, Mortensen (2011) found that some immersive environments can have the unintended outcome of limiting visitor participation by invoking fear, hesitation, or an unwillingness to enter the role-play experience intended by the exhibit's designer.

Summary and Discussion

In this literature review, I synthesized findings from 19 studies into an *Exhibit Element Framework* (EEF) that highlighted exhibit design features that had a moderating effect on visitor learning behaviors. It is important to note that the EEF is not alone in its interpretation of effective design features. In 2004, Sue Allen published a conceptual article where she described four "essential components of high learning potential science exhibits". These components were: (1) immediate apprehensibility, (2) physical interactivity, (3) conceptual coherence, and (4) diversely optimized experience. While *physical interactivity* and *conceptual coherence* are both reasonably familiar terms to audiences across the educational spectrum, Allen's working definitions of *immediate apprehensibility* and *diversely optimized experiences* are more nuanced, particularly with how one might compare them to features in the EEF. *Immediate apprehensibility* addressed the use of familiar tools and activities to design highly interactive science exhibits. Allen's stated position was that the less amount of time and energy a visitor had to spend in decoding the procedures for using an exhibit, the more they could invest in learning by the experiences the exhibit offered. *Diversely optimized experiences* alluded to the variety of presentation techniques, interactive elements and opportunities for visitors to express their learning.

While the EFF and Allen's essential components of high learning potential science exhibits share some commonalities, it is important to clarify how they differ—

namely, in derivation and breadth. The features in the EEF were derived from a structured analysis of 19 empirical studies conducted at institutions across the world and published under the professional structure of peer-review. Sue Allen's essential components were based on a summary of her anecdotal observations as an expert in the field. They were limited to her observations as part of the research, design, and evaluation processes at a smaller sample of institutions—predominantly the Exploratorium.

Limitations

I conducted this literature review to address what effects on visitor learning behaviors researchers associate with exhibit elements? Although the *Exhibit Element Framework* (EEF) emerged from a comprehensive review of empirical studies on visitor learning behaviors around science exhibits, I cannot make a claim that this is complete or exhaustive of the elements that impact a visitor's experience. This review was based on a snapshot of the profession from the perspective of published studies. There are likely a number of relevant studies that have never made it to publication—whether for reasons of purpose (e.g., internal reports for institutions) or insufficient or unpublishable findings (e.g., null findings on hypotheses). Additionally, many experts, like Sue Allen, published conceptual or theoretical papers with relevant information based on their professional experience but because of the nature of the inclusion criteria for this review, that information was not included.

Although the review was limited to a glimpse of one part of the field of research on exhibit design features, I do believe the process was sufficient to accomplish the purpose of this literature review. What I have done within the boundary of this literature review is provided a versatile framework for future research to build upon.

Implications for Future Research

The process and product of this literature review inform future research by (1) piloting methodological practices, (2) providing an emerging set of constructs that need further research to validate and clarify, and (3) identifying additional opportunities for applying the *Exhibit Element Framework* (EEF) in research.

Methodological practices. Two specific examples of novel approaches to methodology in this literature review were: (1) the use of triangulated data collection methods as a quality indicator for inclusion and (2) the use of a theoretical model as a framework for coding and comparing the methods and findings across empirical studies. Extending the use of both practices has the potential to improve the quality of future research, informing policy, and streamlining the professionalization of the field of science education research in informal learning environments.

Quality indicators. Triangulating data collection methods has long been a quality standard in educational research. However, outcome data collection practices in informal science education (ISE) have historically been limited to behaviorist measures such as calculated stay time or specific types of participation with an exhibit (e.g., touch, read, talk or complete). Discourse analysis as a form of outcome data collection is still limited to a specific set of researchers in the field. As such, the benefits of understanding the nature of visitor behaviors are also limited (see Sanford, 2010, for more information on the necessity of discourse analysis for interpreting visitor behaviors). The pairing of quantitative and qualitative observations can only further improve our understanding of informal science learning experiences. My emphasis on data collection as an inclusion criterion hopefully communicates a priority or standard for future empirical research studies to strive towards.

Theoretical frames for coding. Designing a study's methodological approach to collecting and interpreting data reveals a researcher's beliefs about how people learn and how learning can be measured in informal learning environments. This can be done explicitly through a dedicated section or inferred through the methodological choices made in the study. Most ISE researchers align their work to either a variation of the constructivist theory or an interpretation of the sociocultural perspective of learning. The applied use of a theory-based model for interpreting and comparing data between different studies is novel. My use of Bandura's (1986) representative model of the *Social Cognition Theory* provided an opportunity for me to compare the methods, findings, and priorities of a number of different studies.

Construct validation. In light of some elements being the product of a single or pair of empirical studies, effort should be made to further validate the constructs that link design features and visitor learning behaviors. These efforts should include purposeful data collection to (1) test the breadth of each construct and (2) operationally define each construct to reflect its value across various settings and over a period of time.

Validation by scale. More data should be collected and analyzed to expand, clarify, or affirm the constructs within the EEF. A larger sample of exhibits may (1) verify a positive correlation between the constructs in the EFF and visitor learning behaviors, (2) challenge the priority, presence, or subordination between the constructs or (3) identify new constructs that ought to be included in the EEF. By expanding the data collection effort to include a larger sample, the validity of each construct can be further investigated, strengthening the value of the EEF.

Clarification of terms. Each construct in the EEF is broad enough to be utilized differently by a variety of stakeholders; however, these summary definitions also necessitate clarification and definition by experts in the field. Further research should be conducted to compare stakeholders' interpretations of these constructs. These stakeholders should include researchers, exhibit designers, and evaluators in the field of informal science education. A clarification of the terms used to describe the EEF will extend the life of the framework and provide opportunities to adapt the framework into a useful tool to inform the design processes over a number of different learning environments.

Extended applications in research. The exhibit design constructs included in the EEF reflect a perspective limited to the visitor experience with a completed science exhibit. As such, more opportunities for considering what role each construct plays in the exhibit design process as a whole exists. Since Bandura's (1986) Social Cognitive Theory was used as a frame for reviewing empirical studies, the EEF can also be a frame for comparing individual exhibits—a scale that has the potential to open the field to more advanced forms of focused data collection and analysis.

Exhibit design process. Much of the data collected and presented in the articles in this review relate to the exhibit features as experienced by the visitor. It would be advantageous to further explore the role each construct in the EEF plays in other phases of the exhibit's development (e.g., strategic planning, idea vetting, development, and assessment). The role each construct plays behind the scenes in the exhibit design process may reveal their moderating effect of the design features on the visitors experiences. Data to support this role was did not emerge from this review; however, future researchers should collect interviews and observations to investigate this potentially moderating effect on exhibit design features and the visitors learning experiences.

Advancing analysis in ISE. The most transparent use of the framework is as a common structure for profiling exhibits consistently across settings, exhibitions and studies. Profiling exhibits with a common framework creates an opportunity for advanced analyses, like meta-analysis, and improves the quality of secondary data analysis. I believe that the use of the EEF as a comparative frame for describing exhibits would complement the established, comparable methods of collecting outcome data in visitor studies. Together, comparable descriptions and comparable outcome data will support more advanced analysis of exhibit design features and their impact on visitor learning behaviors, thereby improving the quality of future large-scale research efforts.

Implications for Practice

Exhibit designers, evaluators, and educators can benefit from practical applications of the *Exhibit Element Framework* (EFF).

Exhibit designers. Exhibit designers can use the *Exhibit Element Framework* (EEF) as a guide for strategic planning and the remediation of existing exhibits. Each construct can be adapted into an open-ended questionnaire or checklist that guide early discussions around exhibitions and their design priorities heading into a new project. This will have a dramatic effect on the ability of leaders in smaller institutions to communicate their priorities to external design consultants, organizations, or individuals who want to donate exhibits to their institution.

Evaluators. Evaluators can benefit from the products of this literature review by offering research-based categories as evaluation priorities. Each construct can be evaluated against visitor learning behaviors in an institution. Therefore, when an evaluator or evaluation team sits down with the leaders of an informal science learning institution, they can use the constructs from the EEF to shape a series of evaluation criteria that better reflect the values and priorities of the institution they are serving. The constructs from the EEF may also highlight the design features of an exhibit that have a stronger moderating effect on visitor learning behaviors than would have been discernable from an open-ended evaluation.

Educators. Finally, the *Exhibit Element Framework* (EEF) can be used as a guide for designing high-quality learning experiences for classrooms, laboratories, or science centers. Content, presentation, facilitation, and participation, and their sub-elements, have just as much general applicability in how teachers organize their classroom experiences as how designers create experiences around informal science exhibits.

CHAPTER III

EXPERT PRACTITIONERS' DESCRIPTIONS OF AUTHENTICITY IN THE DESIGN OF ENGAGING EXHIBITS

Authenticity in the arena of education has been described as both "seductive" (McDougall, 2015) and "complex" (Kohnen, 2013; Reeves, Herrington, & Oliver, 2002). Its attractive power stems from a commonly held perception that the more authentic the educational experience is to the learner, the greater the level of engagement and knowledge transfer (Fredricks, Blumenfeld, & Paris, 2004; Gulikers, 2006; Sutherland & Markauskaite, 2012). This perspective has been reinforced by studies that have measured the positive impact of authenticity on motivation and engagement (Fredericks et al., 2004; Lee & Luykx, 2005; Marks, 2000; McCune, 2009; Renzulli, Gentry, & Reis, 2004; Sauter, Uttal, Rapp, Downing, & Jona, 2013; Sutherland & Markauskaite, 2012), conceptual understanding (Derry, Levin, Osana, Jones, & Peterson, 2000; Rudolph, Simon, & Raemer, 2007; Van Merri€enboer, 1997), and transfer of knowledge and skill to new contexts (Jeffries, 2005; Maran & Glavin, 2003; Nestel, Groom, Eikeland-Husebø, & O'Donnell, 2011; Rudolph et al., 2007; Strobel, Wang, Weber, & Dyehouse, 2013). These findings are just part of a larger sample of studies that underline the appeal of authenticity in designing learning environments and experiences. The researchers in each study differed considerably in their interpretation of authenticity—this variation characterizes the complexity of these desired constructs.

Baloian, Pino, and Hardings (2011) described authenticity as more of "a blurry demand rather than a well-defined concept" (p.273). Although their perspective was formed from the literature on e-learning environments, the essence of their message rings true in other areas of the educational enterprise. Kohnen (2013) reflected on the limited nature of her understanding of authenticity as experienced in developing authentic writing experiences. "In the beginning, we thought it had to do with the 'authentic' experience of writing in an 'authentic' genre for an 'authentic' audience; however, the concept of authenticity is more complicated" (p.31). According to Kohnen, the three layers of authenticity her team used to design the authentic writing experience (e.g., task, genre, and audience) were insufficient for capturing a complete picture of the role authenticity plays in designing learning experiences.

Layers of Authenticity

I conducted a review of the literature published in educational research journals for a broader perspective of the layers of authenticity applied to the field of education. I gathered terms used to describe the context, measures, and impact of authenticity. I grouped the terms with similar meaning—a process that yielded eight distinct layers of authenticity. I organized the eight layers of authenticity under larger categories according to the prominence of their expression. Table 3.1 highlights how I arranged the eight layers of authenticity under (a) external authenticity, (b) embedded authenticity, and (c) internal authenticity.

Table 3.1.

External, Embedded, and Internal Layers of Authenticity as Extracted from Educational Research Journals

Category	Layer	Expressions	Characterized by	Impact	Consideration
External Authenticity	Task Authenticity	Asking Scientific Questions Making Predictions Testing Ideas Manipulating Variables with Reliability and Purpose Gathering Reliable and Accurate Data Analyzing Data Prioritizing Evidence by Relevance Formulating Explanations Communicating with a variety of audiences	Ill-defined tasks Complex tasks Whole tasks Meaningful tasks Complete nature of profession (tedious, complex, responsible)	Increased motivation and level of engagement Increased expression of positive learning experience Increased collaboration Increased level of reflection Increased operational and conceptual competency Increased deeper thinking Increased problem solving Increased relevance of solutions Lack negatively impacts transfer and perceived value of learner prior knowledge and experience	Open-ended tasks may favor students with more opportunities to participate in science-rich environments
	Artifact Authenticity	Mediation of technology (virtual artifacts, data collection probes, etc.) Mediation of artifacts (access)	Cultural authenticity (origin) Functional authenticity (purpose)	Increased procedural and psychomotor skills Increased transfer of skills Increased motivation and engagement Increased task completion	Access to authentic data collection tools increases motivation but does not guarantee an increase in conceptual understanding

Table 3.1. continued

Category	Layer	Expressions	Characterized by	Impact	Consideration
	Situated Environmental Authenticity	Degree of resemblance to professional settings Connected to the world Presents a complex view of the world Emphasizes role of space on experience Series of conditions	Making connections between students prior knowledge and the situated knowledge arising from the experience	Increased opportunity to learn more complex cognitive sills Increased motivation Increased potential for change in attitudes and beliefs Increased engagement Increased perception of responsibility and accountability	Highly authentic contexts and challenges can be overwhelming for learners—may hamper competence development
	Impact Authenticity	Relevance beyond the learning environment Value of products Multiple pathways for solutions, diverse outcomes Targets real audience	Natural sense of need or necessity	Authentic products have inherent value Seamless integration of assessment	
Embedded Authenticity	Discipline-centered Authenticity	Structure, sequence, and depth of knowledge Level of access to the structure, processes and ecology of the professional community	Varying measures of multi-disciplinarity		

Table 3.1. continued

Category	Layer	Expressions	Characterized by	Impact	Consideration
	Pedagogical Authenticity	Layers of knowledge construction High expectations Assessment	Higher order thinking Support for taking risks	Influenced student identity Increased engagement	Overemphasis on standards, safety, or social skills may compromise authentic learning
Internal Authenticity	Learner-centered Authenticity	Autonomy (opportunity to initiate and regulate) Opportunity to reflect Strong personal frame of reference Personal interest Perceived power	Prior experiences and knowledge are valued	A perceived sense of value, authenticity, and autonomy were strong predictors of increased conceptual understanding	
	Community-centered Authenticity	Substantive conversation Opportunity for reflection on personal and community contributions Level of participation or collaboration Balance of power	Mutual respect, integrity, and trust Multiple perspectives Persuasion, narration, and dialogue	Impacted learners' affective skills development (values, attitudes, beliefs) Increased internalization of content and learning material Improved verbal skills Increased autonomy Reduced concerns about making mistakes Increased naturalistic discussions and interactions	Collaboration should not be forced but grounded in the nature of the task

External Authenticity

Manninen, Henricksson, Scheja, & Silen (2012) first organized the elements of external authenticity and internal authenticity as they were reflected in the clinical practice phase of a nursing certification program. From the perspective of their program, Manninen et al. described context, task, and environment as features that shaped external authenticity. Manninen et al. organized relationships and social interactions between teachers, learners, and their audience (e.g., patients and other medical professionals) under the banner of internal authenticity. They found that the inclusion of both internally and externally authentic features had the greatest impact on nursing residents' sense of autonomy, community, confidence, and responsibility. I have modified their categories to better reflect the variety of the larger educational research enterprise. In this paper, I categorized task, artifact, situated environmental, and impact authenticity as observable external interpretations of authenticity.

Task authenticity. Task authenticity was an amalgamation of professional practices (Bevins & Price, 2016), authentic participation (Anderson, 1998), authentic activities (Buendgens-Kosten, 2013; Sutherland & Markauskaite, 2012), scientific practices (Edelson, 1998) and model practices (Bellamy, 1996). This was the predominant feature of external authenticity among the studies included in the review. The examples and importance of authentic tasks are mirrored in the scientific and engineering practices of the Next Generation Science Standards (NGSS Lead States, 2013). Lee and Luykx (2005) caution their readers about the unintended outcomes of an overuse of open-ended tasks. The findings from their study on non-mainstream students found that authentic, open-ended tasks tended to favor experience-rich students over others who lacked similar experiences.

Artifact authenticity. Manninen et al. (2012) did not include artifact authenticity as an explicit part of their definition of external authenticity; however, there were a number of other researchers who specifically identified artifacts as a relevant consideration for incorporating authenticity into learning experiences. Descriptions of artifacts included physical objects (Khaled, Gulikers, Bieman, & Mulder, 2015), equipment (Maran & Glavin, 2003), tools (Reeves, Herrington, & Oliver, 2002), and data (Sauter et al., 2013). Each artifact's authenticity was measured by virtue of their origin or purpose—a pair of measures further described by Buendgens-Kosten (2013) as cultural authenticity and functional authenticity, respectively. Artifacts were also considered part of the authentic learning environment specifically in the light of how the learner would engage the object (Humberstone & Stan, 2012).

Situated authenticity. Manninen et al.'s (2012) original environment category was expanded to include context authenticity (Barab, Squire, & Dueber, 2000), real-life contexts (Khaled et al., 2015), situated learning environment (Van Merri€enboer, 1997), situated knowledge (Tochon, 2000), authentic settings (Manninsen et al., 2012), functional authenticity (Buendgens-Kosten, 2013; Kohnen, 2013), and authentic challenges (Maran & Glavin, 2003). By expanding the definition to include attributes of situated learning environments and situated challenges, this provided a more complex understanding of the role of environment and its effect on a learner's experience. In their investigation, Maran and Glavin (2003) found that an overemphasis on authentic environments could distract or overwhelm learners and limit their ability to develop focused skills or conceptual understandings.

Impact authenticity. I chose to add a new layer for authentic impact under observable, external authenticity. Authentic impact referred to examples in the literature that highlighted the value of the products created from the experience, as well as the audiences, that would shape the learner's experience. In their study of learners' perceptions of authenticity, Barab et al. (2000) found that there was a significant relationship between the learners' perception of the value and impact of their work and the merit of an authentic experience. Additionally, Newmann (1996) enumerated a list of criteria for a learner's achievement to be authentic. The list included: (a) the construction of knowledge, (b) evidence of the practice of disciplined inquiry, and (c) a value for real audiences beyond the classroom.

Embedded Authenticity

In addition to the inclusion of impact authenticity, I also included a new category to account for the layers of authenticity that exist outside of the learner but are not as explicit as the previous list of external layers of authenticity. As such, discipline-centered and pedagogical authenticities reflect under-the-surface decisions and processes that can be understood best as layers of embedded authenticity.

Discipline-centered authenticity. Although this is not an expansively studied facet of authenticity, DeBruijn and Leeman (2011) and Newman (1996) invested considerable effort discussing the role content experts play in designing experiences that are authentic to the subject matter, structure of the discipline, and are authentic to the field of study. Additionally, Reeves et al. (2002) emphasize the benefit of a multidisciplinary approach to create learning experiences. Reeves et al. found this multidisciplinary approach authentically reflects the complexities of problem solving and collaboration to solve real-world challenges.

Pedagogical authenticity. There was evidence in the literature of another embedded layer of authenticity; pedagogical authenticity—or how the learners' experience aligns with learning science and theory. This layer included the decisions educational experience designers made with regards to chunking big ideas into layers of knowledge construction (Jonassen, 1999), balancing scaffolding with high expectations (Newmann & Wehlage, 1993) and accurately and unobtrusively assessing learning in authentic learning experiences (Herrington, Oliver, & Reeves, 2003). Marks (2000) found that these authentic learning experiences were strong predictors of increased engagement at the elementary, middle grades, and high school levels (effect sizes of .34, .40, and .42 respectively, $p<0.01$) (p.168). Humberstone and Stan (2012) cautioned their reader that an overemphasis on traditional classroom priorities (learning objectives, standardized experiences, safety, teamwork, or social skill development) is a detriment of authentic learning (p.192)

Internal Authenticity

Whereas external and embedded layers of authenticity focused on experiences and the environment prepared for a learner, learner-centered and community-centered authenticities represent more of the internal processing associated with learning experiences in educational research. Splitter (2009) shared a similar sentiment as he evaluated which elements sufficiently defined educational authenticity. He argued for the inclusion of an authentic sense of self and authentic discourse between learners and their community as integral parts of the traditional task and environment-dominated interpretation of authenticity.

Learner-centered authenticity. The dominant feature in this layer of internal authenticity is the role of autonomy, both as designed and as perceived. Terms such as self-directedness, autonomy, motivation, and reflection were clustered into this layer of authenticity. Bevins and Price (2012) defined autonomy as the authentic opportunity to initiate and regulate an experience. Reeves, Harrington, and Oliver (2002) expanded this focus on the learner's internal experience by including the role of reflection as an authentic experience. This category could be expanded considerably in light of the attributes of learner-centeredness of the National Research Council's (2000) *How People Learn* framework.

Community-centered authenticity. Community-centered authenticity was a term I also borrowed from the *How People Learn* framework as I organized social experiences between learners, learners and teachers, and learners and audiences into a single layer of authenticity. This category included terms such as authentic social interactions (Newmann & Wehlage, 1993; Zaltz, 2003), authentic discourse (Hadjuoannou, 2007; Newmann & Wehlage, 1993), and collaboration (Derry, Levin, Osana, Jones, & Peterson, 2000; Petraglia, 2009; Reeves, Herrington, & Oliver, 2002).

Kenkmann (2011) further broadened this layer to include the role of power as a moderating variable on a learner's experience. Specifically, Kenkmann made the distinction between how learners function in a teacher controlled classroom—where students experience less inherent power, and an open environment like an art museum—where the unbalanced power relationship between the teacher and student and its effect on the learner's experience is dramatically diminished.

Layered Interpretations of Authenticity

I would be remiss if I did not acknowledge that there is great value in the variety of ways researchers have organized different layers of authenticity. Kohnen (2013) organized features of learning experiences under two categories: latent authenticity and functional authenticity. Kohnen focused on the perspective of the learner's activity. She addressed two questions in the context of an authentic writing project: what did the learner do that related to authentic behaviors of the writers profession (e.g., functional authenticity) and what did the learner experience that supported their identity development as a writer (e.g., latent authenticity). These experiences were further described as both internal (i.e., through reflection or sub-conscious change) and external (i.e., experiencing the merit of authentic collaboration with editors and peers). Anderson (1998) similarly approached the topic of authenticity as a combination of processes and products. Finally, Barab et al. (2000) organized authenticity into three categories: task, context, and impact authenticity. Their classification infuses the perspective of authenticity as a socially negotiated process into each of the other categories (for more information on learning as a socially constructed phenomenon, See Lave & Wenger, 1991).

Authenticity in Visitor Studies Research

In merging exhibit design features to create the Exhibit Element Framework, I identified four applications of authenticity in exhibit design: objects, phenomenon, environment, and access. Objects such as artifacts or tools could be authentic or replicated (Crowley & Jacobs, 2002; Schwan et al., 2014). The scientific phenomenon could be authentic or modeled (Alfonso & Gilbert, 2007; Schwan et al., 2014). The environment could be staged as an immersive or exhibited authentic environment (Mortensen, 2011; Schwan, Grajal, & Lewalter, 2014). Finally, the access to the people and processes of science could be authentic or staged (Lewalter et al., 2014).

In research conducted on each feature, *authenticity* was found to have a moderating effect on visitors' learning behaviors. Authentic fossils increased visitors' perceived value of a paleontological exhibit (Crowley & Jacobs, 2002). Visitors preferred authentic tools of the trade to virtual experiences in exhibits that focused on engineering design, botany, and nature of science (Schwan et al., 2014). Immersive environments necessitate a visitor's willingness to participate in order to accomplish the learning outcomes (Mortensen, 2011). With many Informal Science Education (ISE) institutions beginning to embed scientific laboratories, workshops, and visiting scholars into their learning spaces, it is important to clarify what this level of access to authentic people and practices might have on learning outcomes.

Purpose of the Study

Reeves et al. (2002) referred to the need to refine our definition of authenticity in educational research. They also identified the need for a specific set of guiding principles for integrating authenticity into learning experiences. Current research highlights the moderating effect of authenticity on visitor learning behaviors (e.g., Aflonso & Gilbert, 2007; Crowley & Jacobs, 2002; Schwan et al., 2014). The challenge has been to understand the diverse and interconnected interpretations of authenticity in such a way that it can be applied in a specific learning environment effectively. The purpose of this investigation was to use practitioners' knowledge and experience to clarify the role of authenticity as part of the exhibit design process. This line of inquiry investigates how authenticity is defined and measured by individuals intimately involved in the design of interactive science experiences in ISE institutions.

Research Question

In order to clarify how authenticity is described in the context of exhibit design and the exhibit design process, I addressed the following research questions:

(1) What descriptions do practitioners use to illustrate the role of authenticity in the exhibit design process?

(2) How do those descriptions and illustrations mirror or extend our current understandings of the layers of authenticity in educational research?

Methods

The design of this investigation was a multiple case study (Creswell, 2013; Stake, 2013). I interviewed expert practitioners from the ISE field to explore the guiding research questions for this phase of the study. In order to identify expert practitioners, I began contacting institutions with a reputation and history of highly engaging exhibits. I selected my participants based on their range of knowledge, experiences, and perspectives on effective exhibit design from the pool of available and interested practitioners. I looked for participants with considerable experience at one or more of the three stages of the exhibit design process: strategic planning, development, and evaluation.

I used semi-structured interviews to collect information from each participant about their experiences, the processes that their representative institution uses to design, develop, and deliver science experiences, and descriptions of exemplar exhibits from their career. I used the participants' descriptions of their experience to better understand their perspective on the exhibit design process. Then, I analyzed each participant's description of her institution's exhibit design process. Next, I analyzed each participant's description of exemplar exhibits. I extracted explicit and inferred references to authenticity from each participant's interview data individually. Then I compared and synthesized the emergent themes across the group of interviews. This multiple and instrumental case study involved an iterative process of adding, revising, and revisiting the original context of each of the six cases. For the purposes of this study design, I treated each participant and her depiction of authenticity in the exhibit design process as an individual case.

Participants

I recruited participants for this study who had experience with the exhibit design process and worked at interactive science centers (Bernard, 2000; Miles & Huberman, 1994). I reviewed open source materials (i.e., popular magazines, travel websites, practitioner journals) to identify ten reputable informal science institutions. I sent recruitment emails to the directors of exhibitions or public relations department for each institution. Of the ten institutions contacted, four responded with the contact information for willing exhibit designers, project managers, and directors. Each participant received a copy of the consent form. Follow up conversations were scheduled to answer questions about the study before collecting any data.

Role of the Researcher

Qualitative research is predicated on the fact that the researcher plays a significant role in the research process (Fraenkel, Wallen, & Hyun, 2012; Miles & Huberman, 1994). Few places can this be more clearly seen than in studies where the researcher is actively collecting data through one-on-one interviews. As an emerging researcher in the field of informal science education, my role as part of the research community provides a fresh perspective on my understanding of the practices associated with exhibit design process.

As a science educator, I believe progressive, developmentally appropriate experiences with authentic science practices frame quality learning experiences in science. These scientific practices are enumerated in the recently adopted Next

Generation Science Standards (NGSS Lead States, 2013). Among these practices, collaboration and communication align with my perspective on the merit of constructivism and social learning theory (see Bandura, 1986; Bruner, 1966; Vygotsky, 1979). As such, I personally believe exhibit elements demonstrate a leveraging effect on simultaneous exploration and dialogue, which are inherently high quality learning experiences.

Semi-Structured Interviews

I collected data through semi-structured interviews with participants (Creswell, 2013). I scheduled phone interviews at the participants' convenience. I prepared a common set of introductory questions to capture both the processes of the institution the participant represents and the participants' perspectives on exhibit elements and their impact on visitor learning behaviors. From here, I asked emerging questions during the conversation that were different from the protocol questions. Each conversation with the participants averaged 50 minutes in length. I took extensive notes during the conversations and rebuilt my notes into a pseudo-transcript immediately following each interview.

Data Analysis Procedures

As a multiple case study design, I analyzed the interview data one case at a time (Creswell, 2013; Stake, 2013). I reviewed the interview notes and separated each idea into individual chunks to establish themes (Saldana, 2014). Some ideas were briefly captured in a single sentence. Other ideas comprised two to three sentences to complete the thought. Beginning with Participant B as the initial case, I open coded each idea in a Microsoft Excel spreadsheet. As an iterative process, I selectively coded each idea in light of its contribution to a broader understanding of authenticity. I sorted and grouped the codes reducing themes with similar meaning. Then I subordinated themes under one another based on their context and shared relevance. These categorized themes were translated into a networked diagram using CMap tools. I used the networked diagram as a basis for coding the second interview.

I followed the same process of chunking Participant A's interview idea-by-idea. I wrote memos on Participant B's network diagram to document themes that were reinforced by Participant A's interview. As a new theme emerged, I made one of two choices: (a) introduce a new theme and reorganize the network diagram to reflect the new theme or (b) integrate the emergent theme into an existing category. This process resulted in a modified diagram and the basis for coding the next interview (for more information on axial coding in multiple case study designs, see Stake, 2013). I continued this constant-comparative cross-case analytic tactic until all interviews were reflected in a final diagram (for more information on this qualitative data analysis strategy, see Saldana, 2014). I refined this final diagram into the combination of themes, mediating elements, evidence, and expressed impacts.

Whereas Figure 3.1 addresses the first research question about understanding the role of authenticity in the exhibit design process, the second question required additional analyses. The final phase of analysis compared the findings from the interview data with the external, embedded, and internal layers of authenticity as expressed in the educational research literature. Both of these analyses are described in more detail in the results and discussion sections.

Results

The purpose of this study was to better understand authenticity as it related to the design of interactive science exhibits. To accomplish this purpose, I asked knowledgeable individuals to describe their design processes and priorities when creating interactive science exhibits. This glimpse into each participants' experience designing, fabricating, and integrating interactive science exhibits into their respective institution provides a unique lens to see the processes behind exhibits and visitor experiences.

Table 3.2.

Sample of Idea Chunking and Theming Process for Participant B

Text (B.16)	Subordinated Theme
"Some visitors do like that kind of direction. Others do not. They prefer more open-ended activities, visitor-directed, kind of 'Let me do my own thing.'"	II. Designed experiences A. Learner preferences 1. Structure v. Autonomy

The data analysis process started with chunking interviews into ideas. I assigned each idea a theme that reflected its relationship to the discourse on authenticity (Table 3.2). I organized similar themes into groups based on their contribution to the research question. Figure 3.1 illustrates a portion of the networked diagram for Participant B's interview. As his interview was open-coded, the diagram reflected his perspective on the role of authenticity in the exhibit design process. In Table 3.1, Participant B's diagram provided a place for *designing experiences* that provided for personalized experiences, but did not have a specific place for *structure v. autonomy*. I revisited the context for *personalized experiences* and found that the statement was about creating individualized experiences versus shared experiences. Therefore, I changed *personalized experiences* to *learner preferences* and subordinated *individualized v. common* and *autonomy v. structure* under this new heading.

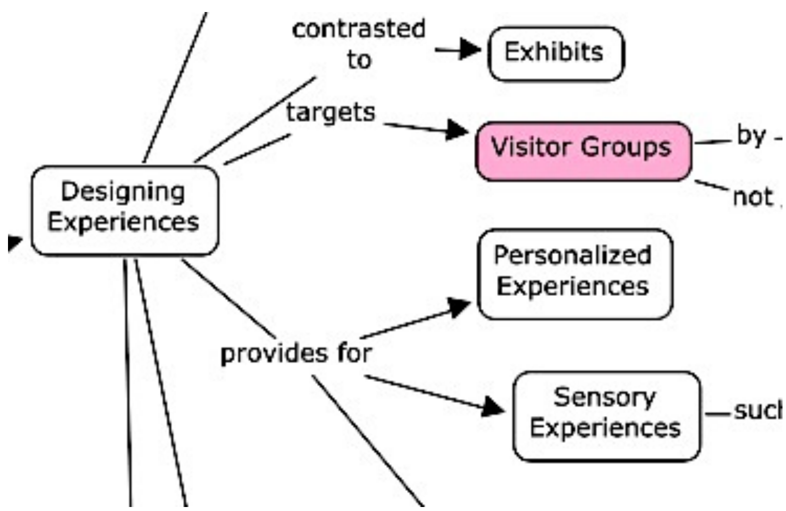

Figure 3.1. Focused Portion of Participant B's Networked Diagram. This graphic represents a portion of the networked diagram summary of themes from Participant B's interview.

The data analysis process produced a series of iteratively refined conjecture maps that framed each participant's descriptions in light of the interviews that preceded it.

The analytic process culminated in the emergence of three primary themes about the role of authenticity in the exhibit design process. The three primary themes were the need to be: (a) authentic to the institution, (b) authentic to the learner, and (c) authentic to science. Each primary theme included subordinate categories that reflected the participants' consolidated descriptions of the mediating processes, evidences and expressed impacts. A summary of these subordinate categories by primary theme can be found in Figure 3.2.

Authentic to the Institution

Each participant shared their perspective on the importance of authenticity in designing exhibits that fulfilled their institution's mission statement, vision statement, or set of institutional priorities. Participants who served in senior leadership positions described these policy statements as "northern lights" (D.6) that shaped the vetting process of ideas and decisions during early stages of strategic planning. Participants involved in the specific design of an exhibit communicated the significance of their institutions' guiding policies and how those policies shaped practical decisions. Participant B captured this sentiment as he described his ability and his expectation of others to be able to look at the design features and embodied priorities of an exhibit and determine its home institution. He said,

> I think the very best exhibits reflect the institution's personality and the institution's mission. If you see an exhibit from my museum, they should be able to say that exhibit is from [our institution] and here is how I can tell. I can tell exhibits that are produced by the Science Museum of Minnesota [for the same reason] (B.8).

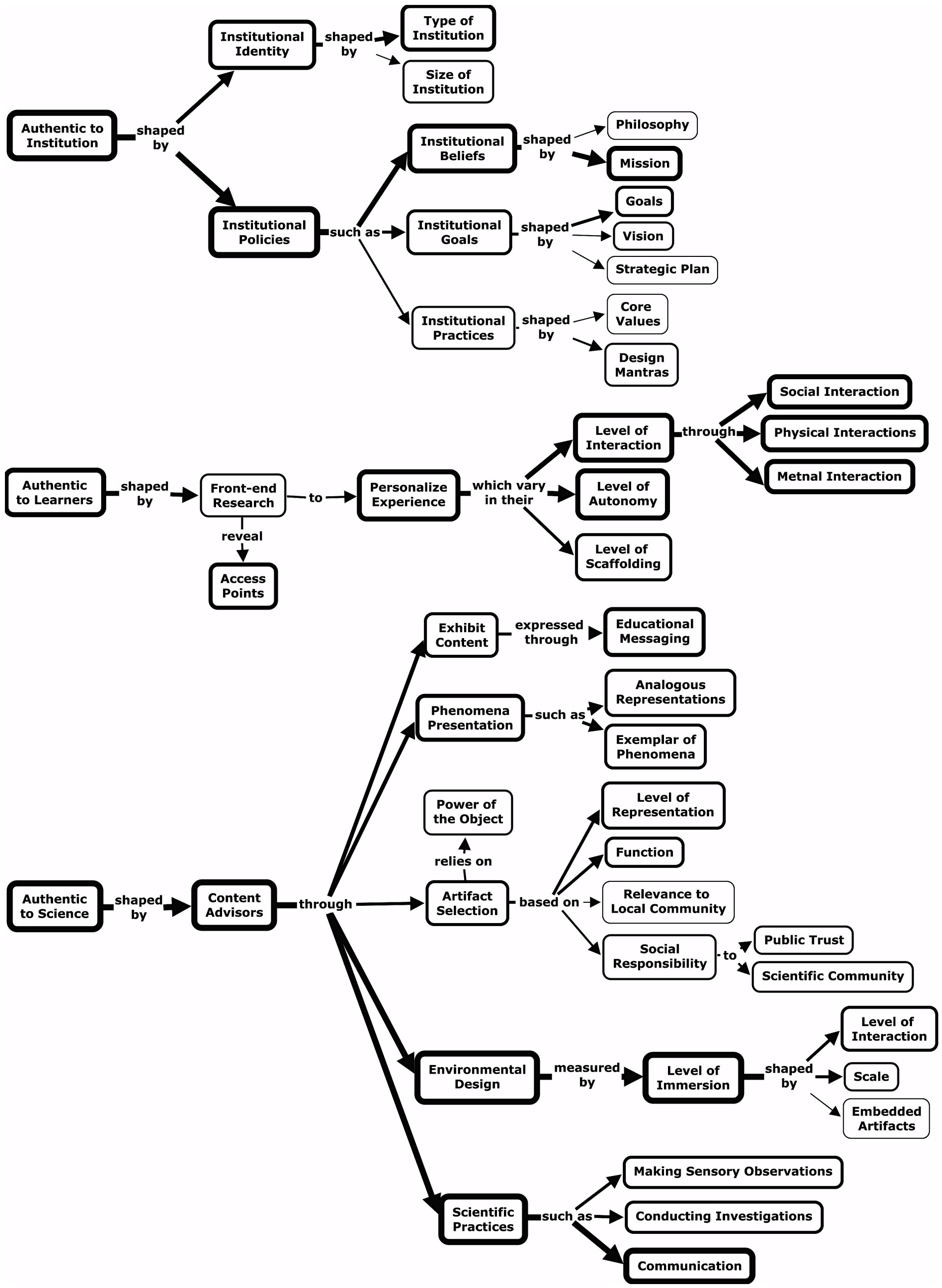

Figure 3.2. Authenticity Major Headings Diagram Coded by Frequency. This represents three major headings in the final consolidated authenticity diagram. The strength of each line and border reflect the frequency of the connection or concept across all interviews.

I do not believe Participant B was inferring that institutions are, or should be, formulaic in their exhibit designs. Indeed, he meant to say that the impact of being authentic to your institution should shape an exhibit's expressed priorities and regional community. Participant F could not recall her institution's mission or vision statement, but as I probed into design decisions related to her favorite exhibits, it became clear there were some things they [reflecting on herself as a representative of her institution] just did not do. She shared several examples of how this was applied at her institution. In one example, she expressed concern that overly-structured directions at an exhibit might have prematurely explained the science behind their exhibits before their visitors had a chance to discover it for themselves.

Whether it was an explicit reference to official documents like Participant B or an inferred cultural norm like Participant F's, there were commonalities in the participants' perceived value of an exhibit's authenticity as related to its institutional policy or culture. Each participant's description of the role these influences played in this pre-development phase of the exhibit design process included an emphasis on the need of those documents to be reflective of her respective community. Participant D succinctly described this perspective when he said, "[Our mission and vision statements] needed to reflect the changes [our institution] had gone through in the last couple of years, so we decided to make some changes to that" (D.1). I interpreted his point to be that policy statements are also evolving documents. As evolving documents, authenticity is not static, but grows and changes with the institution. Also, there appears to be an interdependent relationship between the exhibit design process at the strategic level and the growth and development of the institution's culture over time.   I organized participants' descriptions that highlighted a need for an exhibit or experience to be authentic to its host institution under two secondary categories: (a) institutional identity and (b) institutional policies. Each of these categories sufficiently accounted for all themes that emerged under the larger heading of *Authentic to the Institution*.

Institutional identity. Not all ISE institutions are the same or serve the same communities. They vary by type of institution and by size of institution. As the participants represented a sample of the variety of institutions in the ISE landscape, their descriptions of the role authenticity played included references to how some design choices were rooted in the size or traditional function of their particular institution.

Type of institution. Two participants described hands on experiences as a common priority shared by science centers as a type of ISE institution. In both cases, the descriptions were contrasted to natural history museums' focus on preserved collections. Therefore, visitor experiences with hands on interactivity would be more authentic to a science center. This was not to preclude the fact that a variety of experiences can be found at any ISE institution but emphasized the fact that science centers prioritized a level of interactivity across their institution that was markedly different than a natural history museum whether across the street or on the other side of town. Each type of ISE institution has a prototypical function or role they serve to their community or state. An institution's level of authenticity as expressed in its exhibits then could be compared against the prototypical expectation.

Size of the institution. Additionally, not all museums within a typeset category are the same. Many science centers vary in their size depending on their location and the investment of the community as patrons. Two ways museums compare size are by the square footage of their institution's footprint and by the volume of visitors they have over a given point of time. Participant A acknowledged that there were some things she felt were better suited for smaller institutions—e.g., makerspaces—where consumable materials might have outweighed the merit at a larger site. Participant B's experience at multiple large institutions shaped his perspective on what he termed *throughput,* or the amount of visitors that pass through a given space in the museum. Considering so many visitors would move through the halls on a given day, Participant B had to be considerably more selective about where he wanted visitors to slow down and how long he wanted them to stay before macro-environmental factors like crowding would unnecessarily detract from a visitor's positive experience with science. Participant D shared Participant B's sentiment, but highlighted the macro-environmental consideration of noise—particularly at very contemplative, or "heady" exhibits. Size of an institution and its need to alleviate congestion across parts of the institution reflected another layer of how authenticity to the institution could be measured. The larger the institution—as measured by size and attendance—the higher the importance of flow and throughput were in the design of exhibits.

Identity statements. Participants also shared statements that reflected their institution's identity. Participant D described his institution as being "instigators" of a visitor-directed experience (D.18). This was posited as a modern contrast to a more traditional role of being a "textbook" or authoritative content deliverer (D.34). All but one participant identified their institutions as a space where social experiences naturally occur. Although participants' explicit phrasing might have varied slightly (e.g., social experiences naturally occur versus where people socially engage), this description is consistent with my interpretation of *institutional identity*.

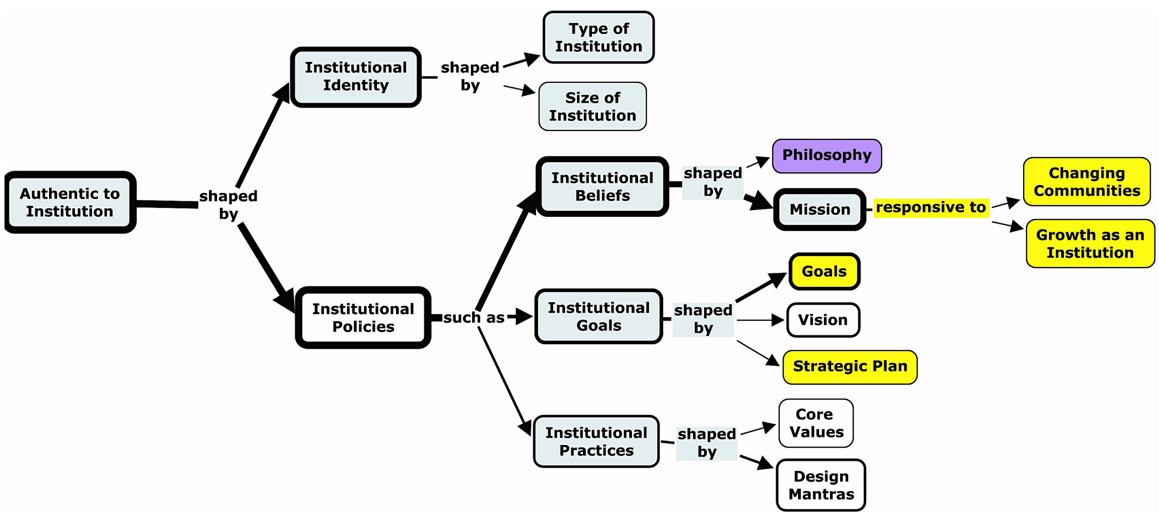

Figure 3.3. Annotated Institutional Authenticity Sub-Diagram. This figure represents how authenticity is interpreted through a reflection of the priorities of an institution. The diagram has been color coded to reflect initial contributions by participants. The strength of each line and border reflect the frequency of references across the interviews.

Institutional policies. Participants described the significant role institutional policies such as mission and vision statements, strategic plans, institutional goals, and core values had on the design decisions for an exhibit. Some participant descriptions referred to formal institutional policies, while others referred to the ideas or statements they include. Positional statements, although not all were directly attributed to a specific guiding policy, similarly described institutional perspectives on how people learn, how to engage the community around them, or how priorities frame decisions made in the exhibit design process. I considered both the guiding policies and positional statements in my interpretation of authenticity as it relates to institutional policies. As illustrated in Figure 3.3, I organized these statements into one of three groups: (a) institutional beliefs, (b) institutional goals, and (c) institutional practices.

Institutional beliefs. Institutional beliefs included expressed philosophies and mission statements. I organized these together based on how the participants reflected on their institutions' position on how people learn, the role of the visitor as a learner, and what they value as an institution. Participant F described one of her institution's explicit philosophies that highlights an example of where her institution places value; "it ties in so much with our philosophy of the everyday things in your world being fascinating and learning to look at things around you differently" (F.12). Exhibits that are authentic to her institution shared this emphasis on seeing common items and naturally occurring phenomena in a new way. In discussing the role of models in exhibit design, Participant F was able to highlight two exhibits that "feel out of place in our museum actually" (F.9) specifically because of their use of large passages of text and models—this highlighted a distinction made between exhibits that naturally fit in with the institution's priorities contrasted with those that do not. Additionally, several positional statements among the participants focused on a shared sense of responsibility in building positive bridges between their visitors and scientific thinking and practices. This sense of purpose or responsibility shaped the next category under institutional policies: institutional goals.

Institutional goals. Another unique attribute is the use of the set of goals that shaped the culture of an institution and ultimately painted a picture of how exhibits could be more or less authentic to the institution that designed them. Participant descriptions of these goals ranged from ambiguous or ambitious vision-casting goals to pragmatic and organized strategic plans. Participants D shared one of his institution's goals was to grow as an institution in order to contribute to the field as a nationally recognized institution (D.2). This goal shaped risks his team were willing to take to try new things in the design of new exhibits and experiences. Vision statements, while described as somewhat "cumbersome and clumsy" (C.1), still represented the long-term goals of the institution and were therefore included as part of this subcategory.

Institutional practices. Institutional practices reflected some of the action statements the participants shared. I organized action statements by their focus on how institutions put their institutional goals into practice. For example, Participant A said that her institution makes it a priority to "designs experiences, not exhibits" (A.23). This powerful retort to my opening question about the exhibit design process highlighted my need for a perspective shift to better understand the decisions that shaped the work Participant A and her team did at their institution. Participant B shared his design mantra, "Don't do anything in a museum that you can do at home, on a computer, or in a classroom" (B.57). In both examples, authenticity could be measured against how well an individual exhibit reflected this perspective. Exhibits that mirrored classroom experiences or that failed to engage a visitor in an active experience would not measure up to the practices at Participant B or Participant A's representative institutions.

Authentic to the Learner

"When I develop projects, I absolutely start with the mission of the organization, but then I spend quite a bit of time *talking to people"* (B.49). The "people" Participant B referred to was the visitors and advisors. Participant B continued emphasizing the significance of understanding the institutions' audience and to get the science right behind the exhibit. In fact, engaging the institution's audience as learners is a shared institutional priority described at length in each of the six interviews. Exhibits can be designed in such a way that as the visitor interacts with the exhibit, it provokes some level of internal processing.

> And you know that there is a mental and emotional interaction going on there, or engagement. The exhibit or display doesn't do anything. *It responds to you. That is an even more important element than literal touching or doing* (emphasis added) (A.20).

Participant B shared his sentiment that, "the best interactives in my opinion are things that engage you, capture you and maybe even confound you a bit" (B.25). In each example, the participant's interpretations of the value of engaging a visitor differed slightly. As such, there were some areas where a consensus formed easily and there were others where specific descriptions varied. As the categories expanded further, I repeatedly reviewed and collapsed categories. The constant comparative process of analyzing the interview data eventually produced a model where front-end evaluation took precedent. Following the front-end evaluation, I subordinated three descriptive categories: (a) what data front-end evaluation collected in order to authentically engage a visitor, (b) how the front-end evaluation data revealed access points and potential barriers, and (c) how access points and potential barriers were used to personalize a visitor's experience to different levels. Each descriptive category helped shape a clearer understanding of how the participants perceived and responded to the need to be authentic to their visitors as learners (see Figure 3.4).

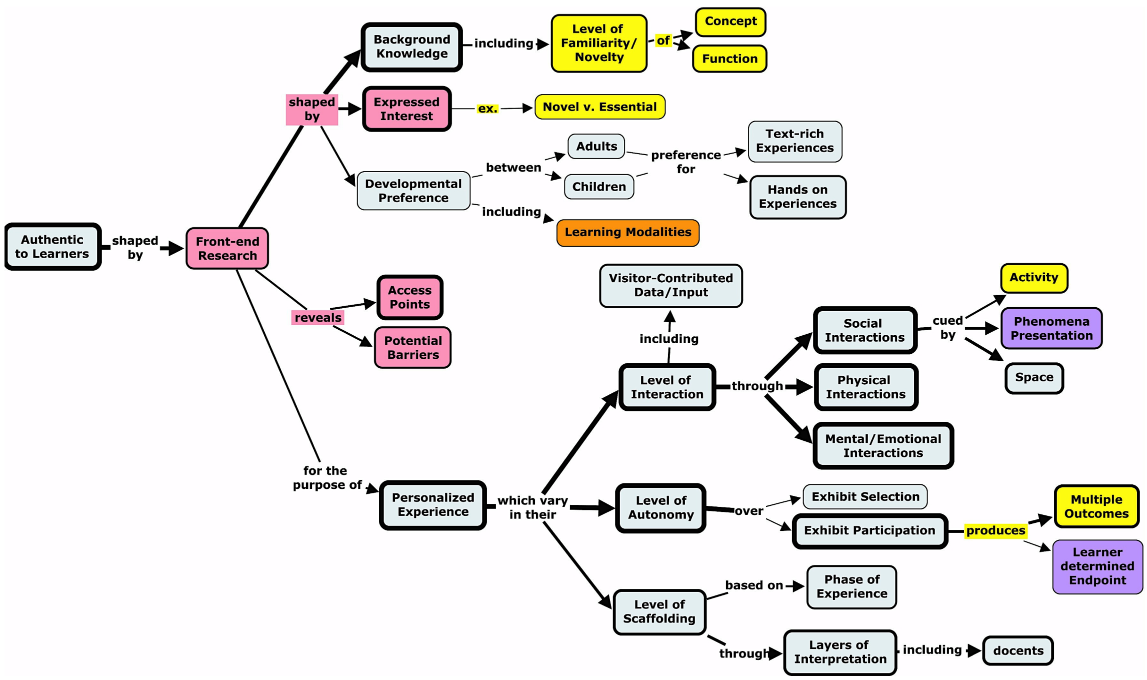

Figure 3.4. Annotated Learner-centered Authenticity Sub-Diagram. This figure represents the ways authenticity is interpreted relevant to the visitor as a learner. The diagram has been color coded to reflect initial contributions by participants. The strength of each line and border reflect the frequency of the concept across all six interviews.

Front-end evaluation data. I opened each interview by asking participants to describe the essential components of the exhibit design process and several of their favorite exhibits they designed. Across all the described exhibit design processes and example exhibits, there were consistent references to visitors' background knowledge and expressed preferences. According to participants' descriptions, a visitor's background knowledge included both content and process knowledge. The participants then based exhibit design decisions on whether or not an idea or process would be familiar or novel, perceived as essential or interesting, or if there were a "preferred delivery system" (D.39) for a specific demographic of visitors. In describing ease of use as one benefit of creating unique experiences around familiar and unfamiliar objects and situations, Participant F shared:

> I think it's great to have something that's familiar, something like soap bubbles that people are familiar with. *You can set it up in a way that people know how to approach it* (emphasis added). It has a natural attraction and it is engaging and if you can push it in new ways like the giant soap film painting or giant bubbles, I think it makes it approachable if it's familiar and I think it's also nice to make that connection so having seen it in this new light, maybe you are encouraged to experiment with it more at home. (F.11)

Participant B described his experience with adult visitors preferring text-rich exhibits while middle school visitors preferred hands on experiences (B.16). Participant A used front-end evaluation to group visitors by common interest, or by "attitude toward the science" (not by age or developmental stage) (A.8). Participant A was specifically talking about a very personal health exhibition where messages and experiences were designed to reflect the fact that visitors in the front-end evaluation were grouped by their attitudes towards specific health concerns or topics.

Front-end evaluation findings. One of the expressed benefits of front-end evaluation is that exhibit developers and project managers get a feel for where, how, and to what extent a visitor might interact with a designed experience. Participants described everything from card sorts to concept mapping to help shape messages that authentically connected to a visitor's understandings and strengths. Mock-ups and illustrations were used to get feedback on an exhibit's approachability or perceived use. Regardless of the method or stage of the front-end evaluation, there were two salient findings that shaped how designers used data to support experiences that were authentic to the learner: (a) access points and (b) potential barriers.

Access points. Access points included participants' descriptions of the importance of understanding visitors as learners with varying background knowledge, experiences and interests. As participants described these learner attributes, they were closely connected to the importance of finding access points that connected the learner to the designed experience the participants and their design teams were trying to create. Participant A described the importance of these access or "entry" points.

> Understanding whom your audience is and what your audience's entry point to a given topic. I think that's the point of entry, not the level. We don't want to be obtuse. Its what points of contact in a given theme is it relevant to their lives. What's the point, why should they even care. (A.32)

Her position on access points was as a means for meeting visitors where they were (point of entry) with the goal of engaging the visitor in a meaningful, relevant experience that parallels their own interests and expectations (A.9). Participant B described a dinosaur dig experience that he determined—through front-end evaluation—needed a linear start to close any misunderstands or gaps in a visitors knowledge that would limit their ability to enjoy and be inspired by the experience (B.11).

Potential barriers. Participants described moments in front-end evaluation when it became clear that an exhibit's design had either illuminated a gap in knowledge or experience or had failed to engage the visitor in a meaningful way. Participants shared two primary concerns related to potential barriers to visitor engagement. The first was that the barrier could limit a visitor's ability or willingness to complete a designed experience. The second was that the potential barrier would limit the overall depth or complexity of the designed exhibit (A.5). Participant B shared an example of both with an exhibition on calculating and mitigating risk in your life;

> The research was asking the question, 'At what point do people cut their losses and leave'—but there wasn't a really clear point where that was and people's understandings about chance and probability was so low, they couldn't figure where that point was. (B.23)

In this scenario, Participant B and his design team had to determine a different way to approach the big idea so that the experience would be accessible to everyone. Their exhibit design decisions were rooted in the front-end evaluation data. Participant B shared another story of a design team who failed to use front-end evaluation and it had a negative impact on the reception of their exhibit. One of Participant B's colleagues had been involved in the design of an exhibit based on a sensitive health-related issue. The focus of the exhibition was a disease that predominantly affected the African American community. According to Participant B, expert advisors were brought in, the quality of the exhibit and its materials was high, and the activities within the exhibit were very engaging by design. However, the exhibit failed to perform to the designer's expectations. Even though the topic was a disease that affected the local community, no African Americans were brought in to meaningfully participate in the front-end evaluation. As a result, there was a different message that was being sent, "Look what us white people have done for you" (B.73). This was not the message the design team wanted the exhibit to communicate. The lack of front-end evaluation created a clear barrier and the exhibit had to be reworked.

Personalized experiences. The second major node encompassed participant descriptions of ways exhibits could be designed to respond to a learner's background knowledge, interest, and preferences. The meta-message across the participants was that if an exhibit were going to be authentic to the learner, it would be require a visitor to engage with the big idea of an exhibition. I organized participant's descriptions of their efforts to engage the visitor under three prioritized headings: (a) levels of interactivity, (b) level of autonomy, and (c) level of scaffolding experienced by the visitor.

Level of interactivity. Among participant descriptions of their response to front-end evaluation, level of interaction was most frequently discussed. Participants described three approaches to shaping an authentic interaction with a visitor: (a) through physical interactions, (b) social interactions, and (c) mental or emotional interactions.

Physical interactions. Descriptions of physical interactions with exhibits included building trusses (D.24), excavating dinosaur fossils (B.59), running against a virtual person or animal (C.8), operating a smoke cannon (F.3), and building sea creatures from recyclables (C.9). In each description, the participants would describe how they purposefully designed the physical interaction. Most physical interactions were designed to model a scientific practice of making discoveries, testing predictions, or investigating variables. Some physical interactions, like makerspaces, created a space for visitors to explore their own creativity.

Social interactions. As highlighted previously, a common thread across the institutional identities of the participants was that their site was a space where social experiences occurred naturally. In each case the context for this statement varied; however, the understanding that the exhibit designers had a role in shaping those experiences was shared. There were several different approaches that each participant described for the purpose of cueing social interactions around exhibits and ideas. Samples of these include embedded prompts (e.g., labels or docent facilitation), the conducive organization of space (e.g., accessibility to the exhibit from multiple sides), and collaborative activities (e.g., challenges that require the participation of more than one person to accomplish).

Orienting space to promote social interactions included suggestions such as using center-facing chairs instead of side-by-side benches and incorporating open semi-circular tables in the place of traditional single-seat desks against a wall. The effect of these open spatial designs included promoting cooperation and centering visitor's attention on one another as part of the experience around a science phenomenon. Participant C described scenarios where exhibit designers were forced to pull tabletop experiences away from walls and turn them around so more people could interact simultaneously. He described the merit of these deliberate changes in several ways.

> Where one person might be physically controlling the experience, [orienting the exhibit to face other visitors allows] now four or five other people can watch how that person is interacting with it. So in a way, the viewer is interacting in a very different kind of way but they are interacting with it. It's more about the connection between one group of visitors and another group of visitors that they've never met before—they've had no prior experience with and they'll probably never see again—but they all sort of connect for that moment. (C.14)

Again, Participant C's emphasis on the opportunity for visitors and visitor groups to interact with other groups through purposeful furniture selection and orientation highlights a unique opportunity for visitors to communicate their observations and experiences with visitors with whom they might not have interacted with. This is a novel approach to promoting social interaction between visitors without a pre-existing relationship. Participant C shared,

> I don't think that many people come to a museum expecting it to be a very highly social experience, not just with the people that you've come with, but also with a wide range of other visitors. I don't think that people realize that their experience at an exhibit is going to be so largely dependent on other visitors. (C.13)

Conversations occur naturally between family groups and student-peer groups during field trips. However, Participant C's inclusion of promoting conversations between visitors who might not have had pre-existing relationships appears to be a unique approach to designing exhibits.

Participant B also described his perceptions of the benefits of orienting space and embedding labels to promote social interaction cues in exhibits. He said,

> So there [are] different ways to do it, but again, knowing that museums are often social experiences whether it is couples or school groups or families or whatever it might be, designing things physically so that people can get around things and work on things together, and then through questioning and labels, is a way to spark conversation. (B.33)

In addition to highlighting the use of questions and labels to spark conversation, Participant B's summary points out the close relationship between collaborating and communicating. This highlights the interconnected nature of scientific practices, which should not be lost in light of my attempt to organize described design principles around specific types of authentic scientific practices. Some cues to promote social interaction mirror the layers of interpretation embedded in scaffolding.

Mental and emotional interactions. Participant F highlighted the value of physical interaction in her perspective on an example exhibit around a smoke cannon.

> It's very simple. You press down on this flexible, disc that's rigid but has this rubber baffle I suppose. You press down and you get a perfect smoke ring. People think you have to press down really hard but that's not it at all. You have to press down gently to get a perfect smoke ring. So you see children using it and it's really rewarding to see them figure it out that it's not about brute force, it's about the delicate touch. I love how simple it is and how beautiful it is. It never gets old for me. (F.3)

In this example, visitors physically explored the exhibit with their sense of touch. The counter-intuitive nature of the phenomenon causes the visitor to navigate some internal processes to make meaning of their sensory experience. As such, the authentic sensory experience alone was insufficient for accounting for the full benefit of the visitor experience. Participant A also emphasized the importance of the visitor being mentally and emotionally engaged by an exhibit. She de-emphasized the need for touch to be one of the ways visitors interacted with an exhibit, but acknowledged that her institution has "those [hands on interactives] in spades" (A.21). Participant D agreed that as visitors were able to mentally or emotionally connect to the content and presentation of an exhibit, their conceptual understanding would grow. Participant D shared an example that illustrated how physical interactions, social interactions, and mental/emotional interactions worked together to support a level of embodied cognition.

Visitor-contributed data. Additionally, half of the participants (n=3) specifically described the use of visitor-contributed data as a central part of the experience.

Participant D described an example of this related to a touch table activity where visitors would practice making healthy choices to extend the life of their avatar in a game. The data shared became part of a growing data set shared with subsequent players and available for museum staff to query against. Participant A continued to describe several examples of how visitors differed in their level of engagement with an exhibit. Whereas many visitors will interact with exhibits directly, Participant A also spent some time describing the importance of engaging those visitors whose comfort level of engagement might have been standing outside an exhibit and observing others' use of a given exhibit. According to her experience, this semi-public display of visitor-contributed information, observations, or experiences encouraged others who might have normally been content as observers to step in and try exhibits. Visitors may change the way visitors interact with exhibits, specifically building on another visitor's experience.

Level of autonomy. "We try to encourage our visitors to find their own path, to engage the experiences that are meaningful to them" (B.10). This was Participant B's perspective on engaging the visitor in positive experiences with science. It highlighted the active role of the visitor but based on the institution, the prospect of creating experiences where a visitor experiences a level of autonomy, or control over the direction and outcome of an experience, could be intimidating.

Despite his own recognition of the success of the experience, Participant C spoke with some uneasiness about going into the open-ended nature of the build-your-own recyclable sea creature (C.9). Participant A spoke about creating a makerspaces, a traditionally open-ended approach to creative tinkering, as though their level of openendedness was beyond something that her department could provide an institutional proposal for. From her perspective, those open-ended experiences were better suited for smaller institutions with less throughput. On the other end of the spectrum, Participant F worked for an institution where open-ended was not only the goal—it was the standard. From her perspective, a well-selected phenomenon dictated an open-ended experience.

> I think the [our institution] differs from many museums in that you don't just press a button and then wa la, something happens. A lot of times, you are the agent that causes the phenomenon to show itself. But then there are things that show themselves. We have this huge mirror and you just walk up to it. It doesn't do much of anything at all. You experience optics of what's going (F.2).

In the case of the large mirror, there were no signs prompting specific behaviors, or specific learning goals, related to the angle of reflection or angle of incidence. A visitor would just approach the mirror and choose how they wanted to engage with it.

The more a designer wants the visitor takes an active role in the experience, the more necessary it becomes that the experience must have multiple paths and likely multiple outcomes. How this was operationalized differed between participants? From Participant F's perspective, a high quality experience cannot have a designed endpoint. She said, "The endpoint has to come when someone is finally getting what they wanted out of the exhibit" (F.16).

Participant D contributed an additional perspective to visitors' experiences with autonomy. "It is not about I'm going to teach you something, or you are going to learn something. It is not even really a conversation—well, on some days it is more of a conversation—but it is just trying to find a way to instigate and inspire" (D.8). Participant B shared a similar perspective, "An interactive exhibit is one where you as the visitor actually have input into the process and might have one of many different outcomes through your involvement in the process" (B.20). Participant C did not share that comprehensive of a picture. He described his perspective as a purposeful balance.

> It is the exhibits that best balance the institution's intended outcomes with the visitor's ability to have choice and control over the experience. That point of balance is going to shift from exhibit to exhibit (C.8).

This sense of purposeful balance still prioritized visitors' active roles in the exhibit but noted the challenge of potential visitor fatigue on overemphasizing any one style of designed interaction.

Level of scaffolding. As participants shared their perspective of the role of authenticity in the design of exhibits, many considerations emerged. One such consideration was the importance of scaffolding as a mediating process. This mediating process reflected the designers' sensitivity to front-end evaluation and learners' experiences. I created a category to reflect this emergent category—level of scaffolding. This new category provided a place for additional comments about the need for elements of an exhibit to be authentic to learners through a purposeful and progressive sequencing of learning experiences. Scaffolding was represented in three of the six interviews. Each interview highlighted the facilitating role of docents in shaping visitors' experiences. Two participants identified docents as one of many layers of interpretation. Other layers of interpretation included embedded videos, interactive virtual interfaces, signage, and text-rich artifacts like paleontologists' notebooks or crime reports.

One of the described challenges of designing a visitor-directed experience is the unexpected or inappropriate intervention by unaware or untrained floor staff. Participant B shared an experience his team had with their crime scene exhibit.

> At one point, one of the advisors came in to my office and told me, "the volunteers are ruining the exhibit" and I said, "what?" and the volunteers had put on trench coats and they were having a ball but they were telling the visitors, "Once you've visited the crime scene, go in there and write down your clues and then you need to go to this station, this station and then this station and it'll help you figure it out" (B.14).

In this scenario, the floor staff was trying to be of help by guiding visitors through the series of experiences. What disturbed the content advisors and exhibit designer was that by actively directing visitors through the fastest path, the floor staff was shortcutting the authentic science practices of basing decisions on evidence, dealing with ambiguity, and processing when they need assistance.

Authentic to the Field of Science

Whether in the classroom or on the museum floor, the first standard that many use to describe a level of authenticity is "to the profession." A great deal of research has already been conducted in the broader context of educational research on how learning experiences and environments are shaped to mirror a specific profession. The expert practitioners in this study highlighted the aspects of the profession they consider in creating experiences that are authentic to the field of science. Authenticity to the field of science was expressed in five aspects of the exhibit design process: (a) exhibit content selection and refinement, (b) presentation of the phenomena, (c) artifact selection, (d) environmental design, and (e) inclusion of scientific practices.

Role of content advisors. Each participant described the use of content specialists as advisors in order to aptly gauge the resemblance of the exhibit's message, environment, artifacts and tasks to the specific field of study. The role content advisors played varied among the participants' described experiences. Participant E described the effort required to maintain healthy partnerships with researchers at nearby universities while Participant A worked at an institution large enough to employ a variety of content experts and researchers internally. Participant B's interest in bringing content advisors together reached beyond local universities. In a description of an exhibit that benefited from the participation of a number of different experts, Participant B shared the following insights:

> We bring outside experts to challenge us. We brought in one guy who was a Wall Street guy so he was all about financial risk (B.50).
>
> Then we brought in a sociologist who did a lot of work on human perceptions of risk and we wanted to bring that in as well (B.4).

Participant B continued on to describe how the visitors benefitted from the contributions of these two experts and their different perspectives of experiencing and mitigating different characterizations of risk.

Content advisors were invited predominantly on their content expertise; however, Participant B did refer to advisors who had previous design experience "working on dinosaur exhibits" (B.2) in the past. In the course of the interviews, I did not dig further into content advisors' specific backgrounds, but it suffices to infer that their previous involvement might indicate that their earlier participation had already been vetted based on their expertise. Although each process varied from institution to institution, it was clear there was a single purpose for inviting content advisors: to make sure science concepts that would be the backbone of the exhibit were accurate to the science discipline and that they "put forward the most compelling ideas" (C.7).

Authentic to science content. "What are the most important things out of this whole discipline we are looking at?" (B.28) This question was a representative one Participant B used to describe how content advisors helped him and his team understand the breadth and depth of a discipline. In this way, content advisors are brought in to transform the big ideas of the field into educational messages. The purpose of the content advisors' contributions is to make sure the big ideas in exhibits' messages reflect the major understandings of the branch of science in a way that is both current and accurate (see Figure 3.5)

Not only did content advisors support shaping the big ideas and messages behind an exhibit, content advisors were also on hand to vet specific facts and details that would be presented in exhibits' features. For example, Participant E recalled the extent to which the design team worked together to develop a reasonably accurate speed for the Tyrannosaurus rex to run and Mosasaur to swim along side visitors at an interactive exhibit at his institution (E.10).

> We spent a lot of time—our research staff did—to figure out what would be the right speed to set this [dinosaur] at [the run exhibit]. So there's this knowledge that I think is getting imparted on some level (E.10).

The 'imparted knowledge' Participant E referred to is directly related to a series of observations about how authenticity expressed in the subtle experiences shaped a perspective or understanding of a scientific phenomenon.

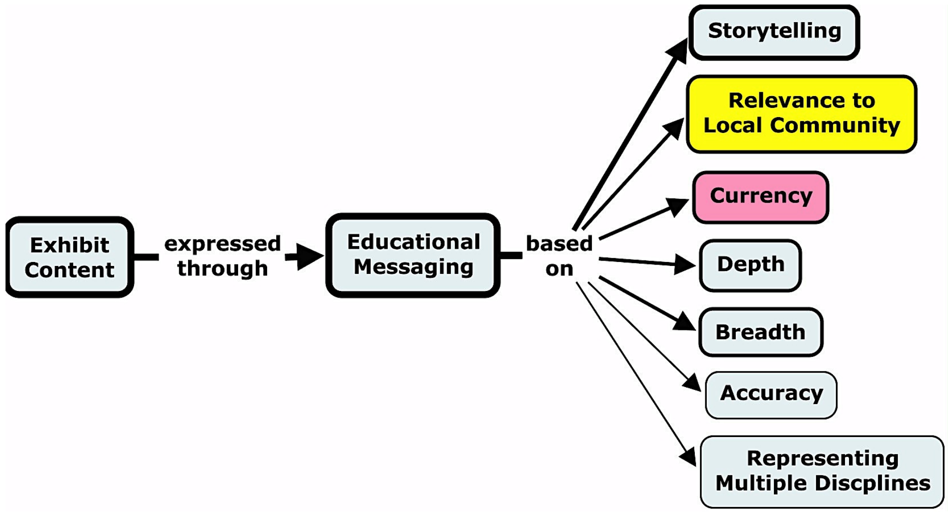

Figure 3.5. Annotated Exhibit Content Sub-Diagram. This figure represents how authenticity is expressed as part of the content development of an exhibit. The diagram has been color coded to reflect initial contributions by participants. The strength of each line and border reflect the frequency of the concept across all six interviews.

Challenges to refining the content. As Participant B recalled, it was in an early planning meeting that he used open-ended questions to get a feel for the discipline. As the scientists would proceed through a list of different ideas and sub-ideas within the area of their expertise, Participant B remembered asking them directly for three to five big ideas. Participant B recounted the scientists' responses as utter shock and borderline offense. How could you take something as complex as their field of study and refine it down to five ideas without losing the *authenticity* of the field? Participant D captured a similar perspective well;

> How do you fill 15 pages in your textbook without it becoming a token gesture? I've crammed so much on my page nobody is reading anything. There's still a design element related to how do I bring them in, how do I guide them through a story or series of experiences, how do I get them to make connections to things that are on the page so to speak if the page is overflowing with every great idea? (D.36).

In reference to incorporating emerging research into exhibit design, Participant D also redressed the importance of selecting ideas *and interpreting them* in an authentic way. "In reality, you might allow yourself to bring one or two of those kinds of things in but you have to be careful not to bring it in in such a superficial way that it becomes a token gesture and it's not really engaging in any meaningful way" (D.35).

Phenomena presentation authenticity. Once the content of an exhibit has been selected, the next layer of authenticity emerges with the decision of how to present the phenomena. The participants shared a number of different analogous representations and exemplars of the phenomenon. While participants described the merit of both types of representations to a visitor's experience, exemplars were described to have had a special role in promoting embodied cognition (see Figure 3.6).

Analogous representations. Scale shaped the two different examples of analogy-based phenomena presentations. The first was an oversized model of a biological cell. Participant F highlighted the role of touch and interaction in the decision to use a model instead of an exemplar of the phenomena. During a series of clarification questions, Participant F noted that her hesitance, or more accurately resistance to using models, was balanced with the incorporation of real microscopes and slides in the same exhibitions (F.8). The second example used scale representations of a real phenomenon. Two participants referenced the same phenomenon from two different institutions. Participant A's described the installation a 40-foot vortex generator (A.13) and Participant D's described the installation of a tabletop vortex generator (D.27). Both participants described the value of the vortex generator in sparking visitor conversations but it was Participant D who focused in on the "contrivance" of the vortex and its reception by visitors.

> When you see the little trusses in the hall or they see the little tornado thing that we create, I've never sensed any disappointment from people that it's not a real tornado. They understand that it is an effect; a sort of contrivance that we have created for them that simulates the scientific principles (D.27).

Exemplar of the phenomena. Participant A described a chick hatchery as an example of an exemplar of science (A.16). Her justification was that visitors were able to observe the growth, development and emergence of a baby chick from a fertilized egg. Participant D described a modeled phenomenon as an exemplar through an earthquake platform. The value of the earthquake table, as Participant D described it, was that it allowed visitors unfamiliar with the experience of an earthquake to climb onboard an eight foot-by-eight foot platform and experience three different historical earthquakes (D.13). Even though the machine only replicates the vibrations, visitors engaged their prior knowledge and imagination to make predictions about when, in the midst of their physical experience, their homes would have potentially collapsed. This sensory experience provided a way for students to connect to the experiences of another community's reality.

Embodied cognition. The novelty of the earthquake table experience for those visitors unfamiliar with the effects of an earthquake is just one example of embodied cognition (Shapiro, 2010; Wilson, 2002). Participant D shared some visitor conversations he overheard near the earthquake platform. Visitor comments, such as

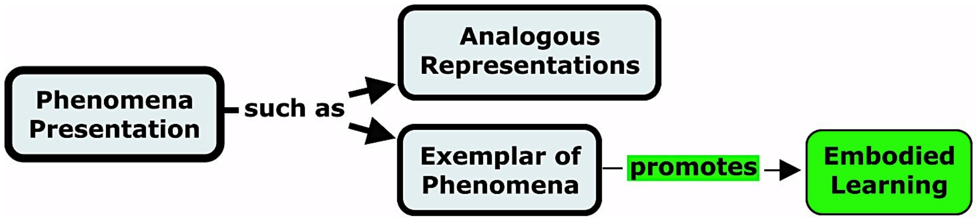

Figure 3.6. Annotated Authenticity of Phenomena Presentation Sub-Diagram. This figure represents the ways authenticity is interpreted as part of the presentation of a scientific phenomenon within an exhibit. The diagram has been color coded to reflect initial contributions by participants. The strength of each line and border reflect the frequency of the concepts across all six interviews.

"I'm pretty sure that is when my house would have fallen down," highlighted the personal connections that visitors made with the earthquake table experience. Another example of the evidence of embodied cognition related to Participant C's observations at a running exhibit. Visitors line up and race one of a list of virtual competitors. There is a digital display along the track that allows a life-size representation of the racer to run against the visitor. Participant C overheard the following conversation and shared his perspective of how the experience shaped a different type of learning:

> But there's also a curious conversation there too because there are some people who will choose the cheetah on purpose knowing that they are going to get beat. But then people have these conversations about picking the cheetah and just getting smoked. I think the exhibit kind of tricks you into learning something. Because you get to the point where you're like, God, the cheetah is really freaking fast. How often can you run next to a cheetah? Or you pick the T-Rex to run along side and you figure that you can almost outrun a T- Rex (C.9).

Racing alongside the cheetah running at a calculated average speed over a 30 yard stretch would bring new value and meaning to numbers on a table or in a textbook. Both the earthquake table and the running exhibit provided visitors meaningful experiences with two different phenomena.

Artifact authenticity. Exhibit designers' selection of artifacts is the most salient interpretation of *authenticity* in the design process. Participant D described his experience, as a veteran exhibit designer, with the power of the object. His interpretation focused on the genuine object and its effect on visitors' experiences.

> The artifact is usually the first place where my mind goes when I think of authenticity. Having done museum work, the power of the object. I've never tried to measure that but I've witnessed that by watching people and how they interact with the genuine article (D.19).

The effect of the power of the object varies from experience to experience and from visitor to visitor. Considering the variety of artifact selection criteria described among participant interviews, being an original or genuine artifact is not sufficient evidence for an artifact to be included in an exhibit. In order to be considered authentic and included in an exhibit's design, artifacts must be more than original materials. Based on the participants' descriptions in this study, there were four considerations that express the level of authenticity of an exhibit's artifacts: (a) level of representation, (b) function, (c) relevance to the local community, and (d) social responsibility. These four considerations are illustrated in Figure 3.7.

Level of representation. The first consideration of determining the authenticity of an artifact was to interpret the artifact's level of representation. Artifacts could range from genuine materials and origin to replicas and stylized representations (e.g., mock stethoscopes in a medical exhibition hall).

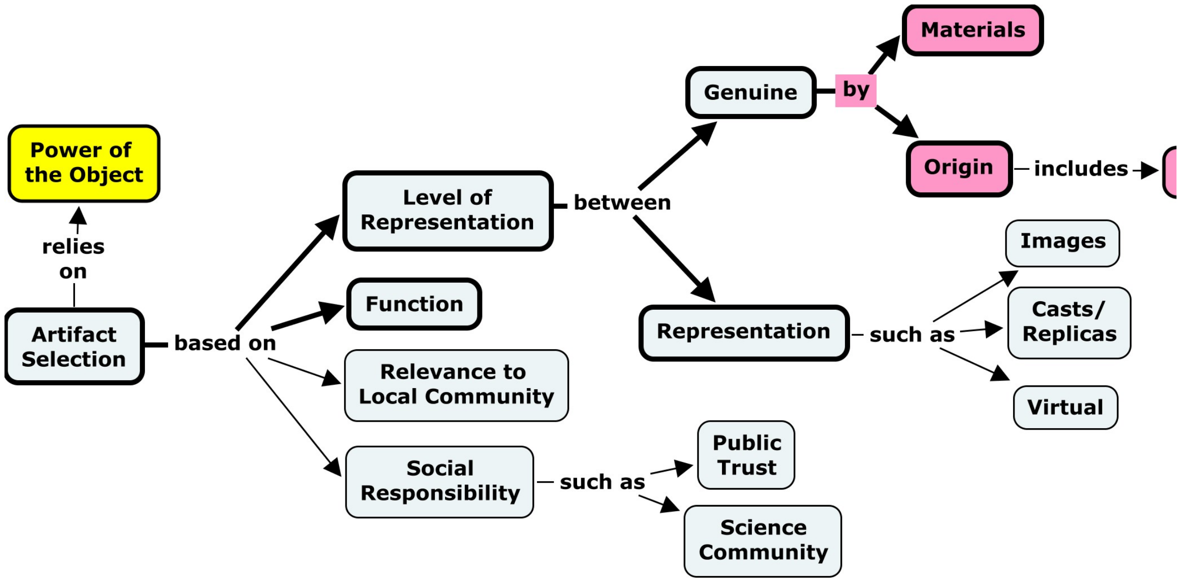

Figure 3.7. Annotated Artifact Authenticity Sub-Diagram. This figure represents the ways authenticity is interpreted as part of the artifact selection for an exhibit. The diagram has been color coded to reflect initial contributions by participants. The strength of each line and border reflect the frequency of the concepts across all six interviews.

Participant B's experience designing exhibits in collections-based natural history and science museums made his position on the importance of genuine artifacts distinctly different from participants from other types of institutions.

> Well, from a museum standpoint, we are *fanatical* (emphasis added) about when we put objects on display that they are real objects, not casts, not reproductions. I think that is part of what museums do. That's public trust and the role it plays on what we do (B.65).

Genuine was also a layered concept. Genuine could refer to living plants (D.28) or genuine materials (e.g., birch bark canoes) (D.20). Genuine was also used to describe an object's origin. From Participant A's perspective, it was not enough to include a submarine as a genuine artifact from World War II. It only became meaningful when it the artifact captured the culture of fear around U-505 submarines and their reputation for taking down American and British military and merchant vessels in the Atlantic (A.28). Her submarine was more than a replica or a real submarine that was never commissioned. It was connected to a real story. Each priority (i.e., genuine materials, genuine origin, and a genuine story), shaped a level of authentic representation.

As complex or as high quality as a staged artifact might have been, understanding and drawing on the meaning and value of an object distinguished effective uses of authentic artifacts in high quality exhibits. Artificial representations include images, casts, replicas, and virtual representations. The design choice to use artificial representations highlights the next consideration: an object's function.

Function. As much as an exhibit designer might have wanted to incorporate authentic artifacts, they had to balance their preference with the artifacts' function or purpose. For example, Participant B shared a description of a large excavation site he had designed that had fossils staged throughout the site. The purpose of these staged fossils was to provide visitors opportunities to make discoveries. To bury real fossils would be irresponsible as custodians of scientific collections. However, Participant B wanted there to be as authentic a set of fossils as possible and so they made the decision to make casts of real fossils, complete with imperfections and incomplete pieces (B.62). The fossil casts served their function in the excavation site.

Relevance to local community. Participant B's excavation site collection could have been based on any number of fossils but his team decided that it was important for the fossil casts to be representative of those fossils that had been discovered in the region around his specific institution (B.45). The fossils' stories were shared in a co-located lab where visitors could also analyze their discoveries. Participant B's description was a unique example of how multiple considerations and their layered effects on visitors' experiences shaped the design of exhibit. Other participants shared similar stories but none that included so many explicit descriptions of the considerations in practices.

Social responsibility. The fourth consideration for selecting an artifact was connected to the ISE institution's responsibility to maintain public trust and respect the science community. Participant B shared two stories to illustrate the social responsibility for selecting artifacts. On the one end of the spectrum, Participant B shared a story of a conversation on a flight leaving Florida.

> She said, "I can't believe I saw the actual dinosaur bones" and I said, "those were casts, they don't actually travel the real bones for Sue" and she looked at me like what? And I said, "The actual Sue is on display at the Field Museum and a lot times these types of specimens are so amazing that they don't travel them. So that was a cast." And she was like, "Well, now I'm mad" She didn't know. So in those times that you use a cast, you have to be really up front that this is a cast of the real thing (C.66).

In this story, the passenger on the flight expressed her feelings of being deceived about the authenticity of the traveling exhibit. But in the story that followed, Participant B described a situation where a high value artifact, Lucy, was really included in the design of a traveling exhibit. Once the exhibit was ready for installation at its first location, the scientific community was outraged at the irresponsibility of traveling a "type specimen" (D.67). The meaning or value of an authentic object might not be shared equally among a group of visitors to an informal science institution. Participant D summarily described his perspective on this phenomenon when he stated, "Some people will be moved by an authentic object while others will walk right by it as they move towards an interactive touch table" (D.30).

Impact of authentic artifacts. Authentic artifacts, particularly artifacts that are personally meaningful and have real stories, can have a powerful impact on those who share experiences with them. Many of these experiences happen where learner's path intersects a well-designed exhibit. Participant B shared a story he had collected in an interview with an emeritus professor about the moments that inspired the professor's journey in the field of paleontology. According to Participant's recollection, the professor had grown up in the Fort Worth area and would visit the Carnegie Library where a large mammoth skull was on display. According to the professor, the skull intrigued him deeply. He looked for books on fossils at the library but there were none. The librarian, seeing the young man's interest and energy, called around the community and found a book at a local bookstore and shared it with the young man. Participant B described it this way:

> In the very best case, we spark a lifelong journey. The engagement in front of that skull sparked him, and *it's a real thing, it's authentic, it has a story* (emphasis added). [The mammoth skull] was found there in that local area. It sparked his imagination and he took it to the next level with a book that he got from the librarian and yeah, 70 years later, here he is. Standing in front of exhibit 1, this large mammoth skull. He is Warren Langston, the father of Texas paleontology. It's incredible. (B.76)

Although Warren Langston's story began in the 1930's, his experience with this authentic mammoth skull, and the path that initial experience set him on, is not limited to a specific era. Participant C was right, there is a power of the object that is not fully understood but it is valuable to an individual and their experience with science.

Environmental authenticity. Not only can the content, presentation, and artifacts be authentically representative of the field, the environment itself can be described as more or less authentic based on its level of immersion. The level of immersion of an exhibit's environment is shaped by: (a) the level of a visitor's interaction, (b) the scale of the environment, and (c) the use of embedded artifacts to support an immersive experience. These three factors are represented in Figure 3.8.

Level of interaction. "So we created a physical path where the visitors could walk through and engage" (B.12). More participants noted the visitor's level of interaction as a dominant feature of shaping an immersive experience than any other design decision. Descriptions of the level of interaction ranged from the visitor being a passive observer to being an active participant, even if only mentally or emotionally.

Participant B shared an example of how an exhibit's environment can set up an authentic immersive experience. The description emphasized the role of the environment on creating and supporting a role-playing scenario for the visitor.

> This particular exhibit was on forensic science and so they navigate through the exhibit as a crime scene and they became the investigators and then they stepped out into a crime lab. At that point it really was all about them going to the station that they thought could help them solve this crime (B.13).

In this example, the visitor adopted the role of a detective and the environment was set up with spaces for the detective visitor to work through a crime scene and analyze their data in the crime lab.

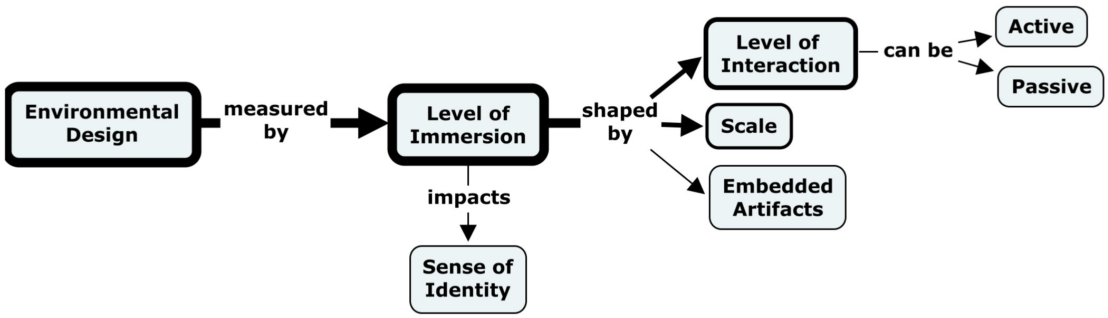

Figure 3.8. Annotated Environmental Authenticity Sub-Diagram. This figure represents the ways authenticity is interpreted as part of the environment of an exhibit. The strength of each line and border reflect the frequency of the concepts across all six interviews.

Scale. Scale had a moderating effect on visitor's experience of an authentic immersive experience. Participant B provided one description that emphasize the effect scaling up a familiar experience can have on creating an immersive experience.

> Digging in the dirt. Every kid knows what that is like. But we had this exhibit where there were like 6 or 8 thousand square feet outdoor exhibit and put a stream running through it with fossils and we buried dinosaur bones throughout it (B.59).

In this example, not only are the visitors adopting the role of a paleontologist but they are stepping into a familiar experience but set in a scale that they would not be able to experience in a classroom or their backyard. Whereas the excavation site described a true scale experience, Participant B described another exhibit that incorporated scale but through visitor perception.

> Again, using the risk exhibit, you entered through kind of a catwalk and the next thing you know your walking over a beam and you look down and your looking down over 80 stories and we did it through photographs and mirrors and stuff like that but it was enough that it jarred you a little. When you look down, it was enough to make your stomach kinda go, the effect was there. You literally were only 2 feet off the ground but because of the way we set it up, you feel like you are way up there. So again,

> taking this simple thing and twisting in a way that you (1) experience risk and (2) you're doing it in a way that you never thought you would (B.58).

Both examples illustrate the effect of scale on shaping an immersive experience and how Participant B interpreted their value based on his experiences with visitors in these exhibitions.

Embedded artifacts. Another way the participants described an immersive environment was through the use of embedded artifacts to recreate an authentic environment Participant B described setting up a crime scene with a dead body in an alley behind a diner.

> It was powerful in that we used a lot of different resources to create the context. When you walked into this crimes scene, it was done at a high level. You know it wasn't just a picture of a body in an alley. You walked into an alley and there was a body there. They alley was behind the diner and there was a robbery in the diner. They were not related but you didn't know that at the time. Though, creating that context was important. (B.39)

Authentic to scientific practices. A final theme that emerged from this study was the role of authenticity as it connected to authentic scientific practices. Participant C reflected on his story with science beginning early with learning by doing.

> I was out in the field playing in the stream and playing in the forest all the time. *And learning a whole lot by building little dams and making things float and just really kind of experiencing the physical world* (emphasis added). To me, that mindset of being a kid and that inspiration to kind of learn about why these things are happening, that there are points in the museum where we have those touch points where those things just happen. Whether it is the earthquake or it is run or where you get that spark—why is that happening? Why did it do that? Why did my building fall over? Why did it stand up the whole time? If we are successful it's just getting them to go deeper than even what we might have here. (C.12)

Participant C's story was a critical reflection on the limited authentic experiences children are having in the physical world around them. Many of the experiences that each participant would go on to describe are consistent with established scientific practices. Three scientific practices emerged as priorities in integrating authenticity into an exhibit's design: (a) making sensory observations, (b) systematic investigation, and (c) collaborating with others. Figure 3.9 illustrates how these three practices are organized under this characterization of authenticity.

Making observations through sensory experiences. "I think people come to a museum for an authentic experience" (F.6) and "We're known for these real experiences" (A.22) were consistent sentiments expressed by participants throughout the series of interviews. "Real to whom?" and "Authentic in what way?" were my typical requests for clarification. Participants' responses to these clarifying questions elucidated the features they believed characterized these real experiences. Engaging a visitor's senses in to explore and observe was one of the scientific practices participants described as a priority in designing a new exhibit. Participant A described a chick hatchery where visitors used their eyes and ears to observe and notice things about the baby chicks as they developed and hatched. "Nobody is touching the chickens, you don't touch any buttons. You don't do any little things but you gather around and you notice, you observe and you talk to each other" (A.17).

Also, as an extension of the role-playing and scale experience of the excavation site exhibit, Participant B highlighted the role scientific practices played to continue the role-playing experience.

> Again, you walked in, you observed, you took measurements, you made sketches and field notes that we gave you. It was just a little sheet with cues for what you could do. From there, you went into a little lab area to analyze what you found in the quarry (B.41).

The examples participants shared illustrated the value of providing opportunities for visitors to make sensory observations and that it can be done in a number of ways.

Conducting systematic investigations. Making sensory observations is only one of three scientific practices that emerged from this series of interviews with exhibit designers. Participant F described conducting open-ended investigations as a natural progression from making sensory observations. She had already shared about the opportunity for visitors to choose how they wanted to push the familiar experience of soap bubbles in new ways. As Participant B generalized out her perspective from soap bubbles to overall design principles, she shared:

> [Great exhibits] have to be hands on, tactile. It engages your senses. Multiple senses. It conveying content in a way that is playful, tactile, and leaves you, not maybe necessarily knowing all the answers of why *but it spurs you to ask questions or urges you to delve further (*emphasis added) (F.1).

Participant F described their priority or including scientific practices, "The idea was we focused on exhibits that were really great for observing, experimenting, or constructing. And we found that having multi-outcome exhibits were key to these experiences" (F.15) .As varied as their examples were, their perspectives were very similar. The second scientific practice that emerged from the interviews came with some different perspectives. Some participants described the second scientific practice, conducting open-ended investigations as a complex challenge.

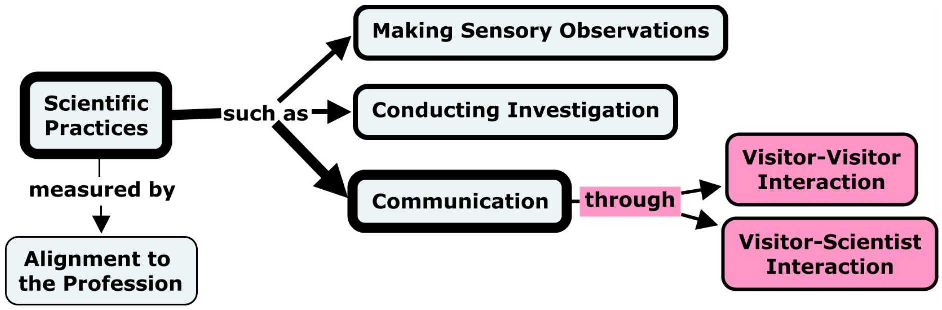

Figure 3.9. Annotated Authenticity of Science Practices Sub-Diagram. This figure represents the way authenticity is interpreted through scientific practices as part of the larger theme of authentic to science. The diagram has been color coded to reflect initial contributions by participants. The strength of each line and border reflect the frequency of the concepts across all six interviews.

Participant C described of the diverse ways visitors can engage the exhibits in his center:

> I think we have every type of modality from full-body interactive to touch screen kinds of things. But I think as much as possible we've tried to individualize the experience for each exhibit. Three of our staff can interact with an exhibit and we may three very different ways of interacting with it and therefore three very different takeaways from the same experience (C.3).

Participant C continued to describe the challenges of individualizing these designed experiences. One of his points was that this level of complexity and almost ambiguity makes measuring explicit learning outcomes challenging for an exhibit designer but according to the participants in this study, it is still a worthwhile goal. In both perspectives, pushing an observation further into an investigation was authentic to the scientific enterprise and of value in creating experiences in their respective centers. Examples of scientific practices specifically related to systematic investigations included references to recording and analyzing data as well as using evidence to making discoveries.

Communicating with others. Visitors' opportunities to share observations and findings from investigations are also critical to an experience with authentic scientific practices. Participants in this study highlighted communication and social interaction around science as a design priority for them and for their institutions. Each participant contributed different perspectives on how they supported this social engagement around science. Participants described three ways they facilitated communication as part of visitor's experience with their exhibits designing opportunities for different kinds of conversations.

The participants in this study shared three different types of conversations that they try to support through an exhibit's design: (a) response to a shared experience, (b) cooperative interactions, and (c) discussion-centered exhibits.

The first type of conversation was an organic response to a shared experience. An example of the type of experiences that fit into this is the hatchery at Participant A's site. There are no buttons and the eggs and chicks are behind a glass. Participant A described the types of observation-based conversations she noticed about visitor's interactions with the hatchery and each other. Supports for this type of response to a share experience included having a changing or detail oriented exhibit or including prompts or questions through labels or docents.

Cooperative interactions. The second type of conversations revolved around cooperative exhibits where visitors share an experience by working together. Participant F's site had an entire exhibition dedicated to this type of cooperative interaction. The exhibit ranged from working in partners to make shapes out of rope, to trust exercises with adjacent center-facing water fountains whose trigger was controlled by a partner. Participant A described an exhibit at her site that shared similar design features.

> We also design two-person interactives where you have to work together in order to make something to happen. For example, in our energy exhibit, we designed it very much so that this is going to be cooperative team play and so that can range from accommodating social learning and recognizing that it is important and sort of letting that happen sort of organically to intentionally design it that way, so it is to say this group is going to interact with it this way so that the only way they can actually accomplish the goal of this experience is to work together (A.25).

Participant A's description mirrors some of Participant C's sentiment about engaging groups regardless of pre-existing relations.

Discussion-centered exhibits. Participant A described a third, more structured experience that focused on conversation as the content of the visitor's experience. She described one of these discussion-centered experiences.

> We have another type of social experience which is a little more precise, which we call future forum, where people are in a group presented with a controversial topic and they are allowed to, the underlying premise behind it is to get people to recognize how they make decisions, so they get to listen to … they get to choose from a panel of experts who they want to listen to and then they get to respond to different questions and all those responses are tallied and displayed for everybody (A.27).

In each of the three scenarios, Participant A described the purposeful approach she chose to provide visitors the opportunity to share their observations, perspectives, and arguments with others.

Summary and Discussion

The purpose of this study was to investigate the role authenticity played in the exhibit design process. I investigated this role by mining descriptions of exhibits and the exhibit design process for evidence of the role authenticity played in designing visitors' experiences. This analytic strategy produced a list of examples of how, where, and to what extent authenticity played a role in the exhibit design process. Authenticity shaped three aspects of an exhibit's design: (a) how elements of an exhibit authentically reflected the priorities of their institution, (b) how elements of an exhibit authentically reflected the visitor as a learner, and (c) how elements of an exhibit authentically reflected science as a field.

Authentic to the Institution

The findings of this study indicated that a museum or science center's guiding documents, policies and culture provide a standard by which the authenticity of exhibits' designs can be measured. The evidence of science exhibits' level of institutional authenticity could be seen in the alignment and style of the exhibits as established during the pre-development or strategic planning phase. Institution set different priorities such as narrative storytelling or the incorporation of larger than life experiences. Exhibits with institutional authenticity mirrored those priorities from pre-development through the installation and maintenance phase. High levels of institutional authenticity supported institutions' capacity to respond to the needs of its local community and remain faithful to the mission and vision of its institution and stakeholders. These findings mirror the discipline-centered layer of authenticity in the educational research literature. Both institutional authenticity and the discipline-centered layer of authenticity are embedded layers of authenticity that hinged on the authority of a set of individuals.. These findings extend the discipline-centered layer of authenticity by highlighting a unique layer to the context of ISE institutions—namely shaping a new layer of institutional authenticity. This new layer plays a similar and yet under-investigated role of the school or school district's priorities and guiding policies in shaping learning experiences that are authentic to their institution.

Both institutional authenticity and the discipline-centered layer of authenticity are measured by an agreed upon authoritative entity. In the scientific discipline, scientists and researchers construct agreed upon authoritative understandings of the field. In the ISE institution, an ad-hoc team of experts from the different departments and community partners assume the authoritative role of making the broad decisions that shape an institution's mission, vision, and culture. Evidence of the strategic planning associated with institutional authenticity and the influence of established conceptual understandings in the discipline-centered layer of authenticity are rarely prominent or explicit features of a visitor's experience. Rather, as embedded processes, the impacts of both discipline-centered authenticity and institutional authenticity are entrenched in the vetting processes and decisions typically unseen by the visitor as they interact with the final product. Subsequently, the diverse and varying composition of the exhibit design teams and the dynamic nature of the institution's guiding policies and culture create a unique interpretation of the role of authenticity in educational research. As such, a case can be made to extend the current layers of embedded authenticity to include a new layer for institutional authenticity.

Authentic to the Visitor as a Learner

Buendgens-Kosten (2014) posited that any measure of authenticity had to be expressed as a socially negotiated process among the learner, the teacher, and the object. Rudolph et al. (2007) and Sutherland and Markauskaite (2012) both made cases for the significance of learners' perspectives of authenticity—describing learner's perceptions of authenticity as even more important than teachers' intentions and as the ultimate measure of authenticity, respectively. As such, the findings from this study affirmed the importance of visitors' perspectives as a primary consideration in the exhibit design process. While no participant explicitly described surveying visitors based on the visitors' perceptions of authenticity, relevant aspects of visitors' background knowledge, experience, interest, and values were collected and used to shape what level of authenticity visitors prefer for a given experience.

Of the three design considerations that emerged from the findings of this study, level of autonomy and level of interactivity mirror findings in educational research regarding the learner-centered layer of authenticity. Autonomy in the selection and level of participation and control mirror Bevins and Price's (2012) interpretation of learners' opportunities to initiate and regulate their experiences as an indicator of authenticity. The findings from this study provide additional examples of the layered effect of role-play and scientific practices in immersive environments on the quality of visitors' experiences.

The level of interaction, specifically the mental and emotional interactions that Participants A, B and D described, were consistent with Reeves et al.'s (2002) position that for an experience to be authentic to the learner there needs to be opportunities for meaningful reflection. Whether it was at Participant A's embryo specimen exhibit or chick hatchery exhibit or at Participant D's earthquake platform or run exhibit, the need to create opportunities for visitors to be mentally and emotionally engaged in an exhibit was a priority for all six participants' respective institutions. The social interaction cues compiled in this study as well as the scientific practice of communicating and collaborating shared connections to the community-centered layer of authenticity.

The third design consideration, level of scaffolding, shared similarities with the pedagogical layer of authenticity—particularly in Jonassen's (1999) use of layers of knowledge construction as an educational tool for engaging learners at different points in their understanding on a given topic. The use of labels and docents were examples of what Newmann and Wehlage (1993) described as the need for a learning experience to provide support for taking risks, or trying something new. Participant A and C both described the impact of using visitor-contributed data as a leveraging point for engaging visitors in taking chances or trying something novel with an exhibit and its elements.

Authentic to the Field of Science

This study highlighted five considerations of how authenticity might have been reflected in the design decisions that shape the message, choices, and physical features on an exhibit. Each of these five bear resemblance to specific layers of authenticity found in educational research.

The exhibit content development process and selection of how to present the scientific phenomena mirrored features of discipline-centered authenticity. The level of resemblance of an exhibit's content to the accepted understandings of the field played a considerable role in determining the scope and structure of the educational messaging behind exhibits as well as the selection and incorporation of select artifacts into a visitor's experience. Participant B's emphasized priority on bringing in a diverse group of experts and making the message of an exhibit reflect multiple perspectives on a phenomenon mirrored Reeves et al.'s (2002) position on the importance of multidisciplinarity and multiple perspectives on recreating experiences that are authentic with regards to the complexity of a profession.

The artifact selection process closely mirrors the emphasis on the power of the object and function of artifact use in educational research. Jonassen (1999) described the mediating role of artifacts and technology on authentic experiences at length. This mirrored the language participants used to describe their experiences with the power of the object. Jonassen (1999) was also reflected in participants' justification for choosing different artifacts into exhibits for different purposes. Participant B's description of the use of casts, or high quality replicas, of genuine fossils uncovered in their local region mirrored the same perspective Maran and Glavin (2003) shared about the merit of using real materials and equipment on visitor functional competence development. Participant A shared a counter argument with Baloian et al. (2011) towards the insufficiency of real tools and data on learning—that these artifacts alone "were not enough to guarantee a successful learning experience" (p.300).

The findings of this study also mirrored principles that shape the role of the situated environmental layer of authenticity. Participant B's crime scene is an example of using both a crime scene and a crime lab as a paired set of environments designed to resemble the environments detectives would use to collect evidence and solve crimes. Having multiple, seemingly connected crimes happening simultaneously also mirrored the connectedness to the real world and the complex view of the world that Newmann and Wehlage (1993) and Jonassen (1999) respectively prescribe for creating authentic contexts for learning. Where this study expands the research community's understandings of situated learning environments as a layer of authenticity is in their unique ability to use scale to shape an environment in a meaningful way. Not many educational contexts are able to design experiences that mirror the scale of a 2000 square foot excavation site or an experience walking across a rafter that appears to be 30 or mores stories above ground to illustrate the internal processes related to experiencing risk. These experiences of scale bring the level of immersion of an environment higher than traditional settings and are a worthwhile avenue to explore further.

Finally, scientific practices described as part of an authentic experience mirror the expressions and characterizations of task authenticity and community-centered layers of authenticity in educational research. Participant B's visitors were able to not only enter the crime scene and crime labs, but they were also able to actively participant in the practices of making sensory observations about clues. The visitors could take notes about their thoughts and analyses of the evidence, and then share their notes with a recognizable CSI agent through a computer interface. The CSI agent would provide feedback to the visitor on their case. This single example illustrates Bevins and Price's (2016) descriptions of mechanical skills (observing and measuring) and enabling skills (organizing and communicating). The fact that the crimes appear at first glance to be connected, but in fact were not, reflected the complex nature of the profession that Cronin (1993) described as a priority for authentic tasks.

The crime scene experience was not an isolated scenario. It was consistent with descriptions from Participant A's U-505 submarine shipyard and Participant F's science of sharing exhibit where participants got to model social scientists as they explore issues of trust, reciprocity, and deception in the midst of common experiences. Experiences such as the smoke cannon and the pendulum machine at Participant F's institution prioritized Bevins and Price's (2012) description of inquiry skills—specifically, the purposeful and reliable manipulation of variables in order to understand a phenomenon through investigation. They also reflect the processes of gathering data, testing ideas, and making predictions consistent with Milner-Bolotin's (2012) interpretation of authentic practices.

Limitations

I anticipated artifacts and scientific practices to be common references, but I did not expect the consistent emphasis on the role authenticity played before the first schematics are ever drawn for an exhibit. My original perspective was limited to authenticity as directly experienced by the visitor. As such, I was surprised by the comments of content experts and professional science educators referring to the indirect effect of authenticity on creating the messaging that would authentically represent the field and its priorities.

By analyzing the perspectives of a sample of experienced practitioners, the generalizability of the findings is limited to a reflection on the emergent framework and the perspective of exhibit designers (Miles & Huberman, 1994). As learners have diverse interests, agendas, and motivations, there might have been a gap between the exhibit designer's perspective of what is a meaningful, authentic experience and what a given visitor might have internalized in their experience as meaningful or not. This study did not highlight the distinction between what is authentic to one specific set of visitors over another.

As practitioners involved in the design of exhibits, each person described the importance of bringing in a variety of visitors at different stages of an exhibit's development to see how visitors would connect with elements of the exhibit. To a certain degree, the definition of authenticity was stretched to incorporate what was perceived by the participants as authentic to the visitors—particularly what is meaningful and considerate and relevant to unique sets of visitors at an institution. However, as this was outside the boundary of the purpose of this study, I made the choice not to include their perspectives on this strand of conversation.

Implications for Practice

My analysis of participants' descriptions of the role of authenticity on effective exhibit design paired with their application in examples of real exhibits can be a powerful resources for a number of practitioners. Exhibit designers at any institution can use this framework of how an institution's priorities, and understanding of visitor and access to quality information about a discipline come together to shape their own layers of authenticity in an exhibit. Grant writers can use the layered model described in this study to shape proposals that highlight the broader impacts individual decisions can have on visitor outcomes. Museum professionals can use the framework to shape the conversations they have with external exhibit designers or consultants to make sure that the exhibition they produce reflects a level of authenticity that mirrors their institution's priorities as well as the profession and visitor evaluation data. This reflective and forward thinking process may prevent a smaller institution administrator from experiencing the disappointment common at the conclusion of the exhibit design process.

Implications for Future Research

As this study was designed around collecting and understanding the role of authenticity from the perspective of persons with intimate knowledge of exhibit design processes, the findings of this study would benefit from being further investigated from the perspective of other stakeholders in the enterprise of learning science. These stakeholders include, but are not limited to, exhibit evaluators, floor staff and docents, visitors, and policymakers. Additionally, the perspectives shared came from predominantly high volume institutions, which might not reflect the same experiences of exhibit designers that support smaller or rural institutions.

Additionally the findings of this study were based on past experiences with designing exhibits and did not emerge from a concurrent active development of a new exhibit. As rich as the participants' descriptions were, the level of depth of understanding from collecting data as an observer or participant-observer throughout the exhibit design process may highlight additional implications or roles that authenticity plays in the exhibit design process.

Finally, in order to better support future policy decisions and investment, more research should be done to measure the educational and financial value of each application of authenticity on the visitor learning experience. Examples of how this may be reflected in policy include the considering the financial burden of bringing in content experts have on institutions—particularly in light of the lack of experimental evidence of a positive effect of authenticity on visitor experience and participation. Likewise, the benefits of investing in an authentic fossil or in docent training to support authentic scientific practices and active participation of a visitor need to be validated with new data and analyses.

CHAPTER IV

AUTHENTICITY IN EVALUATORS' DESCRIPTIONS OF SCIENCE EXHIBITS

The search for authentic science experiences draws people out of classrooms and cubicles and into different experiences in their community. Some experiences are found in interactive science centers—one part of a broad and growing network of Informal Science Education (ISE) institutions. When the science center doors open, so do opportunities to blow bubbles large enough to step in or discover fossils waiting to be uncovered in a dig site the size of a football field. Are those experiences authentic though?

Authenticity in Learning Environments

What makes any learning experience more or less authentic can and has been argued from a number of different perspectives. Baloian, Pino, and Hardings (2011) described these varying and conflicting perspectives of authenticity becoming "a blurry demand, rather than a well-defined concept" (p.285) in the context of e-learning research. Buendgens-Kosten (2014) conducted a literature review on Computer-Assisted Language Learning (CALL) and reported that the term authentic or authenticity was found in over half (52%) of the CALL articles published in 2010 across three educational technology journals. Authenticity is undisputedly an important topic; however, as Buendgens-Kosten investigated further, a majority of the references in the manuscripts were a passing comment on the lack of authenticity (p.273). The depth of the argument on authenticity is still lacking.

Authentic to the Profession

Education researchers highlight a number of ways to describe their perspective of authenticity. Many researchers have described authenticity in terms of the activities the learning participates in or the tasks she completes (Anderson, 1998; Barab, Squire, & Duebar, 2000; Bellamy, 1996; Bevins & Price, 2016; Buendsgen-Kosten, 2012; Edelson, 1998; Fredricks, Blumenfeld, & Paris, 2004; Sutherland & Markauskaite, 2012). Authors have often used the resemblance of a learner's practice to the practices of the profession as a measure of a task's authenticity. This method of pairing description and measure extends to other interpretations of authenticity as well. Among the examples of this paired interpretation of authenticity are (a) situated environmental authenticity and the level of resemblance to features of a professional setting (Barab et al., 2000; Buendgens-Kosten, 2014; Khaled, Gulikers, Bieman, & Mulder, 2015; Renzulli, Gentry, & Reis, 2004), (b) discipline-centered authenticity and the level of alignment to the content and structure of professionally accepted understandings (DeBruijn & Leeman, 2011); and (c) impact authenticity and the level of comparability between the products and impacts of a learner's experience with the professional community (Barab et al., 2000; Bellamy, 1996; Newmann, 1996).

Authentic to the Learner

Not all interpretations of authenticity in educational research have been hinged solely on the practices, environment, and products of the profession, however. A number of interpretations of authenticity have been reflective of the learner and measure authenticity by the level the learner's strengths, values, and needs were used to shape the experience. Examples include (a) learner-centered authenticity, (b) community-centered authenticity, and (c) pedagogical authenticity. Each of these interpretations emphasizes the role of authenticity as experienced by the learner internally.

Learner-centered authenticity considers perceived autonomy, opportunities to reflect, and perceived power as valuable measures or expressions of authenticity (Bevins & Price, 2016; Gulikers, Bastiaens, Kirschner, & Kester, 2006; Khaled et al., 2015; Knowles, Holton, & Swanson, 1998, Petraglia, 1998). Community-centered authenticity reflects on principles related to authentic conversations and authentic collaboration among others. Within these interactions, the focus is on the value and use of individual contribution, the level of transparency between interpreted and expressed ideas, and the level of trust among participants as valued measures of authenticity (Brown, Collins, & Duguid, 1989, Buendgens-Kosten, 2014; Humberstone & Stan, 2012; McDougall, 2015; Newman, 1996; Renzulli et al., 2004; Rystedt & Sjoblom, 2012). Finally, pedagogical authenticity considers the learner from the perspective of how closely a series of designed educational experiences are to the practices and processes of the field of education (Marks, 2000; McDougall, 2015; Newmann & Wehlage, 1993). For instance, a measure of pedagogical authenticity may address the question, 'How effectively were a learner's background knowledge, skills, and attitudes used to shape the experiences to move the learner along the continuum from novice to expert?'

Layered Interpretations of Authenticity

Many educational researchers consider multiple interpretations of authenticity as having a layered effect on the overall level of authenticity of an experience. Kohnen (2013) subordinated several interpretations under latent authenticity and functional authenticity. Anderson (1998) organized a learner's experience into sets of authentic processes and authentic products. Barab et al. (2000) expressed their perspective through layers of task authenticity, context authenticity, and impact authenticity. For the purposes of this study, I aligned my own interpretation of authenticity with a variation of Manninen, Henricksson, Scheja, and Silen's (2012) organization of the layers of authenticity.

External layers of authenticity. Manninen et al. (2012) proposed a model that interprets authenticity through two lenses: (a) external interactive expressions of authenticity and (b) internal relational expressions of authenticity. They grouped context, task, and environment under the heading of external authenticity. They subordinated relationships and interactions between teachers, learners, and audiences under the heading of internal authenticity. In this study, I reviewed exhibit descriptions for evidence of the role authenticity played in the design of interactive science experiences. My focus on the exhibit as a learning environment predicated the need to focus on how authenticity was expressed in the exhibit descriptions. My examination of expressed authenticity best aligned with Manninen et al (2012).

Evaluations in Informal Science Education

The Center for the Advancement of Informal Science Education (CAISE) is a valuable resource that serves the ISE community in several key ways. One of these ways is through the development and maintenance of an online portal and data repository for CAISE community partners to share (CAISE, 2013). This repository includes descriptions of exemplary exhibit designs, relevant research publications, and a myriad of formative and summative evaluations.

Fu, Kannan, Shavelson, Peterson, and Kurpius (2016) proposed that high quality evaluations can be used to “inform practice and build theory in ISE and ISE evaluation” (p.13). Fu et al. (2016) described high quality evaluations as those that met or exceeded standards, such as those published by the American Evaluation Association (AEA, 2004) and Visitor Studies Association (VSA, 2008). Additionally, Webb, Campbell, Schwartz, and Sechrest (2000) highlighted the role of triangulation in data collection and analysis to improve the quality of the evaluations.

Building Informal Science Education Network (BISEnet) Database

At the time this study was conducted, the CAISE website (http://informalscience.org) had a sizeable repository of evaluations contributed from projects from partners across the ISE landscape. As an extension of the National Science Foundation (NSF)-funded Advancing Informal STEM Learning (AISL) initiative, many NSF- and Institute for Museum and Library Services (IMLS)-funded projects have been required to publish their evaluations through the CAISE portal (NSF, 2014). A long-term goal for the funding institutions has been to launch future projects. One of these projects was the NSF-funded *Building Informal Science Education Network* (BISEnet) database.

The BISEnet database included 521 formal evaluation reports on exhibitions, programs, and institutions across the ISE landscape (https://visa.memberclicks.net/bise) at the time this study was conducted. The BISEnet research team had extracted metadata from each evaluation report and categorized as searchable elements or variables for further analysis. The metadata included evaluation-specific data such as evaluators, data collection methods, and data analyses. These metadata also included sample-specific data such as sample size, recruitment, participation, and demographics. Few data sets of this scale available to ISE researchers. Publications that used the BISEnet data were limited to research questions that compared quality standards associated with the evaluation process. No report was published utilizing the content of the evaluation for systematic research comparing multiple exhibitions or their associated outcome data at the time this study was conducted.

Purpose of the Study

A need exists to systematically investigate exhibit design elements and their effect on visitor learning behaviors in ISE institutions. Authenticity is one of the elements found to have a moderating effect on visitor's learning behaviors (see Exhibit Element Framework in Fleming, 2017). McDougall (2015) described authenticity as a "seductive" (p.96) concept—one that makes grandiose promises that are challenging to cash in in the field of education. As such, a need also exists to investigate the role authenticity plays in educational research (Baloian et al., 2011; Splitter, 2009). My purpose in this investigation was to use evidence from a selected set of exhibit evaluations to develop a deeper, richer understanding of the complex layers of authenticity as expressed in features of science exhibit descriptions.

Research Questions

I developed two research questions to guide the investigation of this study. I focused my first research question on the extent *authenticity* was discernable or evident within the descriptions of individual exhibits in the sample. I used the second question to guide my interpretation of the data in terms of its value to educators working in the field of ISE.

(1) To what extent did the evaluators use *authenticity* to characterize the descriptions of science exhibits included in the BISEnet evaluation data?

(2) In what ways does the findings analysis extend current understandings of *authenticity* in the field of educational research?

Limitations

Research using secondary data shares several limitations. Working with the BISEnet data was no exception. Each evaluation in the BISEnet data differed. I selectively chose the set of evaluations for this study on the basis of selection criteria to assure some uniformity across the individual evaluations within the data set. This process might have eliminated some studies with additional information that might have been helpful in the analysis. Any set chose for study, however, would have represented the work of professionals possessing a variety of experiences and objectives. Furthermore, these professionals did not complete their evaluations to be sources for large-scale analysis. I attempted to address this limitation by requiring clear selection criteria for inclusion in this study.

Methods

In this study, I performed a content analysis on 106 exhibit descriptions and documented the extent to which authenticity was evident in the evaluators' description (Neuendorf, 2002; Patton, 2002). As an attempt to clarify authenticity as an element of science exhibits, I chose to base the deductive content analysis on a set of pre-determined categories (Gilgun, 2014; Hseih & Shannon, 2005). My initial analyses of exhibit descriptions across three evaluations reveal four exhibit features that have been linked to authenticity: (a) artifacts, (b) sensory experience, (c) phenomenon presentation, and (d) environment. I organized these four exhibit features into a working coding guide for the deductive content analysis. I used a set of inclusion criteria to select a sample of BISEnet summative evaluations suitable for analysis. Next, I interpreted the results of the analysis by discussing how the findings within each sub-element contributed to our understanding of the larger construct of *authenticity* in regard to science exhibitions. I closed the discussion with recommendations for practice and future research.

Selection of Cases Within the BISEnet Data Set

Fu et al. (2014) extensively described the variations in quality of evaluations included in the CAISE website. Many of these variations can be linked back to each evaluator's choice of data collection methods. In order to limit the effect of these variations, I purposively selected evaluations comparable in structure, context, and quality.

The evaluations included in the BISEnet data set were publicly available and searchable through the CAISE website (http://informalscience.org, 2016) at the time this study was conducted. An SPSS-ready excel spreadsheet was also publicly available on the BISE website (https://visa.memberclicks.net/bise). This spreadsheet contained metadata extracted from each evaluation in the BISEnet data repository. I used these metadata as filters for selecting evaluations by evaluation type (summative), location (science centers), and focus (exhibition).

Selecting "best" summative evaluations. I chose purposive sampling to accommodate the variability in the quality of evaluations included in the BISEnet data set (Creswell, 2013). Within the BISE metadata, seventeen categories existed for reported measures of visitor learning behaviors. I condensed these categories into three data collection strategies: *explicit recall*, *timing and tracking,* and *observable behaviors*.

Each of the three types of visitor learning behaviors had characteristic attributes. *Explicit recall* was a form of active data collection (e.g., pre-tests, post-tests, interviews, surveys, etc.) that occurred outside the visitor's immediate interaction with an exhibit. *Timing and tracking* was a standard form of passive data collection that involved measuring a visitor's path and stops using a structured protocol for measuring time and attendance to an exhibit. Similar to *timing and tracking*, *observable behaviors* included passive data collected at the moment of the visitor's interaction with an exhibit. These data might have included both the visitor's physical interactivity with an exhibit and conversation with other visitors. Based on the subordination in Figure 4.1, I selected summative evaluations that included all three visitor learning behaviors for the final sample exhibition evaluations.

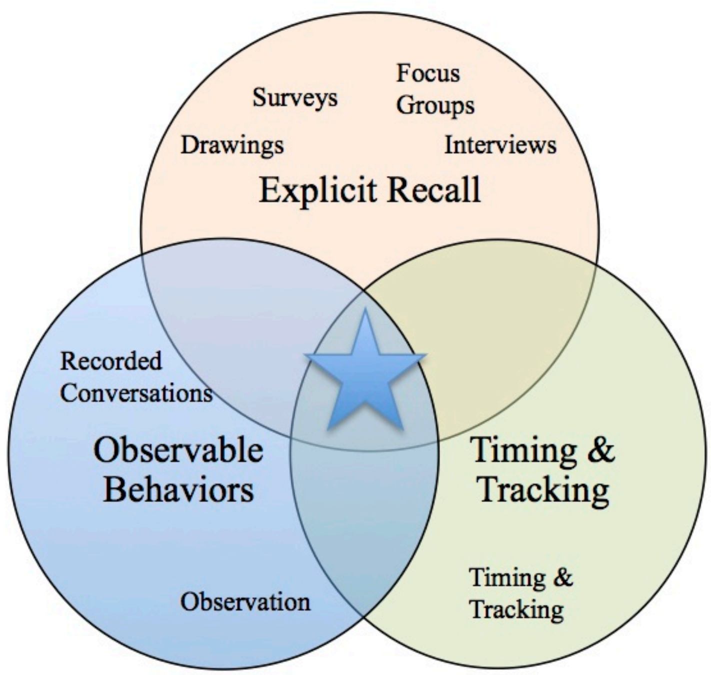

Figure 4.1. Distribution and Overlap of Sample Data Collection Categories*:* This figure illustrates how I subordinated the seventeen original data collection codes under the three types of visitor learning behaviors.

Selecting individual exhibits from best summative evaluations. An exhibition is a group of exhibits sharing a common theme and learning objectives. Each exhibition in the BISEnet data set varied in the number of exhibits. Evaluator's reports also varied in the number of exhibits described. As such, I read each summative evaluation and refined a list of individual exhibits that had sufficient descriptive data for analysis.

Table 4.1

Measures of Authenticity and Inter-Coder Reliability within Exhibit Descriptions

Category	Measure for Authenticity	Inter-Coder Reliability
Artifacts	0 – none 1 – loose/stylized reproduction 2 – high quality reproduction 3 – authentic artifact	Percent Agreement 94.3% Krippendorf Alpha 0.726 Fleiss' Kappa 0.718
Sensory experience	0 – none 1 – exploring with sight, focused observations 2 – exploring with touch, tactile-kinetic sense 3 – exploring with sound, auditory senses 4 – exploring with smell, olfactory senses	Percent Agreement 96.2% Krippendorf Alpha 0.463 Fleiss' Kappa 0.448
Phenomena	0 – none 1 – diagram 2 – modeled phenomena representation 3 – exemplar of phenomena	Percent Agreement 95.3% Krippendorf Alpha 0.733 Fleiss' Kappa 0.725
Environment	0 – no immersive elements 1 – partial immersion/diorama 2 – exhibit-specific immersion 3 – exhibition-wide immersion	Percent Agreement 100.0% Krippendorf Alpha 1.000 Fleiss' Kappa 1.000

Data Analysis

The unit of analysis in this study was the individual exhibit and its description. I reviewed the descriptions of each exhibit based on a set of four pre-determined codes. I used the text to rate the level of authenticity of the exhibit's *artifacts*, use of *sensory experience*, presentation of the *phenomena,* and *environment*. Each pre-determined category was divided into four characterizations based on how authenticity might have been expressed within the category. While the reported levels of 0, 1, 2, and 3 remained constant across the four categories, I characterized each of the levels within the sub-element by its own set of descriptive categories. For example, I characterized these levels in the sub-element *Artifacts* from 0 to 3 based on a loose progression from no artifact to an authentic artifact. I used the same reporting numbers (e.g., 0, 1, 2, and 3) for *Sensory experience* but characterized each categorically (i.e., 0 – none; 1 – exploring with sight, focused observations; 2 – exploring with touch-kinetic; 3 – exploring with sound, auditory senses). Table 4.1 reflects the final characterization of each of the four sub-elements of authenticity used in the analysis.

Inter-coder reliability. As coding text is a subjective process, I used inter-coder reliability to measure the quality of the content analyses in this study (e.g., see Krippendorf, 2013; Neuendorf, 2002). Estimating the inter-coder reliability of a coding scheme is a formal, iterative process that assures a high level of quality in the interpretation of qualitative data. The process engages a primary coder and a selected number of secondary coders who code the same sample data set and then compare codes to improve the level of agreement, and thus the reliability of the interpretation of data into codes, between coders (Saldana, 2015). Results of the inter-coder reliability test are reported by item in Table 4.1.

As the primary coder, I created a working coding guide based on 18% of the final sample (n=19). Two colleagues served as coder participants to assist in calculating inter-coder reliability. Each colleague used the working guide to code 23% of the final sample (n=34). Each colleague coded two full evaluations individually with three pairs of overlapping evaluations between pairs of coders. This resulted in a minimum of two coders for 50% of the final sample (n=53) and a minimum of three coders for 14% of the final sample (n=15). This overlap of coding responsibility for the inter-coder reliability is illustrated in Table 4.2.

Table 4.2

Participant Coder Sample Distribution and Overlap

Coder	Exhibit	Sample (n)
Primary Coder (author)	BJC Sportsworks	19
	Cyberchase	19
	Wild Minds	15
Participant Coder A	Wild Minds	15
	BJC Sportsworks	19
Participant Coder B	Wild Minds	15
	Cyberchase	19

I entered our individual codes into a web-based calculator to calculate Fleiss' kappa, Krippendorf's alpha, and percent agreement (http://dfreelon.org/utils/recalfront). The overall Fleiss' kappa was 0.799. The overall Krippendorf's alpha was 0.80. The overall percent agreement was 85.6%. These results were within a reasonable range for inter-coder reliability. I continued to code the remainder of the text in a manner consistent with the observations and discussions in this inter-coder reliability process. I made changes to the coding guide based on conversations and a recognized need for clarification. An example of these changes includes clarifying *sight* as a sensory experience. Taken loosely, any graphical representation or the presence of any features within an exhibit would result in a rating for *sight* as a sensory experience. We agreed to change the language from "sight" to "exploring with sight, focused observations."

Statistical analysis. Measures for design features include both nominal and ordinal scales, thus requiring separate calculations. I calculated descriptive statistics and frequency counts from the ordinal scales used for measuring the level of authenticity in the exhibit's *artifacts*, presentation of the *phenomena,* and *environment,* using the SPSS statistical software package. I calculated the range in levels of authenticity related to the use of *sensory experience* by comparing frequencies across all exhibits within the final sample. Finally, I described the emergent patterns among the ordinal or nominal data in the narrative of the results.

Results

I present the results of the content analysis results in three sections. The first section includes results of the sample reduction process. The second section includes results of the analysis of descriptive data on the prevalence of *authenticity* as an observed design feature of science exhibits. The third section presents correlational data on the prevalence of *authenticity* as an observed design feature of science exhibits.

Limiting the Sample

The first stage of the selection process was to limit the sample to summative evaluations of science exhibits set in science centers. I filtered the data to include only evaluations on exhibitions with science museum or science center as primary, secondary, or tertiary setting. This process reduced the full sample of 521 evaluations to 86 total evaluations for further analysis. Figure 4.2 illustrates the reduction process by inclusion criteria.

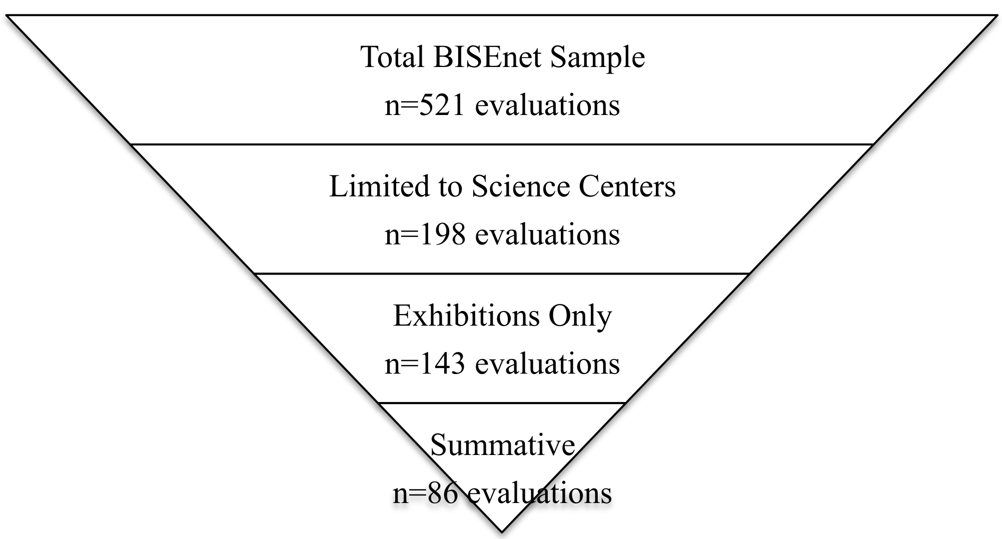

Figure 4.2. Selection Results by Limiting Factor. Schematic representing the selective process by which evaluations of exhibitions were chosen for analysis.

Categorization by data collection method. Then, the data were categorized by data collection methods. For this process to yield usable results, I reduced the original 17 data collection categories to three primary categories: *explicit recall, timing and tracking,* and *observable behaviors*. I did not include card sort, comment cards, concept maps, and interactive methods in any of the three primary visitor learning behaviors because there were no evaluations that used these methods in the reduced sample. I also did not include professional critique, web analytics, "other" and "did not describe" because they did not reasonably fit into one of the three primary categories. Table 4.3 describes how the original data collection categories were reorganized.

Table 4.3.
Data Collection Category Reduction

Visitor Learning Behavior Categories	Explicit Recall		Timing & Tracking		Observable Behaviors	
	Category	n	Category	n	Category	n
Original BISEnet Metadata Category	Drawings	2	Timing & tracking	38	Audio	3
	Focus groups	14			Observation	41
	Survey	44			Participation data	3
	Interview	76				
	Journals	3				
Total (n)		79		38		42

Table 4.4

Final Sample of Exhibitions and Their Exhibits for Data Analysis

Exhibition	Site	Footprint (sq. ft.)	Sample Exhibits		Valid Exhibits
			Potential Sample (n)	Viable for Analysis (n)	
Marvelous Molecules	NY Hall of Science	3500	8	8	*Build, Structures, Zoom, Smell, Odor, Medicines, DNA, Food*
Traits of Life	Exploratorium	2900	8	8	*Cell Explorer, Zoom in on Cells, Chick Embryo, Energy from Death, Glowing Worms, Jarred In, Energy from Wood, Trading Materials*
It's a Nano World	Sciencenter	3000	13	11	*Cell Sorter, Magnification Station, Scope on a Rope, How Many Nanometers?, Dusty Tippy Table, Germ Launcher, Scale Gallery, Look Closer, Giant Magnification Glass, Blood Drop, Pollen Pinball*
Wild Minds	Oregon Museum of Science and Industry, Portland Zoo	1800	15	12	*Remembering Numbers, Is it Thinking?, Wild Minds at the Zoo, Brain Comparison, What Animals Think, Get the Peanut Problem, Mimicking Sounds, Birds with Big Brains, Learning Colors, Shapes and Numbers, What Dogs Want, Is that Me I See?, Thinking Octopus*
Waters Journey through the Everglades	Museum of Discovery and Science, Ft. Lauderdale		9	9	*Core Sample, Tree Island, Human Encroachment, Hydrologic Cycle, Wet & Dry Seasons, Sheet Water Flow, Hurricane: Storm, Hurricane: House, Invasive Species*
BJC Sportsworks	St. Louis Science Center	12000	19	8	*Balance Timer, Baseball Pitch, Chair Race, Rockwall, G-Force, Balance Beam, Dance Revolution, Green Screen*

Table 4.4 continued

Exhibition	Site	Footprint (sq. ft.)	Sample Exhibits: Potential Sample (n)	Sample Exhibits: Viable for Analysis (n)	Valid Exhibits
Black Holes Experiment Gallery	Museum of Science, Boston; McAuliffe-Shepard Discovery Center, Concord; Springfield Science Museum	2500	17	14	*What's on the Horizon for Black Hole Research, What is a Black Hole?, Where are Black Holes? , Weigh a Black Hole, Take their Temperature, Explore a Feedback Black Hole, Do Black Holes Matter?, How Do We Find Black Holes?, Energy from Gravity, Got Gravity?, What's Inside a Black Hole?, Is It True What They Say About Black Holes?, Black Holes Inspire our Imagination, Black Hole Adventure*
Skyscraper!	Liberty Science Center	12800	18	10	*Excavating Tools, WTC Steel, Skyscraper Lineup, Wind Tunnel, Skyline of Greats, The Schedule, Foundation Testing, Shake Table, Top of the World, Crane Simulator, Walking the Steel*
Cyberchase	Children's Museum of Houston		19	11	*Restore the Power, Jimayan Mystery, Aim is the Game, Playing With Patterns, Magnetite Rocket, Bicycle, R-Fair City, Kahuna-huna Race-a-Runa, Hand Crank, Poddle Family Patterns, Rebuild Eureka*
Amazing Feats of Aging	Oregon Museum of Science and Industry	2500	18	14	*Free Radical Attack, Healthy Aging Brain, Older Males or Females, Age Machine (Monitor), Age Machine (Computer), What to Do About Aging, Older Younger, Sticky Situation, Longevity Parade, Amazing Lifelong Learning, Can Older Brains Learn New Tricks?, Longer and Longer Lives, You Are Many Ages, Aging Animals*
Total			167	106	

Finally, I filtered the sample to include only evaluations with all three major categories of data collection. I used this final round of data reduction to identify evaluations with more robust data collection. Table 4.3 illustrates the distribution and overlap of the data collection categories within the final sample. I identified fifteen evaluations that utilized all three data collection categories. After a review of the remaining summative evaluations, five were eliminated due to a lack of exhibit-specific information. Table 4.4 describes the final sample.

Among the remaining ten summative evaluations, I identified 167 potential exhibits, but only 106 exhibits had sufficient descriptive data to be used for analysis. The criteria for an exhibit to have sufficient descriptive data for analysis is the presence of text describing the exhibit and its features or an image of the exhibit and its features, or both. The mean number of exhibits with sufficient data per evaluation was 10.6 (SD=3). Of the included exhibits, 84.0% (n=89) had text descriptions of the exhibit and its features, 81.1% (n=86) had images of the exhibit and its features available, and 65.1% (n=69) had both descriptions and images available.

Descriptive Findings

I used SPSS statistical software to count and compare the presence of each characterization of the four pre-determined codes in this deductive content analysis: *artifacts, sensory experience, phenomena presentation* and *environments*. I provide a summary of the descriptive findings in Table 4.5.

Artifacts. A large majority of the science exhibits had either no artifact present (53.8%, n=57) or a loose interpretation or stylized artifact present (26.4%, n=28). Of the exhibits where no artifact were present, a majority were kiosks with graphics and text in the midst of a larger group of interactive exhibits or kiosks with an embedded monitor

Table 4.5

Comparative Presence of Measure of Authenticity by Design Feature

		Frequency	
Design Feature	Measure of Authenticity	n	Percent
Artifacts	0 – none	57	53.8
	1 – loose/stylized reproduction	28	26.4
	2 – high quality reproduction	7	6.6
	3 – authentic artifact	14	13.2
Sensory experience	0 – none	11	10.4
	1 – exploring with sight, focused observations	88	83.0
	2 – exploring with touch, tactile-kinetic sense	68	64.2
	3 – exploring with sound, auditory senses	4	3.8
	4 – exploring with smell, olfactory senses	2	1.9
Phenomena	0 – none	8	7.5
	1 – diagram	34	32.1
	2 – modeled phenomena representation	26	24.5
	3 – exemplar of phenomena	38	35.8
Environment	0 – no immersive elements	66	62.3
	1 – partial immersion/diorama	21	19.8
	2 – exhibit-specific immersion	16	15.1
	3 – exhibition-wide immersion	3	2.8

where visitors could watch a looped video presentation of scientists working with animals in different settings. Examples of loose or stylized artifacts include everything from a stuffed black bird on display in the *Wild Minds* exhibition to stylized “batteries” to complete an oversized circuit on the wall of a kiosk in *Cyberchase*. The oversized batteries were simply models that served as conductors; the power for the exhibit actually came from within the exhibit wall. There were twice as many exhibits with authentic artifacts (13.2%, n=14) as high quality reproductions (6.6%, n=7). An example of the type of artifacts identified as authentic included brain comparison where the exhibit designers plasticized animal brains and had them on display side by side underneath a glass case.

Sensory experience. A sizeable majority of the exhibits provided visitors an opportunity to either use their sense of sight to make careful observations (83.0%, n=88) or use their sense of touch to explore a learning experience (64.2%, n=68). More exhibits in this sample were designed with touch as a sensory experience in all five domains with the exception of an even split among the life science exhibits (Table 4.6). Very few exhibits in this sample were designed to provide visitors an opportunity to explore with their senses of smell (1.9%, n=2) or hearing (3.8%, n=4). None of the exhibits in this sample provided visitors an opportunity to explore with their sense of taste. Considering the fact that at any one exhibit a visitor can explore using multiple senses, I felt it was important to note how many exhibits provided opportunities to explore with a single sense, two senses or three or more senses. After identifying cases where multiple sensory experiences could be used to interact with the science exhibit, I found 28.3% (n=30) of the exhibits provided for a single sensory experience, 59.4% (n=63) of the exhibits provided visitors with two sensory experiences for exploration, and 1.9% (n=2) of the exhibits provided visitors with three or more sensory experiences for exploration.

Phenomena presentation. When a presentation of the scientific phenomenon was included, there was a reasonably even distribution of diagrams (32.1%, n=34), analogous models (24.5%, n=26), and exemplars (35.8%, n=38). I felt it was important to note that exemplars of phenomena included video recordings embedded in the exhibit that presented exemplars of the phenomenon. Only 7.5% (n=8) of the exhibits had no presentation of a scientific phenomenon.

Table 4.6

Sensory Experiences by Exhibition Domain

	Observe (n)		Touch (n)		Listen (n)		Smell (n)	
Exhibition Domain	With	Without	With	Without	With	Without	With	Without
Life Science	35	7	21	21	2	40	0	42
Earth Science	9	0	9	0	0	9	0	9
Physical Science	24	9	20	13	1	32	2	31
Engineering	10	1	7	4	0	11	0	11
Mathematics	10	1	11	0	1	10	0	11

Environment. A majority of the exhibits had no immersive elements (62.3%, n=66). Of the exhibits that had immersive elements, there were more exhibits with some immersive elements (19.8%, n=21) than immersive exhibits (15.1%, n=16). There were very few exhibits in this sample that were designed as part of an immersive exhibition or hall (2.8%, n=3).

Correlational Findings

Although the codes used for each sub-element of *authenticity* were not scale in regard to interval or based on a zero-value, they were ordinal numbers. As the code increased in each category, the level of perceived *authenticity* of the sub-element also increased. Therefore, I ran a correlation table to compare the patterns of frequency within each sub-element against the other sub-elements. The results of the correlation analysis are illustrated in Table 4.7.

Presentation of the phenomenon. The analysis yielded a positive, moderate correlation between the level of authenticity of the artifacts within exhibits (artifact) and the level of authenticity in the presentation of the phenomenon (phenomenon) within ($r = 0.317$; $p < 0.01$). This finding also makes reasonable sense considering the fact that an authentic artifact that is present (e.g., a human brain) would also be presenting the scientific phenomena related to the artifact. The analysis yielded a negative, low correlation between the level of authenticity in the presentation of scientific phenomenon (phenomenon) and the designed ability of a visitor to explore through touch (touch) within individual exhibits ($r = -0.226$, $p < 0.05$). This correlation between the level of authenticity in phenomenon presentation and the designed ability of a visitor to explore the phenomenon through touch within individual exhibits was consistent with expected outcomes.

Table 4.7

Correlation Matrix Between Sub-levels of Authenticity

	Artifacts	Sight	Touch	Sound	Smell	Phenomenon	Environment
Artifacts							
Sight	.055						
Touch	-.168	.291**					
Sound	-.008	.090	-.058				
Smell	.160	-.307**	-.041	-.027			
Phenomenon	.317**	-.193	-.226*	.174	.086		
Environment	.116	.075	.261**	-.078	-.014	.227*	

Note: * $p < 0.05$; ** $p < 0.01$

Level of immersion in the exhibit. A positive, low correlation also existed between the designed ability of a visitor to explore through touch (touch) within individual exhibits and the level of immersion (environment) in exhibits across the sample ($r = 0.261$; $p < 0.01$). In other words, as the nature of the immersive elements of the exhibit transitioned from partial to fully immersive, the opportunities for visitors to explore through the sense of touch also increased. There was a positive, low correlation between the level of authenticity of the presentation of scientific phenomena (phenomenon) and the level of immersion (environment) in exhibits ($r = 0.227$; $p < 0.05$). As the number of immersive elements increased in the exhibits, so did the ability of visitors to see exemplars of scientific phenomena also increased.

Designed ability to use sight to explore. The analysis yielded a positive, low correlation between the designed ability of a visitor to explore through sight and through touch in an exhibit ($r = 0.291$, $p < 0.01$). The analysis also yielded a negative, low correlation between the designed ability of a visitor to explore through sight (sight) and through smell (smell) in an exhibit ($r = -0.307$, $p < 0.01$). These findings indicate that there were some consistencies between a visitor's ability to look and touch an exhibit whereas when smell was used to investigate a phenomenon, the ability to see the origin of the smell was removed.

Summary and Discussion

Each evaluation that met this study's inclusion criteria provided different interpretations or applications of *authenticity* in isolated exhibits at specific institutions in certain communities. My purpose was to use the four pre-determined codes and their characterizations to measure the extent to which a large sample of exhibit descriptions presented authentic artifacts, sensory experiences, phenomena presentation, and environments. In the analysis of these studies, I counted and compared the occurrences of these four interpretations of *authenticity* in a large sample of exhibits across a number of institutions and communities. This summary of findings is organized by those four interpretations or sub-elements of authenticity: *artifacts, sensory experiences, phenomena presentation,* and *environment.*

Artifacts. A majority of the exhibits in this sample had either no artifact or highly stylized artifacts. According to Friedman (2010), this is not an unexpected finding. This low or limited level of authenticity in artifacts present is consistent with the nature of the institutions that they represent. A majority of the institutions represented in the sample are highly interactive science centers. One of the ways that science centers differ from science museums is that many do not maintain traditional artifacts. Science centers prioritize engaging, interactive, hands-on experiences over the general caution and maintenance required to responsibly care for scientific specimens.

Sensory experiences. Where a visitor's ability to engage authentic artifacts might have been limited by the host institution type (i.e., science center v. natural history museum), the visitor's opportunity to explore with their senses were not. A majority of the exhibits were designed in such a way as to provide between one and two sensory experiences for visitors in exploring a scientific phenomenon. While the ability of visitors to use focused observations and touch to explore the features of an exhibit dominated the design features of the exhibits in this sample, creative uses of purposeful sounds and smells were also present.

Presentation of phenomenon. What makes a science exhibit different from a historical exhibit or an art exhibit is the science exhibits typical use of diagrams, models, or instruments to point to the patterns in nature that supersede a specific context or timeframe. These cross cutting ideas and concepts can be communicated in a variety of ways depending on an exhibit designer's purpose. In this study, I categorized communication in three ways: visually represented in diagrams, physically represented in analogous models, or authentically detectable through a visitor's senses or a provided instrument. Although most science exhibits had graphics and diagramed representations, we decided as coders to focus on the dominant presentation of the scientific phenomena. Future research may consider approaching this sub-element as individually counted features for a more fine-grained investigation of the presentation of science through visuals and models. Although there were slight variations in the frequency of each dominant presentation mode, it was clear that most science exhibits presented the scientific phenomena intentionally and provided the supports for exploring in the dominant mode.

Immersive environments. As with the visitor's ability to explore with multiple senses and ability to see phenomena visually represented in one form or another, there were also a few exhibits that provided visitors with opportunities to be immersed in the experience at the exhibit. These experiences were rare and closely connected to the use of non-traditional senses for exploration (auditory and olfactory senses). The role of immersive elements and experiences has been found to have a range of effects on visitor learning behaviors (e.g., Mortensen, 2011; Schwan et al., 2014). This sample reflected a lack of sufficient examples of immersive exhibits to confirm these findings.

Limitations

The purpose of this study was to characterize how exhibits manifest different levels of authenticity across a large sample of summative evaluations. Based on the data collected in this study, I was able to organize a preliminary set of measures of the extent authenticity might have been presented in an exhibit's selection and use of artifacts, provision of sensory experiences, presentation of the scientific phenomenon, and level of immersion. Although this study fulfilled its purpose, limitations did exist, which should be considered in both policy and practice: (a) the nature of the sample and (b) nature of visitor use of the exhibits.

Sample. Although the coding process was comprehensive and reliable, this larger sample was limited by the nature of the form of communication that was analyzed; namely, summative evaluations. In order to address and compensate for this limitation, only descriptions and images of exhibits were used for analysis in this study.

Intended use versus actual use. Another limitation of this study is that the findings have been analyzed from the perspective of how a visitor could interact with an exhibit, not how visitors actually interacted with each exhibit's features. The only way I could have accounted for this limitation would be to control for the nature and quality of outcome data as collected by the original evaluator. As such, I determined that the designer's intended use was an important feature for analyzing the presence of authenticity as a design feature.

Implications for Future Research

Researchers in the field of informal science education identified *authenticity* as an exhibit design element with an expressed link to visitor learning behaviors (Crowley & Jacobs, 2002; Schwan et al., 2014). Each study focused on different interpretations or applications of *authenticity* in isolated exhibits at specific institutions in certain communities. This pilot-test of a method looking for patterns across a larger number of exhibits across a number of different sites could be useful as a template for additional studies investigating design features of exhibits.

Additionally, I accomplished a content analysis at a scale considerably larger than most studies of exhibit design features. Investigating patterns on extant data sets like the BISEnet data repository can be a useful guide to design larger more resource-intensive studies. Considering the evaluators' reports in the BISEnet data repository spanned across multiple locations and years of study, learning science researchers might be able to use content analysis to look for evidence of patterns across sites and evidence of changes to exhibit style and design priorities over different periods of time.

Finally, the correlation data highlighted the potential of organizing exhibits into profiles for future research. In this sample, two polar groups of exhibit emerged from the selection process. One group of exhibits presented authentic scientific phenomena in highly immersive environments where visitors had the ability to explore with a breadth of sensory experiences (e.g., observation, touch, and listen). The other group of exhibits presented authentic experiences through video-recorded presentations and static displays of authentic artifacts. Future research is needed to validate these profiles.

Implications for Practice

The content analysis for this study focused on the design of each exhibit within a chosen sample of analysis. As such, this study did not attempt to link visitors' outcome measures to the exhibit's design features. Instead, implications for practice reside with the museum professionals and exhibit designers who can use the terms and descriptions that emerged from this study to navigate design choices. In particular, this study should be most relevant to practitioners in institutions that have priorities for high quality, authentic objects and experiences.

CHAPTER V

CONCLUSIONS

Well-designed exhibits engage museum audiences in rich learning experiences. The standards of quality for science exhibits are evolving at faster rates than ever before. The timeframe between when an exhibit opens on the museum floor and when its replacement is in the development process is also diminishing at a rapid, possibly unsustainable rate. Exhibit designers and decision makers need the best information available and in a form they can use in order to keep up with the evolving quality standards and truncated timeline of the exhibit design process. The purpose of this dissertation was to contribute to the informal science education (ISE) community's effort to narrow the gap between the quality of a science learning experiences and the capacity of ISE institutions.

In this chapter, I summarize the methods, findings, and impact of the three articles that comprise this dissertation. Next, I discuss how the findings from these studies highlight considerations for practice for learning environments. I close with a section where I compare the findings from these studies to the current interpretations and interest reflected in two of the most current National Research Council's (NRC) handbooks on research in ISE: Bell, Lewenstein, Shouse, and Feder's (2009) *Learning Science in Informal Environments* and Fenichel and Schweingruber's (2010) *Surrounded by Science*.

Summary of Findings

Each article in this dissertation represented a progressive series of studies that were built on the understandings that emerged from the study that preceded it. The first article was a literature review. The findings from this review produced a framework of exhibit features that had a moderating effect on visitors' learning behaviors across the ISE landscape. The second study focused on *authenticity* as an exhibit element that needed further clarification. For this study, I recruited participants from nationally recognized ISE institutions who had experience with the exhibit design process. I compared participants' descriptions of the exhibit design processes and examples of their favorite exhibits against eight layers of authenticity as expressed in educational research. In the third study, I looked for evidence of the layers of authenticity as expressed in a sample of exhibit descriptions included in the Building Informal Science Education Network (BISEnet) database. Findings from each study contributed to the larger conversation about the role of authenticity in education.

Review of Exhibit Design Features and Visitor Learning Behaviors

In Chapter II, I systematically reviewed the published literature to gather evidence of design features that had a moderating effect on visitor learning. I created an Exhibit Element Framework as a means of synthesizing empirical findings into a two-tiered matrix of eight exhibit design elements. I proposed that this framework could be used to support research-based decision-making in the exhibit design process. This literature review contributed to the field by supplanting Allen's (2004) institutional research agenda with a universal framework based on empirical findings from a number of different institutions. While some of the design features that emerged from that study were relatively concrete, others were more complex and required further clarification particularly in the design process of highly engaging science exhibits. The need to clarify *authenticity* shaped the next study.

Qualitative Interviews with Exhibit Designers

In Chapter III, I opened with a brief literature review on authenticity as it was interpreted in the larger enterprise of educational research. A three-pronged model of authenticity in educational research emerged from the findings of this literature review. In Table 3.1, I summarized the subordination of eight layers of authenticity (i.e., task, artifact, environment, impact, discipline-centered, pedagogical, learner-centered, and community-centered layers of authenticity) under three broad categories (i.e., external, embedded, and internal authenticity). Characterizations and the research-based impacts of each layer were also described in Table 3.1 and became the basis for interpreting the findings for a multiple case study.

I collected interview data from six participants that focused on understanding the role authentic experiences played on the exhibit design process. I used a constant comparative method to analyze the interview data. This process of open-coding and progressive axial coding transformed the initial model into a final model that was representative of the contributions of all six participants. In Figure 3.2, I provided a simplified version of the final analytic map. I used a color-coding scheme to reflect initial contributions from the constant comparative process. I also increased the boldface of the arrows and borders of concepts as more participants referenced an idea or relationships. I interpreted the findings from this ISE study on the role of authenticity in exhibit design as they mirrored or extended the eight layers of authenticity in the broader field of educational research. While many areas overlapped between the findings and the field, there were specific areas that the findings extended our understanding of authenticity in educational research.

I recommended a new layer of authenticity—institutional authenticity—proposing that some learning experiences and exhibits are more representative of an institution's priorities. This is an expression of authenticity that has been under-represented in educational research. It does, however, have specific implications on how formal learning experiences can be more or less reflective of a school, district, or state's priorities and guiding policies. I also highlighted the role of scale and role-play as facets of designing an immersive environment that complement the embedded artifacts and scientific practices unique to ISE institutions.

Content Analysis of Exhibit Descriptions

In Chapter IV, I focused on how the layers of authenticity were expressed in the design features of a large sample of exhibit descriptions. I used a deductive content analysis to compare and describe how authenticity was expressed in four pre-determined categories: (a) artifacts, (b) sensory experiences, (c) phenomena presentation, and (d) environment. I used a rigorous set of inclusion criteria to select a sample of exhibit descriptions from high quality summative evaluations in the BISEnet database. I based this process on my findings related to the variations of quality in the studies included in Chapter II. I worked with two additional Science Education researchers to determine the reliability of the scale using percent agreement, Krippendorf's alpha, and Fleiss' kappa. All three measures of reliability were within acceptable ranges. The findings from this study affirmed the effect of an institution's priorities on the frequency highly authentic artifacts (e.g., natural history museums) over others hands-on experience focused institutions (e.g., science centers). Based on the rigorous selection procedure, I made recommendations to researchers and exhibit evaluators to use the inclusion criteria as a set of quality indicators for future studies or evaluations.

Implications and Future Research

I believe that the findings from this series of studies contribute to the narrowing of the gap between research-based findings on exhibit design and the capacity of informal science education institutions to engage their audiences with highly engaging, authentic science experiences. Specifically, I believe that the findings from this series of studies do move the conversation forward and contribute our understanding of the "seductive" (McDougall, 2015) and "complex" (Kohnen, 2013; Reeves, Herrington, & Oliver, 2002) nature of authenticity in educational research.

Chapter II

By conducting a literature review on exhibit elements (Chapter II), I was able to identify a need to (a) revisit exhibit design features as a moderators for visitor learning and (b) clarify terms that researchers used to describe exhibit design features and their effect on visitors.

Revisiting exhibit design research. In the process of selecting studies to be included in the literature review, I found a surge between 1970-2000 in the number of studies that attempted to connect learning and exhibit design. These studies were conducted primarily using timing and tracking behaviors as a sole outcome. The reduced numbers of studies published between 2000-2016 highlight an evolution in the methodological approach to investigating visitor interaction and learning. As such, there is a clear need to revisit exhibit element research with modern methodological approaches to triangulating visitor learning data.

Exhibit elements needing clarification. I selected authenticity as an exhibit element that needed clarification. There were several concepts that emerged from the findings of this literature review highlighted a similar need for clarification. Future research could extend the value of the Exhibit Element Framework by investigating other educational implications of: (a) familiarity v. novelty, (b) layers of complexity, and (c) different interpretations of accessibility.

Chapter III

I used a small sample of experienced exhibit designers from nationally recognized institutions as participants in Chapter III. These participants' perspectives contributed to the field by highlighting interpretations of how authenticity shaped the unseen part of an exhibit's design (e.g., strategic planning, inclusion of experts in predesign process). The findings from this multiple case study identified an opportunity for future research by (a) actively collecting data during a concurrent exhibit design process and (b) considering the value of the learners' perspectives on authenticity.

Concurrent data collection in the exhibit design process. The findings from this study were based on interview data about the participants' earlier exhibit design experiences. A way to further investigate the themes that emerged in this chapter would be to follow a design group as a passive observer throughout the process. Additional exhibit design decisions may emerge from this type of active data collection and extend the findings from this study.

Investigating new perspectives. Additionally, the findings from this study focus on practitioners' perspectives of highly effective exhibit design. As highlighted in the literature review, authentic experiences are socially constructed. The field would benefit from future research that takes the findings from this multiple case study and investigates their value from the learners' perspective.

Chapter IV

I used characterizations of authenticity of four exhibit design features as a coding framework for analyzing content in a sample of summative evaluations. Before I decided to move forward with pre-determined categories, I recognized the value of ISE evaluation content as a rich source of information about exhibits and visitor learning behaviors in different ISE institutions. Because of the volume of evaluations included in the BISEnet database, there are many opportunities for future research that investigate moderators for learning across time and location. Of the original 521 evaluations included in the BISEnet project, my inclusion criteria limited the sample down to 10 evaluations (approximately 2%). Future research can also validate the final measures of authenticity scale (Table 4.5) by broadening the inclusion criteria to add formative evaluations and evaluations of exhibits not located in science centers.

Practical Considerations

I consider practical implications from the perspective of how authenticity can be expressed in learning environments and inform the exhibit design process.

Learning environments design. Learning environments shape the way people engage science. The impetus to design authentic experiences with science stem from a history of designed experiences that oversimplify the practices and presentation of science (Strobel, Wang, Weber, & Dyehouse, 2013, p.144). As learning environment designers take steps away from traditionally inauthentic experiences with science, they will come face-to-face with a what Baloin, Pino, and Hardings (2011) described as a "blurry demand rather than a well-defined concept" (p.285). I believe the findings from this study contribute to (a) a clearer picture of what authenticity means and (b) how it can be incorporated into the design of a quality learning experience.

Layers of authenticity. A literature review included in Chapter III highlighted authenticity a series of external, embedded, and internal layers. Internal and embedded layers of authenticity shape how a visitor internally processes an experience as they associated value and meaning from a personal and socially constructed lens. External layers of authenticity included the design features that a learner would physically interact with. Features of a learning experience that might have expressed levels of external authenticity include: tasks, objects, environmental, and impact. This layered approach to understanding authenticity complements Anderson's (1998) process-product interpretation of authenticity, Kohnen's (2013) latent v. functional categories of authenticity. The findings of this study extend Manninen, Henricksson, Scheja, and Silen's (2012) external v. internal layers of authenticity by introducing an embedded layer of authenticity. This embedded layer provided a place for how an experience is designed to authentically reflect the structure of the scientific discipline (Newmann & Wehlage, 1993; Reeves, Herrington, & Oliver, 2002) and research-based pedagogical practices (Marks, 2000; McDougall, 2015; Newmann & Wehlage, 1993). The embedded layer of authenticity also provides a home for the findings from Chapter III; specifically, how an institution's identity and priorities are expressed authentically in a learning experience. Each of the three layers and their subordinated design features provide multiple opportunities for designers to consider how their own priorities might be expressed in formal or informal learning environments. The layered perspective of each expression of authenticity also provides considerations for how each layer contributes to an overall authentic experience.

Design considerations. Reeves, Herrington, and Oliver (2002) described a need to clarify authenticity in practical terms; specifically, to translate authenticity into actionable features of a science learning environment. Strobel, Wang, Weber, and Dyehouse (2013) also found that the "ubiquitous" use of authenticity hinders a practitioner or researcher's ability to investigate authenticity's specific dimensions or components (p.144). I believe the findings from this series of studies provide a perspective of authenticity that addresses its complexity as well as presents opportunities for shaping the design process of new learning experiences.

Kenkmann (2011) posited authenticity as a powerful lens for reflecting on learners' experiences, but cautioned its use in empirical studies of experience. Radinsky, Boullion, Lento, and Gomez (2001) questioned the usefulness of authenticity as a design feature as they piloted an industry-education partnership-centered curriculum. Radinsky et al.'s (2001) perspective was limited to traditional classroom settings. The findings in this study highlighted the ISE institution as an educational environment that is uniquely positioned to provide visitors with authentic experiences unparalleled in formal education environments. As the contributions and practices of designing high-quality learning experiences in the ISE community are better understood, traces of what makes these unique experiences engaging will find their way into more educational experiences.

Contributions to the Field

I discovered a number of ways authenticity is expressed, applied, and measured. I captured them in the language and imagery of layers and investigated evidence of their presence through exhibit descriptions across a number of settings. I used two of the currently recognized handbooks on informal learning to reflect on how these studies contribute to the field as a whole.

Learning Science in Informal Environments

Bell et al. (2009) refer to authenticity in four expressions throughout their seminal handbook: (a) authentic social interactions, (b) authentic inquiry, (c) spontaneous visitor behaviors, and (d) authentic evaluation. I describe how the findings from this series of studies address each expressions of authenticity independently in the following sections.

Authentic social interactions. The first mentioned way is through social interactions in a community of practice. An example of this expression of authenticity was in the apprentice-like interactions with experts in their field (p.33). In chapter III, I found two examples of the role of apprentice-like interactions. The first example was with Participant B and their description of a crime scene exhibition where real detectives shaped the case and the narrative for three separate crimes and crime scenes. Visitors could collect and analyze evidence and then share their evidence at a computer terminal where one of the characters from a popular CSI television show would give them feedback on their evidence and analysis. This process modeled the role feedback plays in an authentic social interaction between experts and novices. The second example was also in Chapter III, when Participant A shared several of the models they used to provide opportunities for social interaction. One of the models was a focused panel where visitors could have heard the perspectives from different experts and could have chosen which expert they had most aligned with before moving into a topic-based discussion activity. The inclusion of these examples in the findings from Chapter III affirms the significance highlighted in the NRC handbook on learning research in the ISE.

Authentic inquiry. Another expression of authenticity is described as "self-directed exploration and discovery" (p.66). This expression mirrors the description of the role of autonomy as part of designed physical interactivity in Chapter II, and as one of three keys to creating experiences that are authentic to the learner in Chapter III. The findings from this dissertation highlight specific examples from the field, making special note of the challenge some institutions might face in order to create these experiences. In Chapter III, Participant F described creating open-ended inquiry experiences as part of their institutional identity. In the same chapter, Participant E described the process of creating open-ended experiences (e.g., the build-your-own undersea creature experience) as a challenge for them to give up a level of control over what might happen in a designed experience. Some of the described exhibits from Chapter III were completely open-ended (i.e., Participant F's smoke cannon and giant mirror) while others were structured with multiple specific designed outcomes (e.g., Participant B's crime scene exhibit and Participant D's truss-building experience).

Spontaneous visitor behaviors. One of the challenges of connecting the findings from my studies to the descriptions or references to authenticity in Bell et al.'s (2009) *Learning Science in Informal Environments* is their use of the word unplanned to describe "moments of curiosity and exploration" (p.102) and "parent-child discourse" (p.149). The basis of all three studies in this dissertation approached the visitor experience from the exhibit designer, researcher, or evaluator perspective of an exhibit's design. While the findings from this study might have not specifically addressed the unplanned aspect of the visitors' behaviors, they did contribute to a picture of how experts in the field have used an exhibit's design to facilitate "moments of curiosity and exploration" as well purposeful conversations among different groups of visitors.

Authentic evaluation. I did not see authenticity expressed in terms of evaluation in the findings of these studies. I did not see a transition in the practices of evaluation from traditional methods to authentic assessment, or embedded and consistent forms of data collection used to shape an iterative process of improving a visitor's experience with an exhibition. This is an area of educational research that I organized under the pedagogical layer of authenticity in the literature review for Chapter III but did not see as an expressed priority among the interviews that followed. This might or might not reflect the significance of this expression of authenticity among the ISE community. It might be a reflection of my hesitance or lack of mentioning it through the interview process.

Surrounded by Science

Fenichel and Schweingruber's (2010) *Surrounded by Science* highlighted two additional factors that shape how authenticity has been expressed in the ISE field: (a) content validity and (b) authentic tools and practices. I describe how the findings from this series of studies addressed both expressions of authenticity in the sections below.

Content validity. Authenticity was initially used to describe a level of authority and expertise to the presentation of science. Fenichel and Schweingruber compared this to what scientists bring to their participation at Science Cafes. This expression of authenticity first manifested itself in the literature review (Chapter II) as a series of studies considered the role of accuracy, breadth, and depth of the content of an exhibit and its effect on visitor's learning behaviors. This expression of authenticity also emerged from the interviews in Chapter III as a justification of the inclusion of content advisors in the exhibit design process. The expertise and diversity of these content advisors shaped the decision-making process in the exhibit's messaging, phenomenon presentation, artifact selection, environmental design, and inclusion of scientific practices. These findings provided a detailed look at how practitioners accounted for content validity in the design of exhibits and experiences for visitors.

Authentic tools and practices. Fenichel and Schweingruber described an authentic experience where visitors put on safety equipment (e.g., coat, goggles, gloves) before entering the *Cell Lab* (p.43). This experience mirrored the equipment and expectations of a biological research lab but was embedded in an ISE institution. This emphasis on the tools and practices embedded in an informal environment is an extension of a similar description on citizen science projects managed through partner institutions in the ISE landscape. Fenichel and Schweingruber identified these scientific tools and experiences as authentic as they complement our understanding of scientific inquiry. This distinction was mirrored in broader educational research findings (e.g., Bevins & Price, 2016; Milner-Bolotin, 2012) and in the findings from this series of studies.

Authentic tools and practices overlapped in how they were interpreted both by researchers included in the literature review in Chapter II and exhibit designers' descriptions in Chapter III. I found authentic practices were interpreted by their resemblance to the field and their function. I found that authentic artifacts or tools were interpreted through similar lenses but also included an additional perspective: how authentic the artifact was by origin.

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APPENDIX

IRB DOCUMENTATION

DIVISION OF RESEARCH

TEXAS A&M UNIVERSITY

DATE: October 26, 2015

MEMORANDUM

TO: Carol L Stuessy
TAMU - College Of Education & Human Dev - Teaching, Learning And Culture

FROM: Dr. James Fluckey
Chair, TAMU IRB

SUBJECT: Expedited Approval

Study Number:	IRB2013-0763D
Title:	Inductive Evaluation of the Value Added by Designing for Social Interaction in Exhibits in Informal Learning Centers
Date of Determination:	
Approval Date:	12/10/2013
Continuing Review Due:	09/15/2016
Expiration Date:	10/15/2016
Documents Reviewed and Approved:	Only IRB-stamped approved versions of study materials (e.g., consent forms, recruitment materials, and questionnaires) can be distributed to human participants. Please log into iRIS to download the stamped, approved version of all study materials. If you are unable to locate the stamped version in iRIS, please contact the iRIS Support Team at 979.845.4969 or the IRB liaison assigned to your area.

Document of Consent: Written consent in accordance with 45 CF 46.116/ 21 CFR 50.27
Waiver of Consent:

Comments:

- (To answer PI's question in stipulations) Consent forms need to be re-stamped annually because there is an expiration date on them. For an expedited study such as this, the forms expire after one year.
- Research is to be conducted according to the study application approved by the IRB prior to implementation.
- Any future correspondence should include the IRB study number and the study title.

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Semi-structured Interview Protocol

Identify myself and my role

Explain the purpose of the interview

Confirm the participant's name, role and signed consent

The first series of questions are used to categorize the museum for comparison sake

Who participates in the design, selection process?

What is your unique role in the selection, design and evaluation process?

What are the big goals of the museum?

How do you engage visitors in new learning?

The second series of questions are used to capture your unique institution's values, motivations and goals in designing highly interactive exhibits.

What are the attributes of a good exhibit?

Describe your most effective exhibit (temporary and/or permanent).

How do you evaluate the quality of an exhibit?

What is your definition of interactive exhibits?

What percentage of your exhibits are "interactive"?

What role does social interaction play in design?

How do you support the connections between formal and informal learning?

ATM

IRB NUMBER: IRB2013-0763
IRB APPROVAL DATE: 12/10/2013
IRB EXPIRATION DATE: 12/01/2014

TEXAS A&M UNIVERSITY HUMAN SUBJECTS PROTECTION PROGRAM
CONSENT FORM

Project Title: Inductive Evaluation of the Value Added by Designing for Social Interaction in Exhibits in Informal Learning Centers

You are invited to take part in a research study being conducted by Kenneth Fleming, M.Ed. and Carol Stuessy, Ph.D., researchers from Texas A&M University. The information in this form is provided to help you decide whether or not to take part. If you decide to take part in the study, you will be asked to sign this consent form. If you decide you do not want to participate, there will be no penalty to you, and you will not lose any benefits you normally would have.

Why Is This Study Being Done?
The purpose of this study is to understand the impact of social interaction in the design, selection or success of science museum exhibits.

Why Am I Being Asked To Be In This Study?
You are being asked to be in this study because you have unique knowledge of the design processes that go into researching, designing and developing interactive museum exhibits among the top rated museums in the U.S.

How Many People Will Be Asked To Be In This Study?
Five people (participants) will be invited to participate in this study.

What Are the Alternatives to being in this study?
The alternative to being in the study is not to participate.

What Will I Be Asked To Do In This Study?
You will be asked to participate in a semi-structured interview. The interview may last up to one hour.

Are There Any Risks To Me?
The things that you will be doing are no greater than risks than you would come across in everyday life.

Will There Be Any Costs To Me?
Aside from your time, there are no costs for taking part in the study.

Who may I Contact for More Information?
You may contact Kenneth Fleming, M.Ed. or Carol Stuessy, Ph.D., to share your concerns or complaints about this research at 979-530-8193, kennethflemingjr@tamu.edu or c-stuessy@tamu.edu.

For questions about your rights as a research participant; or if you have questions, complaints, or concerns about the research, you may call the Texas A&M University Human Subjects Protection Program office at (979) 458-4067 or irb@tamu.edu.

What if I Change My Mind About Participating?

IRB NUMBER: IRB2013-0763
IRB APPROVAL DATE: 12/10/2013
IRB EXPIRATION DATE: 12/01/2014