Museums, aquariums, and technology centers are informal learning environments that facilitate the understanding of scientific phenomena while supporting self-motivated learning. Families are a social group that frequently visits these sites. There are multiple opportunities for adults and children to engage in independent sense-making and collective discussion about their experiences with exhibits. In recent years, touch surface technology has been scaled from handheld phones to larger tables and walls. These technologies are being adopted by museums and aquariums to showcase content beyond static signage. As this technology carries an element of awe and attraction, what are the engagement levels between adults and children as they use a multi-touch table together? Twenty-five family groups were filmed interacting with a 55” Ideum Pro multi-touch table exhibit through unobtrusive video and audio recording at Hatfield Marine Science Center Visitor Center in Newport, Oregon. Groups were interviewed following use of the exhibit regarding their motivations and experience using the multi-touch table. A rubric was used to analyze the video and
code for the presence of verbal and non-verbal behaviors expressed by the family group on the following dimensions: responsive engagement, learning strategies and opportunities, and directive engagement. Levels within the rubric ranged from very low, low, moderate, high, and very high. While families varied in engagement levels, the highest frequency of families rated moderate for responsive engagement, moderate for learning strategies and opportunities, and low for directive engagement. The results of this study provides evidence for the social learning strategies that adults and children use while interacting with multi-touch technology and making sense of science content in this context. Exhibit and content developers can incorporate this information in the design of digital interactives that are installed in the museum and science center environment.
An Exploratory Study on Family Group Use of a Multi-touch Table Exhibit at a Public Marine Science Center

by

Jennifer L. East

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APPROVED:

Major Professor, representing Marine Resource Management

Dean of the College of Earth, Ocean, and Atmospheric Sciences

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

________________________________________
Jennifer L. East, Author
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CONTRIBUTION OF AUTHORS

Dr. Shawn Rowe was involved with the design, methodology, and writing of Chapter 2 and Chapter 3. Dr. Bridget Hatfield was involved in the design of the methodology, providing guidance on the rubric design for Chapter 2.
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Chapter 1: INTRODUCTION

The Significance of Science Literacy

Humans are naturally curious. In an effort to understand the external environment, humans have developed tools and processes to make sense of their observations and answer questions. These tools and processes include the development of science and the scientific method. Many would argue that science has improved the quality of human life and solved challenges afflicting societies. These improvements range from basic necessities for survival, to medicines, and technology. One of the tenets of technocratic, post-industrial societies is that a basic understanding of science concepts is necessary to generate ideas, evaluate solutions, and implement policy. In 1990, participants in the World Conference on Education for All proposed the Jomtien Declaration, which directed attention to the significance of the acquisition of basic learning tools, such as written and oral literacy, and content knowledge for all humans on the planet (United Nations Educational Scientific and Cultural Organization [UNESCO], 1990). This declaration recognized that education and lifelong learning are necessary not only to accomplish basic personal survival strategies, but to expand the quality of life, participate in cultural development, and to make well informed decisions (Maslow, 1954; UNESCO, 1990). In addition to a basic understanding of scientific concepts, as the STEM (Science, Technology, Engineering, and Mathematics) and STEAM (Science, Technology, Engineering, Arts, and Mathematics) movements in the United States demonstrate, the ability to acquire, integrate, and apply this knowledge to other areas of life is increasingly seen as important to generating creative ideas for interdisciplinary solutions to problems across the natural and social sciences.

As societies are facing complicated issues and policy decisions regarding the environment and human health, national funding agencies and non-governmental organizations
have raised questions about what the public knows about science and where people learn about it once they leave schools. Over the past 40 years, large-scale national and international surveys have been conducted to gather more information on the public’s interest and understanding of science, including the assessment of science literacy or general science knowledge (Bauer, Shukla, & Allum, 2012; Falk, Storksdieck, & Dierking, 2007). These studies, however, tend to be based not on a literacy model of science learning, but on a deficit model. If respondents on these large-scale surveys could not accurately recall answers to specific science content questions, there was an assumption of a deficit in knowledge. Generally speaking, the usual solution offered is providing more information under the assumption that additional knowledge will lead to an increase in public engagement with science. While deficit models in traditional literacy have been challenged since the late 1970’s (see Heath, 1983, for example), science literacy models have only recently begun to argue that what might be lacking from the development of such large-scale national surveys is the consideration of the diverse life and educational experiences that contribute to the individual accumulation of science knowledge over time. Rather than testing broad science knowledge, some researchers have called for recognizing that each individual is unique in their knowledge set, based on their personal needs and interests (see, for example, Falk, Storksdieck, & Dierking, 2007; Miller, 2001).

**The Learning Process**

Learning reflects a culmination of processes that connect on a personal, socio-cultural, and physical level (Falk & Dierking, 2000). On a personal level, humans collect, interpret, and store information in order to make sense of their external environment. One or more of the five senses acquires information from a stimulus which proceeds through the nervous system (Hedge, 1995). The flow of information is transferred between perceptual and cognitive processes and
translated into feelings, actions, and behaviors (Hedge, 1995). Motivations, attitudes, and beliefs, which are ultimately linked to identity, are another layer to learning in the personal context (Falk & Dierking, 2000). Despite the unique acquisition of information on the individual level, learning does not occur in isolation. Social learning occurs directly in the presence of another individual through conversation, or indirectly via cultural tools such as written language in a text or other forms of media (Falk & Dierking, 2000). People use both language (verbalizations) and behaviors to convey information and to teach and learn from activity (Falk & Dierking, 2000). The physical environment also influences the learning experience as a setting’s layout, spatial arrangement of objects, and environmental conditions all play a role in the development of our thoughts, memories, and actions (Smith & Bugni, 2006). As people navigate physical behavioral spaces for learning, they form cognitive maps, relying on these memories to navigate and adapt to their surroundings (Falk & Dierking, 2000).

**Learning Outside of a Classroom Environment**

The accumulation and interpretation of information is driven by many elements starting with an individual’s motivations to know about a particular topic, the resources used, and the frequency of accessing those resources (Falk, Storksdieck, & Dierking, 2007). Only a small percentage of a given lifetime is spent in the formal classroom environment; therefore, science learning (like all learning) continues outside the formal academic environment (Falk, Storksdieck, & Dierking, 2007; National Research Council, 2009). In 2007, Falk, Storksdieck, and Dierking reflected on two rounds of surveys conducted in 1997 (Falk, Brooks, & Amin, 2001) and 2000 (Falk & Coulson, 2000) that included randomly selected adult residents of Los Angeles, California. Participants were asked to describe their science and technology knowledge and what sources they access to obtain information. Almost half (43 percent) reported spending a
portion of their free time learning about science and technology, and approximately 23% relied “a lot” on museums, zoos, or science centers as a resource for that information (Falk & Coulson, 2000; Falk, Storksdieck, & Dierking, 2007). Though not everyone visits museums or similar forms of cultural institutions organized for informal education, conducting research on the diverse resources people access provides a more complete picture of the lifelong learning process and how people make sense of science content.

Designed environments like museums differ from formal classrooms because the learner has the ability to choose what and where they direct their interests and attention (Falk & Dierking, 2000). These sites may be called “informal” education spaces and are “defined as including learner choice, low consequence assessment, and structures that build on learners’ motivations, culture, and competence” (National Research Council, 2009, p. 47). The visitor takes an active role in their exploration of these sites and the construction of personal meanings of the experience (Hein, 1998; Falk, 2001; Fenichel and Schweingruber 2010). In the museum, this is recognized through the physical manipulation of exhibits, reading posted signage, or interacting with staff on-site. Since the experience is open-ended, there are multiple possibilities of what content is acquired, assimilated, and connected to the prior knowledge that the individual brings to the experience (Falk & Adelman, 2003; Roschelle, 1995; National Research Council, 2009). While the imprint may be unique to the individual, the museum experience is also social, allowing the individual an opportunity to engage with the group they came with, volunteers, or other staff.

**Learning Within the Family Group**

A major segment of museum visitors are family groups (Ash, 2003; Falk & Dierking, 2000; Hilke, 1989). The members of these multi-generational social units may not all be directly
related, but they are likely to have a close or familiar relationship (Borun, 2002). During a visit to a learning environment like a museum, these social units shape both independent exploration and group engagement with activities and exhibits. The combination of verbal and non-verbal forms of communication during the experience can lead to both personal and shared meaning-making within the group (Diamond, 1986; Rowe, 2002).

Understanding family learning is important because across a wide range of cultures adult caregivers, parents, and teachers have a significant role in supporting the development and learning strategies of young children (Ash, 2004; National Research Council, 2009; Rogoff et al., 2003). This support role is accomplished not only through momentary assistance, but also over longer periods of time (National Research Council, 2009). Members of a family group know each other well, therefore the learning strategies and methods they apply are unique to their relationship. They may also be unique in terms of outcomes. Opportunities to learn about science take place spontaneously in everyday life including activities such as personal hobbies, interests, and conversations surrounding momentary events without necessarily involving a predetermined or externally articulated learning outcome, (National Research Council, 2009). Whether it is an adult and child discussing why the sky is blue, participating in the construction of a birdhouse, or growing vegetables in a backyard garden, there are limitless opportunities for the exchange of skills and knowledge involving science. The museum provides a space where personal interests and motivations surrounding science can be placated while facilitating the implementation of learning strategies that families use in everyday activities.

**Adult and Child Interactions in the Museum Environment**

In the museum, families may have an underlying goal to develop their personal relationships and learn between the generations (Falk & Dierking, 2013). Throughout the course
of their interactions and experiences within this setting, adults and children may reinforce the values and beliefs that are unique to their family, or encounter new information and interpret that in a way that is meaningful to them (Borun, 2002; Pianta, 1997). One other notable feature of social learning in family groups is that the collective group may encompass more knowledge than any of the individuals do. The knowledge and learning of a group thus resides in an important sense in the cooperative learning strategies using conversation and gestures (Ash, 2004; Callanan, Valle, & Azmitia, 2007; Crowley & Callanan, 1998; Crowley et al., 2001) through which actions and utterances are exchanged, adopted, and applied for distributed meaning making (Rowe, 2002). The children may look to the adult who models a behavior to use at the exhibit, observe that behavior and replicate it, in turn imprinting the experience at the individual level (Falk & Dierking, 2013). Observation and analysis of these interactions during the museum experience can provide a glimpse of how this cultural institution interprets science content through the process of social learning in the context of an informal setting (Ash, 2003).

Research on family learning behaviors in museums dates back multiple decades (Diamond, 1986; Hilke, 1989). Many key research studies have had a qualitative and descriptive focus on social interactions and have provided evidence that families do learn while in attendance (Borun, Chambers, & Cleghorn, 1996; Diamond, 1986; Hilke, 1989; Zimmerman, Reeve, & Bell, 2010). These social interactions can include both verbal and non-verbal methods to make sense of the experience. Verbal strategies that have been documented involving use of exhibits include questioning, identifying, describing, interpreting, and applying (Ash, 2004; Borun, Chambers, & Cleghorn, 1996). Parents play a noticeable role as guide and interpreter for their children, offering explanations that relate to how the exhibit works and how it relates to the real world or scientific principles (Crowley & Callanan, 1998). References to popular culture,
literature, or other experiences are linked as metaphors and analogies (Zimmerman, Reeve, & Bell, 2010). There is also evidence of scientific reasoning taking place in family science interactions. While making interpretations of their experience at live animal touch tanks in an aquarium setting, Kisiel, Rowe, Vartabedian, and Kopczak (2012) documented families making and testing predictions and constructing arguments. These research studies are linked by their focus on adult and child interactions. The results point to the idea that participation by the parent is important to improving the level and quality of the child’s engagement with exhibit content (Borun, Chambers, Dritsas, & Johnson, 1997; Crowley et al., 2001). Though time spent in the museum is a brief moment within a lifetime, the experience produces a shared understanding of cultural content and can add to past and future experiences beyond the museum walls (Ellenbogen, Luke, & Dierking, 2007).

**Interacting with Digital and Non-digital Objects**

Historically, museums have been a place where culturally significant objects and artifacts are on display for purposes both of building national or regional identity and pride, and for learning (Conn, 1998). They have evolved over time, in some ways to meet the demands of the visitor, keeping frequent visitors returning and encouraging new ones. Much research in museums has focused on the role of objects in learning, but most often these objects have been biofacts, artifacts, signs, or even live animals (see for examples, Paris, 2002). Increasingly, however, because technology has evolved as well, there are many new formats for presenting objects virtually as a way to supplement objects that may not be handled, easily displayed, or to offer a connection to an object not possessed in the museum collection (Stogner, 2009). Technological novelty and open-endedness are also strong contributors to visitor attraction and holding power for interactive exhibits (Sandifer, 2003). While technology may be an attractor for
use, there are both advantages and disadvantages to virtual representations of objects, models of phenomena, or science content.

One benefit of the use of technologies, particularly digital technologies in museums is that digital interactives allow for data, content, and models of real world processes to be displayed in multiple alternative formats (Gammon & Burch, 2008). For example, an object can undergo a virtual dissection of layers and components, not seen by a visitor if they only have the ability to view or touch the surface. Media options ranging among text, video narratives, images, and links to other resources, allow for movement and multiple outcomes driven by the learner and not accessible with static content. The installation of technology may also appeal to a younger audience who are viewed as the future “users” of the museum. With the availability of novel technology available for use, questions have come up regarding the balance of enhancement and education without minimizing the significance of a cultural artifact or affecting the representation of phenomena (Stogner, 2009). While digital media and exhibits can be rich to some of the human senses and encompass new layers, for visitors, this is a different experience than engaging with “authentic” objects (Frost, 2002).

For some settings, technology may not be the best option to showcase objects due to the expense, or due to staff capacity to put forth the time and effort that goes into effective design. As with any other exhibit element or platform, the museum has to consider whether they are establishing a barrier to access for a diverse audience that prevents interpretation, as certain types of technology might be of limited use by some socioeconomic groups or for those without full function of their sensory systems, such as the vision or hearing-impaired visitors (Stogner, 2009). While technologies may serve as affordances and advantages to learning for those familiar with the technology, those lacking access may not be able to enjoy the experience as much if they are
spending an extended period of time trying to figure out how to navigate the exhibit. As designed, free choice spaces have the capacity to present interpretations of science phenomenon in multiple formats. There must, however, be consideration for reaching a diverse audience who vary in knowledge backgrounds, cultural models, and accessibility (Fenichel and Schweingruber, 2010). If the adoption of digital interactive exhibits continues in museums and science centers, we need a better understanding of how visitors make sense of these forms of interactives, and how it contributes to social learning process and science meaning-making.

Figure 1.1. A family group using the multi-touch tabletop exhibit at HMSC Visitor Center.

In this study, a multi-user digital touch interface provides a unique platform for research on the family group within an informal science setting (Figure 1.1). As an exhibit it can communicate and visualize science content to display, enhance, and supplement information in an attractive way. Observations of families using digital technology can provide information as to how the tool mediates their social interactions and learning strategies, particularly in informal science settings. There are verbal strategies or physical behaviors that we know families employ when using exhibits (Ash, 2004; Borun, Chambers, & Cleghorn, 1996; Crowley & Callanan,
1998; Diamond, 1986; Kisiel, Rowe, Vartabedian, & Kopczak, 2012; Zimmerman, Reeve, & Bell, 2010), so are similar strategies used when the exhibit is a novel digital interactive? A touch table affords multiple users, lending itself well to questions about social engagement such as whether novel technologies like multi-touch tables support engagement or whether users feel compelled to explore on their own with limited conversation.

The Use of Interactive Tabletops as Exhibits

The presence of interactive tabletops in some museums and galleries dates almost a decade, allowing guests to explore the representation of cultural artifacts or science phenomena in a different way (Geller, 2006; Hornecker, 2008). Ranging in size and shape, these exhibits showcase the advancement of touch technology and the ability to support multiple users at the same time. Unlike a desktop computer, the table format allows for visitors to gather around, orient themselves face to face, and have the potential to collaborate over a large surface, all elements that can support family learning (Borun, et al., 1997; Geller, 2006). With a touch response like a tablet or smartphone, visitors can use one or two hands to manipulate objects on the screen. Gestures may include dragging, enlarging, shrinking, or rotating an object depending on the goal of the user and the design or function of the content. Ease of use upon approaching this type of exhibit may indicate a reference to a mental model or prior knowledge and experience with tablets and smart phones (Gammon & Burch, 2008). This type of background experience or knowledge could also reduce the time it takes visitors to determine how to manipulate an exhibit using this format by improving “immediate apprehendability” (Allen, 2004, p. S20). While there is the assumption that these installations could promote increased stay time and support social engagement, the challenge is designing content that allows multiple users
to participate in social collaboration rather than losing individuals into solo exploration (Heath et al., 2005).

Interest and research on multi-touch tabletops that connects the learning sciences and use in public settings is increasing. Much of the research that has previously been conducted on interactive tabletops includes understanding usability and functionality of the hardware (Corriea, Mota, Nobrega, Silva, & Almeida, 2010), software, such as games that take advantage of the multi-touch capabilities (Antle, Bevans, Tanenbaum, Seaborn, & Wang, 2011; Block, Horn, Phillips, Diamond, Evans, & Shen, 2012; Martinez, Collins, Kay, & Yacef, 2011), or the attraction and discoverability in public installations (Hornecker, 2008; Seto, Scott, & Hancock, 2012). There are also examples of investigations of collaborative use in classrooms (Higgins, Mercier, Burd, & Joyce-Gibbons, 2012) and in controlled lab settings (Buisine, Besacier, Aoussat, & Vernier, 2012). A focused analysis of the natural expressions of family learning strategies between adults and children as they use this type of exhibit in museums is still lacking.

Among the research that has been done on visitor use of multi-touch surface tables in museums, usability, dwell time, and collaborative learning strategies have been areas of interest (Block et al., 2015; Davis et al., 2013; Hornecker, 2008; Hornecker and Nicol, 2011). One of the earlier reviews of visitor use was done by Hornecker (2008) on a multi-touch table that incorporated top-projection on a flat surface with capacitive sensor technology, rather than tables that are designed and respond similar to a smart phone. Hornecker (2008) observed the various gestures the visitors used to interact with the content which included multiple fingers, the entire hand, and single fingers. She also noted that through observation of other users manipulation of the exhibit could be picked up quickly (Hornecker, 2008). There were limited verbalizations of questions or conversation, and the conversation that did take place focusing primarily on the
“how-to” versus thematic content, and through her observations, she indicated a low level of social engagement (Hornecker, 2008).

Block et al. (2015) made naturalistic observations and video recordings of visitors using an interactive tabletop at the California Academy of Sciences, with a portion of the study focusing on a quantitative assessment of engagement between visitors and dwell time at a tabletop. The exhibit content involved a visual representation of evolutionary relationships that included both imagery and text. Statistical analysis on data collected through these naturalistic observations indicated that group size, age composition, and the occurrence of specific social behaviors significantly influenced group engagement with the tabletop exhibits (Block et al., 2015). In their analysis of social interactions, they found that a mixture of adults and children using the exhibit stayed longer and discussed the scientific content together (Block et al., 2015). The results of this study also indicated that adult-child groups engaged in conversation that included content and not just how-to talk on the functionality of the exhibit (Block et al., 2015). Thus, families were going deeper into the exhibit rather than spending the entire experience figuring out how to operate the technology. Block et al. (2015) compared the naturalistic data to data collected from video recordings of exhibit use. The video data was collected independently from the naturalistic data and they did not find a significant difference in the composition of groups in size and age, and social engagement (Block et al., 2015). They noted that the process of asking for consent from participants may have affected visitor behavior and introduced a sampling bias (Block et al., 2015). They proposed that the affect may be reduced if there was space and time between consent and recording, such as upon initially entering the museum rather than immediately before approaching the specific exhibit (Block, et al., 2015).
Hornecker and Nicol (2011) and Davis et al. (2013) focused their investigations on the facilitation and learning strategies between adults and children, and child pair groups respectively, while interactive table surfaces in an informal learning environment. In 2010, Hornecker and Nicol (2011) observed families using prototypes of historical content as part of a formative evaluation in a controlled museum space. The exhibit was projected onto a flat surface and responded to the user pressing physical buttons on the table. They observed a range of parental involvement with episodes of adults standing back and allowing their child to figure out the exhibit, but also facilitation, and team play (Hornecker and Nicol, 2011). Davis et al. (2013) found evidence of the child pairs demonstrating “reactive, articulated, and contemplated exploration” (p. 7) when using a multi-touch surface in a natural history museum. These behaviors played a role in how they made sense of the presented content, which was a hierarchical tree structure that visualized ancestral relationships among species. Though this study did not include a mixed group using a multi-touch surface, it does provide evidence of how science content has been presented via this technology and the types of responses that users express.

These research and evaluation studies are similar in attempting to understand visitor behavior with interactive tabletops in a museum setting in a social context. The research has categorized and noted the presence of the behaviors, but does not indicate a depth of engagement between adults and children, such as a consistency of responses to verbal comments made by family members, integration to prior knowledge that is personally relevant, or explicitly modeling tasks at the table for children. In addition to investigating the richness of engagement, this study will address a limitation mentioned in the research by Block et al., (2015) by giving
time and space for inferred consent for video recording with notification upon entering the center, which could reduce the potential for camera presence affecting behavior.

**Purpose of the Study**

The purpose of this research study is to unobtrusively observe and analyze the unprompted behaviors that mixed generational groups express during their interactions with a tabletop exhibit. Considering that learning takes place in social contexts, the observations and analysis will focus on the behaviors expressed among family members. Therefore the results of the observations will provide insight to the levels of engagement and learning strategies that are used within the group to make sense of the exhibit and content presented on touch surface technology.

**Guiding Questions.** This investigation was designed to address the kinds of questions raised above in a descriptive and naturalistic way using novel technologies combined with traditional methods for data collection. The question framed here is *what levels of interaction and engagement are expressed between adults and children at a multi-touch table exhibit installed in a public marine science center?* To what degree were interaction indicators framed as “responsive engagement,” “learning strategies and opportunities,” and “directive engagement” expressed between adults and children while using the exhibit?

As museums, science centers, and aquariums develop new exhibits to engage the public with science content, having an understanding of how visitors arrange and interact to make-meaning of this information on a social level needs additional investigation (Heath, Vom Lehn, & Osborne, 2005). The results of this study could offer ways to improve content design for multi-touch table technology that support and leverage the behaviors expressed by the family group, strategies to consider for communicating science using this form of technology, and
contributions to the growing body of knowledge of how people make sense of interactive, multi-user technology in designed learning spaces such as museums.

**Overview of the Methods**

This study incorporates multiple forms of data including recorded footage of exhibit use, post-use group interview, and post-visit phone calls. The behaviors and verbalizations expressed among adults and children were rated using a rubric modeled after the family performance indicators documented by Borun, Chambers, and Cleghorn (1996) in the museum setting and the framework of the Classroom Assessment Scoring System for teacher interaction with students (Pianta, La Paro, & Hamre, 2007). The rubric includes three dimensions of interactive teaching and learning behaviors including responsive engagement, learning strategies and opportunities, and directive engagement (Piscitelli & Weier, 2002). These dimensions contain categories coded along a five-point scale describing group behaviors. Analysis of the post-use group interview provided information related to what motivated the visitor to use the exhibit and how they defined their experience. Post-visit phone calls indicated what visitors recalled about their visit and use of the tabletop exhibit. The combination and analysis of this data provides an overall picture of the family group experience at this location.

**Setting and Exhibit.** This observational study took place at Hatfield Marine Science Center Visitor Center (HMSC), located in Newport, Oregon, on the west coast of the United States. HMSC is affiliated with Oregon State University (OSU), a research-focused, Land, Sea, Space and Sun Grant publicly supported university and operated by Oregon Sea Grant. Approximately 150,000 people pass through the center over the course of the year, with the highest attendance counts in the summer months. The center includes a combination of interactive exhibits and live animal displays that showcase both local and regional research and
projects done by OSU faculty and graduate students, state and federal agencies, and private industry.

A 55” Ideum multi-touch tabletop exhibit, approximately the size of a small kitchen table that four people can stand around and use at the same time, is installed onsite (Figure 2). For the duration of this study, the content displayed on the table was designed by Ideum and is titled “Electromagnetic Spectrum.” There are five different images that a user can drag across the screen, re-size, and rotate (Figure 1.2). Changes are observed in the image depending on where it is located along the spectrum, such as infrared, visible, ultraviolet, and X-ray. There are tabs along the bottom of the screen that can be tapped, with text appears on the types of wavelengths represented in the exhibit. Touching a small information icon on the image allows the user to read additional content about the image under that particular wavelength. For example, flipping the moon image, the user can read what aspects of the moon show up via X-ray.

*Figure 1.2. The Ideum 55” multi-touch tabletop with the electromagnetic spectrum software program.*

The exhibit is located in the middle of a large gallery that is along the main pathway through the center. It is surrounded by three live animal exhibits and a display on the local
commercial fishing industry. The multi-touch table exhibit has been customized for HMSC to include four microphones to audio record visitor conversations. In addition to the audio recording, there are several video cameras installed in the gallery. One camera view is focused on the multi-touch table and includes several feet surrounding it on all sides. The view includes what is occurring on the surface, so all manipulations of the exhibit can be seen. A research protocol is filed with Oregon State University’s Institutional Review Board regarding use of audio and video recordings in this public space.

**Participants.** Data collection took place in August 2014, with observation periods that included morning and afternoon sessions on each day of the week for a distribution of visitor attendance. For this research, a “family group” is defined as two or more members of a social group, with one member presumed to be above the age of 18. Adults and children approached the exhibit under their own influence and stayed for as long as they liked. The adult and child had to use the exhibit at the same time for at least a minute to qualify for participation. After they had walked away from the exhibit, I recruited the adult regarding the group’s participation in the study. A total of 25 family groups agreed, and no one that was recruited declined.

**Data collection and instruments.**

**Post-use surveys.** I collected information about basic demographic details for each family group including the ages of family members, highest education level of the group, and where they were visiting from on a paper-based survey. The families were interviewed as a group regarding their motivations for using the exhibit and a description of what they were doing at that time. A small number of the adult participants also agreed to be called to talk about their experience approximately eight weeks later.
**Video observation.** Since 2011, the Visitor Center at HMSC has been developing and installing an infrastructure to support research in the museum space. Up to 35 cameras have been placed in the public galleries for the purpose of recording visitor interactions with other guests and staff, and how they engage with exhibits, to understand elements of free choice learning. Surveillance cameras are placed above the exhibits to create a less obtrusive experience and have the capacity to record continuously during open hours. Microphones are strategically placed to collect data in the form of verbal utterances for analysis. I analyzed the video recordings of 25 family groups for the verbal and nonverbal behaviors they expressed while interacting with the digital tabletop.

**Observational rubric.** To categorize the combination of verbal and nonverbal behaviors from the overall interaction during exhibit experience, I constructed a rubric that was comprised of three dimensions with increasing engagement levels along a 5-point scale. The format and content of the rubric was modeled after observational coding strategies employed in the classroom between teachers and students (Pianta, La Paro, & Hamre, 2007), family behaviors in the museum environment (Borun, Chambers, & Cleghorn, 1996), and the teaching-learning behavior categories outlined by Piscitelli and Weier (2002). I coded adult and child behavior using the operationalized definitions of the three dimensions titled responsive engagement, learning strategies and opportunities, and directive engagement.

**Overview of the Thesis Chapters**

This thesis incorporates four chapters that provide a description and analysis of a study of family interactions around a multi-touch table in a marine science center, the methods used to collect the data, how this work contributes to the field of informal science education, and recommendations for communicating science content via multi-touch technology. Chapter 2 (to
be submitted to *Visitor Studies*) includes an in-depth focus on the methods of this research project, which involves the development of the tools used to assess family engagement while interacting with the multi-touch table. The results and discussion of that analysis, and how it relates to existing literature, are also found in this chapter. Chapter 3 (to be presented as a white paper for the National Science Foundation which funded the Cyberlaboratory at Oregon State University) provides an overview on the unobtrusive video technologies that have been used for this research project as a way to document family interactions. This project demonstrates the functionality of this camera system to conduct research. The final chapter includes a summary of prior chapters, the original question, previous work, and how the results connect to informal science education and science communication involving the public. This piece also outlines implications and recommendations for improvement of the use of multi-user touch technology as a vehicle for presenting science content to diverse audiences in a way that fosters distributed meaning-making and social engagement. Limitations of the study and suggestions for future research are also discussed.
References


Chapter 2: INTERACTIONS AROUND THE TABLETOP: ANALYSIS OF FAMILY ENGAGEMENT WHILE USING A TOUCH TABLE EXHIBIT

Learning Within the Family Group

Learning is not simply a biological event; it is part and parcel of culture. At birth, while we have the capacity for perception, awareness, emotional connection, even rudimentary reasoning schemas, we lack the knowledge and skills for automatic social competency in our surrounding culture, including the ideas, values or behavior patterns typical of our social and cultural groups (Ogbu, 1995). Biological factors of development are important, but from as early as we can interact with caregivers, cultural drivers of development operate as well (Vygotsky, 1934/1981). Cultural values, beliefs, and norms are imparted beginning at a young age with our caregivers having a distinct role in shaping and scaffolding our social interactions within the family group (Pellegrini, 2009; Rogoff, 1990; Wood, Bruner & Ross, 1976). We learn about culture from our caregivers and family groups, and our culture defines what we learn (Ogbu, 1995).

Two strategies of learning that promote cultural values within family groups are the communication of information in verbal and nonverbal forms and learning through observation (Rogoff, 1990). Verbal communication refers to the use of language, whereas nonverbal communication can involve gestures, facial expressions, or body language. All of these forms have cultural value and must be learned by the child (Ogbu, 1995). The communication and conversation that incorporate these behaviors takes place in everyday situations and settings, such as the home or other places where families spend time together. In these situations, caregivers may instruct or demonstrate how to perform an activity or task to which the child observes. They may attempt to model this behavior on their own and the caregiver assesses the ability of the child to accomplish such a task. These experiences may not have a formal
educational outcome, but learning is taking place, transpiring in a non-linear fashion. As previously mentioned, learning opportunities can take place whenever the family is together, including where they spend their leisure time together. One of those locations are informal science settings, such as museums, science centers, and aquariums.

Museums are seen as a place for learning, or a resource that fits into the broader sociocultural context of society that integrates culture, education, and leisure (Cremin, 1976; Falk, Moussouri, and Coulson, 1998). Family groups are a large segment of the population that attend museums in their free time with at least 50% of visitors coming as part of a related multi-generational group (Falk & Dierking, 2000; Hilke, 1989). As with any caregiver interaction, parents may play a role in facilitating engagement with exhibits and ideas in a museum whether it is demonstrating how to use an exhibit element (Borun, Chambers, & Cleghorn, 1996), explaining the content (Crowley & Callanan, 1998; Diamond, 1986) or telling explanatory stories (Rowe et al., 2002). These behaviors are indicative of social learning processes, with museum objects mediating the physical and verbal expressions, and facilitating the articulation and transfer of beliefs, values, and attitudes unique to the group (Borun, 2002). These interactions are important within the family group as it allows for the expression of new ideas or explanations, contribution to group meaning and understanding, and provides the meaningful social interaction that drives motivation, identity development and mastery of content and skills (Ash, 2004; Borun, Chambers, & Cleghorn, 1996; Crowley & Callanan, 1998; Rowe, 2002, Wertsch, 1988).

Most studies that have focused on family learning strategies in the museum setting have been qualitative naturalistic observations (e.g., Borun, Chambers, & Cleghorn, 1996; Diamond, 1986; Hilke & Balling, 1985; McManus, 1987). Early on, researchers began exploring the role
conversation played, recognizing that it is an important element of social interaction that facilitates not only for the transfer of knowledge, but also organization of activity, clarification of goals and roles in interaction, and even clarification of group identity or purpose (Allen, 2002; Ash, 2003; Borun et al., 1998; Gutwill & Allen, 2010). These studies also indicate how families make meaning of content while exploring their interests in a cultural institution like a museum. Crowley and Callanan’s (1998) research at the Children’s Discovery Museum of San Jose, demonstrated that parents had a significant role in the guidance and facilitation of the exhibit experience. Explanations included how to make the exhibit work, how the purpose or function of the exhibit links to real-world phenomena, and making links to formal scientific principles (Crowley & Callanan, 1998). The facilitation and involvement of a parent supported a deeper level of engagement by the child than if the child was using the exhibit alone (Crowley & Callanan, 1998). Ash (2004) observed parents using questioning strategies with children as families explored dioramas in the Natural History Museum of Los Angeles County. These strategies incorporated prior knowledge, were open-ended, and provided further explanation as they made sense of the biological themes represented on display (Ash, 2004). Additional evidence on family interactions involving science content includes the work of Zimmerman, Reeve, and Bell (2010). The methodology was a combination of ethnography and discourse analysis, interviews, and video observations of family groups attending to a biological content exhibit at the Pacific Science Center. Zimmerman, Reeve, and Bell (2010) found that families used “connecting and analyzing talk” (p. 486) to make sense of exhibit content as a way to transfer knowledge. The applied use of analogies and metaphors linking to popular culture, literature, and everyday experiences were also documented (Zimmerman, Reeve, & Bell, 2010; p. 500). While these research studies show evidence of parent and child interactions at exhibits,
they also contribute to a broader understanding of social learning methods within a particular cultural group such as the family.

While there is value in what is said between adults and children to make sense of cultural content in museums, what is often missing from analysis is how it is said and the other physical behaviors that are going on simultaneously that contextualize what is said. For example, the mere presence of the adult at the exhibit with the child allows for the opportunity for verbal engagement to occur. Nonverbal gestures such as pointing and demonstrating in combination with verbal utterances add other layers to communication and to the learning experience (Rowe, 2002; Rowe & Bachman, 2012). The physical orientation of a group may influence the responsiveness to others’ actions or statements. The gestures that family members make to the exhibit can influence the experience or what is interpreted based on the content presented. Investigating talk and action as it relates to objects, including those that are digital, provides a more complete picture of the interaction and engagement within the family group.

**Visitor Interactions with Technology**

Digital technology is another type of exhibit that can be used to represent a cultural object or to supplement the presence of the physical object. It is one form of communicating information and can facilitate multiple layers of open-ended exploration depending on design. With the increasing presence of digital interactives in the museum environment, questions that have been proposed include engagement levels between users, whether it creates a distraction from other objects on display, and what meaning making strategies may be expressed between users (Hornecker, 2008; Davis et al., 2013; Gammon & Burch, 2008). Digital interactives can range in scale from a single-user kiosk to large multi-user tables and walls. Research and evaluation studies that focus on the elements of learning between visitors using interactive
Tabletops in the museum environment are limited despite the increasing presence in these spaces (Block et al., 2015). Much of the research on interactive touch tables has focused on usability and functionality of the hardware (Corriea, Mota, Nobrega, Silva, & Almeida, 2010), software (Antle, Bevans, Tanenbaum, Seaborn, & Wang, 2011; Block et al., 2012; Martinez, Collins, Kay, & Yacef, 2011), in controlled lab settings (Buisine, Besacier, Aoussat, & Vernier, 2012) and in public spaces (Peltonen et al., 2008). There have also been investigations on multi-touch tables and their contribution to fostering collaborative use for problem solving and discussion in a format that is playful and engaging (Buisine, Besacier, Aoussat, & Vernier, 2012; Higgins, Mercier, Burd, & Joyce-Gibbons, 2012; van Dijk, Lingnau, Vissers, Kockelkorn, & Nijholt, 2014). The design of a multi-touch table allows multiple users to contribute input at the same time, which is not the case with many kiosks or computer formats, particularly in the museum environment. The device allows for the users to gather around the table, which contributes to working together, but Buisine et al. (2012) pointed out that the attractiveness of the object may influence collaboration levels as the users focus on the tool or system. In a review of the literature, research focusing specifically on engagement levels between adults and children, or family groups, while using this technology in a museum environment is lacking. The value of the outcome and experience of these types of interaction requires further investigation, particularly for exhibits that are seen as enabling social learning (Hein, 1998).

Hornecker (2008) conducted one of the earlier qualitative studies on engagement with interactive tabletops in the museum environment. In the Berlin Museum of Natural History, a tabletop was installed with the “Tree of Life” application that presented content on different animal species. This exhibit had a projector setup and used sensor technology that detected physical movements in proximity of the surface. Using rapid ethnographic methodology,
Hornecker (2008) observed and documented behaviors and conversations occurring around the exhibit without intervening. She found that there were several gestures used to manipulate content, including one or several fingers used to tap content (Hornecker, 2008). While the general functionality was discovered relatively quickly, particularly if watching others, there were visitors that walked by without recognizing that the exhibit could be manipulated by touch (Hornecker, 2008). From the analysis of conversations, Hornecker (2008) found that most comments surrounded “how-to” use the exhibit versus the content and there were limited examples of connections to prior experiences or knowledge through anecdotes. Hornecker (2008) indicated that consideration is needed for applications in the museum space, and creating content that is beyond browsing of information to reach deeper levels of engagement by the visitors.

In 2010, Hornecker and Nicol (2011) conducted an evaluation of young families exploring historical content presented in a game format on touch screens and a table at the Robert Burns Birthplace Museum in Scotland, United Kingdom. The table game was designed with overhead projectors pointing down to the surface; therefore, it was a different design from a true touch screen monitor. The goals of this evaluation were to investigate ease of use, enjoyment, and game play in order to provide recommendations for improvement (Hornecker & Nicol, 2011). From their observations there was evidence of parental facilitation, particularly showing younger children how to use the technology, and reading content aloud. Despite this support, parents also allowed their children the freedom to explore the functionality of the exhibit (Hornecker & Nicol, 2011). The evaluation took place in a controlled environment, so the question remains as to how the families would have behaved without researcher intervention and encountering this exhibit on the museum floor (Hornecker & Nicol, 2011).
Davis et al. (2013) investigated dyadic interactions surrounding content on the topic of evolution via a tabletop exhibit installed in two natural history museums in the United States. The program called “DeepTree” presented a visual representation of the ancestral relationships between organisms, while providing content on biodiversity and shared traits between common ancestors (Davis et al., 2013). The dyads that were the focus of the study consisted of children ages 9- to 15-years, with the pairs randomly assigned to one of four different activities, one including the use of the “DeepTree” software on a multi-touch table. Through the qualitative analysis of video footage of the physical and verbal interactions as well as individual interviews, Davis et al. (2013) found that the dyads negotiated goals for use of the exhibit, as well as “spontaneous” and thoughtful meaning-making involving the content (p. 7). Davis et al. (2013) noted that the children learned how to use elements of the exhibit by observing the other, and though they may have had conflicting goals, such as what to explore, they negotiated this through speech and actions. Davis et al. (2013) also found limited instances of utterances that indicated the children were relating the content they were interacting with to prior knowledge and experience. This provides some insight that the technology is mediating a learning experience between peers while allowing interpretation of science content.

Recent research conducted by Block et al. (2015) at the California Academy of Sciences on interactive tabletop exhibits contributed evidence related to group engagement while assessing use of data collection involving both naturalistic and video recording methods and effects on behavior. Study design incorporated quantitative assessment of engagement that included dwell time and the frequencies of physical and verbal behaviors. The software that was used in this study were two different programs that involved evolutionary relationships and allowed visitors to explore visualizations of the Tree of Life, one being DeepTree, the other
Build-a-Tree (Block et al., 2015). Two methods of observation were incorporated to independently document engagement twice, one being real-time coding of behaviors and the other through review of video recordings. Data was collected on the behaviors of 629 visitors spanning the ages of young children to adults (Block et al., 2015). Statistical analysis on data collected through naturalistic observations indicated that group size, age composition, and the occurrence of specific social behaviors significantly influenced group engagement with the tabletop exhibits (Block et al., 2015). These results have implications not only on how groups interact with touch tables and whether they are discussing content, but also how to design software programs that correspond with observed use and engagement.

**Purpose of the Study**

The previously mentioned studies are linked in their focus on digital tabletops in the informal space and on visitor use and engagement. There was an emphasis on noting how people use table tops to make sense of presented information, documenting the interactions that were occurring, via conversations or physical gestures, and whether particular strategies were employed. All of these studies had an element of performing a particular task or some form of researcher interference, whether by prompting or shadowing to note user behavior. Though the specific content varied with three of the studies, this type of content was primarily information browsing. Users could read text and look through pictures. Build-a-Tree is designed as a puzzle game linking evolutionary relationships, so this is a different level compared to basic information browsing (Block et al., 2015). Despite their similar project aims, what is missing is the combination of the unobtrusive documentation of behaviors between adults and children on an active museum floor, with the freedom to explore content on their own and under their own motivations. Considering the combination of these elements, what depth of interaction and
engagement do family groups reach while using an interactive tabletop together? My research design expands or improves upon the work of studying use of multi-touch exhibits in these ways.

**Guiding Question**

The question framed for this study is *what levels of interaction and engagement are expressed between adults and children at a multi-touch table exhibit installed in a public marine science center?* To what degree are performance interaction indicators framed as “responsive engagement,” “learning strategies and opportunities,” and “directive engagement” expressed between adults and children while using the exhibit?

This qualitative, descriptive case study of 25 families, uses observational techniques and semi-structured interview methods to investigate these questions. A purposive sampling strategy was used to target adult and child use of the exhibit, where at least a minimum of one minute of time was spent manipulating the exhibit. As a way to assess the engagement levels, this study adapted a rubric format that combined behavioral indicators of family learning in museums with teacher and student interactions in a formal classroom setting. The scale increases in complexity incorporating both verbal and nonverbal behavior in consideration of the socio-cultural framework that supports individual learning.

**Methods**

**Overview.** This study took place at Hatfield Marine Science Center Visitor Center (HMSC), located in Newport, Oregon. HMSC is affiliated with Oregon State University (OSU) and operated by Oregon Sea Grant. Approximately 150,000 people pass through the main entrance over the course of the year, with the highest attendance counts in the months of June, July, and August. There is a combination of interactive exhibits with descriptive signage and live
animals that showcase both local and regional research and projects done by OSU faculty, graduate students, state and federal agencies, and private industry.

Exhibit. A 55” Ideum multi-touch tabletop exhibit (Figure 2.1) is installed in the Visitor Center. This particular touch surface is approximately the size of a small kitchen table that four people can stand around and use at the same time. For the duration of this study, the content displayed on the table was designed by Ideum and is titled “Electromagnetic Spectrum.” There are five different images that a user can drag across the screen, re-size, and rotate (Figure 2.1). The images are a robot, the moon, the crab nebula, an alarm clock, and a human foot in a shoe. Changes can be seen in the image depending on where it is located along the spectrum, which spans the length of the screen. The different sections are infrared, visible, ultraviolet, and X-ray. For example, when the image of a boot is moved to the X-ray section of the spectrum, the user can see the bones inside the foot. There are tabs along the bottom of the screen that can be tapped, so that text appears about the types of wavelengths represented in the exhibit. Touching a small information icon on the image allows the user to read additional content about the image under that particular wavelength. For example, flipping the moon image, the user can read what aspects of the moon show up via X-ray.

Figure 2.1. The Ideum multi-touch table with the electromagnetic software program.
The exhibit is located in the middle of a large gallery that is along the main pathway through the center. It is surrounded by three live animal exhibits and a display on the local commercial fishing industry. The multi-touch table exhibit has been customized for HMSC to include four microphones to audio record visitor conversations. In addition to the audio recording, there are several video cameras installed on the gallery walls. One camera is focused on the multi-touch table, including several feet surrounding the exhibit on all sides. The view includes the changes in the content occurring at the exhibit interface, so all manipulations of the exhibit are recorded. A research protocol is filed with Oregon State University’s Institutional Review Board regarding use of audio and video recordings in this public space.

**Data collection and organization.** Data collection took place in August 2014, with observation periods that included morning and afternoon sessions on each day of the week for a distribution of visitor attendance. For this research, a “family group” is defined as two or more members of a social group, one member presumed to be above the age of 18 and the other below that age. Adults and children approached the exhibit freely, stayed for as long as they liked, and explored the exhibit without interference. The adult and child had to use the exhibit at the same time for at least a minute to qualify for a post-use interview. I observed from a distance, sitting approximately ten feet away from the exhibit taking notes. The start and stop time at which each family used the touch table together was documented in field notes and then referenced later for to extract the associated video from the Milestone video management software that archives the recorded footage. Participant selection involved purposive sampling following the moment-by-moment judgment of the researcher (Allen et al., 2007); for example, if two interviewed groups in a row included younger children, I waited for an eligible group that consisted of older children. After they had walked away from the exhibit, I approached the adult regarding potential
group participation in the project studying use of the multi-touch table. Some groups moved away from the table quickly and were not able to be approached in time. Potential participants were informed about the study per an Institutional Review Board protocol and asked if they were interested in responding to interview questions about their experience using the exhibit. They were also notified that audio and video recordings of their time at the touch table would be combined with interview data. Out of all the families that were recruited, none of them declined participation after having the purpose of the study explained to them. A total of 25 family groups agreed to participate. There were two other families that were asked that did not move forward with participation. The adult for one of the groups was fluent in a language other than English, and a child declined participation in another case.

After providing an explanation of the research study and obtaining verbal consent and assent from the individual members of the group, one adult participant filled out a paper survey containing questions related to the demographics of the group, highest-level of education achieved within the group, and the zip code region they were visiting from (see Appendix A). The entire group was asked to describe their experience with the exhibit, including what motivated them to want to use it, and what they were doing, and I hand recorded these responses. Additional questions (e.g., “Can you tell me more about that?” “Does someone else have a different idea?” “Was that the case for each of you?”) were also used to probe answers for more specific details. A small percentage of the participants agreed to be called approximately 8 weeks later to talk about their experience. Out of the eight adults that provided their contact information for a post-visit interview, four adults completed the phone interview. The questions asked were related to recollections of their recent visit to HMSC, including what exhibits they used, if they
have visited again, and whether the family had talked about the touch table or had seen similar
technology since and these responses were hand recorded.

All of the interview responses were compiled and each group was assigned a number that corresponded in the order of their participation. I reviewed the demographic data to describe the characteristics of the 25 groups. The qualitative data from the interviews were imported to NVivo analysis software, and I conducted a content analysis as described by Berg & Lune (2012) on the responses the families provided to the open-ended questions. I approached the analysis inductively, limiting it to the manifest content of each family’s response, or their direct responses (Abrahamson, 1983). I examined the data at the level of words and phrases separated by natural pauses that were documented while I hand-recorded their responses. For the category of attraction and experience, I used the original question to systematically review the responses to uncover patterns or categorical themes that were revealed or repeated. The responses were then sorted into coding themes (Berg & Lune, 2012). Eleven themes were documented in relation to the attraction responses, and nine themes were documented with the experience responses. I tabulated the frequencies of the coded responses to determine which categories were referenced the most for each question.

**Video analytical framework.** To assess the quality of the engagement during the interaction with the exhibit, I developed a coding rubric modeled after performance indicators in the museum setting (Borun, Chambers, & Cleghorn, 1996) and emotional and instructional processes in the formal classroom environment (Pianta, La Paro, & Hamre, 2007). The rubric was used to assess visible behaviors or observable actions and activities by members of the family group while at the tabletop exhibit (Boehm & Weinberg, 1997, p. 67). Rubrics and rating scales have been used to place a value on classroom observations including assessments on the
quality of the learning environment and teacher and student performance (Boehm & Weinberg, 1997; La Paro, Pianta, & Stuhlman, 2004). As La Paro et al. (2004) noted, much discussion has taken place to define or operationalize the quality of early childhood classrooms and how that relates to academic achievement. A similar challenge takes place in the field of informal science education, particularly in the museum space as there is complexity to assigning value to the behaviors between adults and children and understanding the extent of the personal imprint from a brief experience. The aforementioned studies of family learning indicate that there are patterns of behaviors, including the facilitation of the child’s experience by adults, and these behaviors were considered in the design of the rubric for this research.

**Rubric development.** In association with the Philadelphia/Camden Informal Science Education Collaborative (PISEC), Borun et al. (1996) investigated family learning at four institutions in the United States including a zoo, aquarium, science center, and natural sciences museum. Through unobtrusive observation of families using exhibits, they coded exhibit-related verbal and physical behaviors. Behaviors were grouped as a form of measure that increased in learning complexity along a scale (Borun, Chambers, & Cleghorn, 1996). Referenced as “Learning Levels,” the base level consisted of the family identifying elements within the exhibit, the second level is describing, and highest level considers interpreting and applying the knowledge or information (Borun, Chambers, & Cleghorn, 1996). From the results of the research conducted by PISEC, there was evidence that “families do learn from exhibits” and “the level of learning is related to specific observed behaviors” (Borun, Chambers, & Cleghorn, 1996, p. 135).

In the classroom, observational methods have been used to assess emotional and instructional interactions in early childhood development between teachers and students through
use of a rubric known as Classroom Assessment Scoring System (CLASS) (Pianta, La Paro, & Hamre, 2007). Pianta et al. (2007) observational measure of quality dimensions between teacher and child that incorporates social features as a form of responsive interaction, and instructional aspects that support concept development. Use of Likert-type scale values from 1-7, with segmented ranges of 1, 2 as “low,” 3, 4, 5 as “mid-range,” and 6, 7 as “high.” This assessment tool has been generated to investigate the global quality of the classroom across nine different constructs for various grade levels. The format of the metrics, vocabulary and description of behaviors provided a useful foundation for the development of the rubric proposed here.

The categories of interactive teaching and learning behaviors I used directly were based on the examples outlined by Piscitelli and Weier (2002) that referenced family engagement with objects in an art gallery. Their proposed categories included “nondirective,” “scaffolding,” and “directive” with several examples of the types of behaviors that fall under those headings (Piscitelli & Weier, 2002; p. 127). Examples of nondirective behaviors include physical proximity, listening, acknowledging, and encouraging. Examples of scaffolding include providing information, reading, explaining, questioning, and co-constructing. Examples of directive behaviors include instructing and directing in relation to an activity or task. Piscitelli and Weier (2002) stated that some behavior strategies may support learning on their own, “a balance of behaviors from each of the three categories contributes significantly to the quality of an extended adult-child interaction” (p. 128). Components of these categories and the example behaviors were incorporated into the rubric, but modified in consideration of the work done by Borun et al. (1996) and Pianta et al. (2007).

The assessment of the overall interaction between adults and children at the touch table are reflected in the design of the coding rubric (see Appendix B), which incorporated strategies
from both the formal and informal learning environment and included verbal and nonverbal behaviors. The categories, or dimensions of learning, were designated as the following: responsive engagement, learning strategies and opportunities, and directive engagement.

*Responsive engagement.* Responsive engagement is the degree to which the adult and child remain within physical proximity and recognize the comments and questions of other members of the group through verbal or behavioral actions. Examples of these types of behaviors include the adult and child maintain proximity with each other and the exhibit. There is evidence of the adult and child listening to ideas, acknowledging that they have been heard, which could be a verbal response.

*Learning strategies and opportunities.* Learning strategies and opportunities is a category that reflects the degree to which the adult and child engage in sharing information about concepts, questioning the content, and recalling and integrating this experience to external events. These behaviors could be demonstrated by the adult and child having conversations that involve providing information, answering questions, describing or providing examples, and reading exhibit content aloud. The adult and child may use questioning strategies that are either open or closed in nature. The adult and child may also reference events external to use of exhibit to recall and integrate information. This could include recalling previous experiences from memory or referencing prior knowledge.

*Directive engagement.* These behaviors are defined as the degree to which the adult and child participate in demonstration, instruction, or direction as related to a task or skill oriented behavior during use of the exhibit. These tasks are related to the manipulation of the exhibit to explore the content. Evidence of this type of behavior includes the adult showing the child how a task is done to help the child acquire that behavior, such as how to drag an image across the
screen. The adult may instruct or pass information on to the child or gives guidance on how to perform an action. The adult may guide the child’s behavior in order to facilitate the manipulation of content.

Within the coding rubric, each dimension or metric was stated and defined with example behaviors and a rating value along with the requirements that constitute each code value. Similar to CLASS (Pianta, La Paro, & Hamre, 2007) a numerical scale with values of (1) low, (2) moderate, and (3) high were initially used to code the behaviors at the dimensions of responsive engagement, learning strategies and opportunities, and directive engagement. These values provide an indication of the presence of behaviors that were seen during interaction with the exhibit, increasing in complexity or frequency along the scale. For example, the more questions that were asked would point to a higher level of engagement as defined along the scale.

Coding of the video recorded interaction began when the adult and child started using the table together. I would watch the interaction between the adult and child in its entirety and assign a value for the behaviors based on the definitions outlined in the codebook. The start and stop times of the coded interaction were noted. If either the adult or child stepped away from the exhibit, remained in the gallery, and came back to the exhibit to re-join the group, I only coded the portion when the group was together. For example, if the adult walked to another part of the gallery and the child remained on their own, this portion was not coded. This occurred with four family groups, where either the adult or child walked away and came back in a short time frame. Therefore their complete interaction together was considered holistically.

Assessing the rubric. I trained a fellow researcher to code a sample of videos, randomly-selected, within the overall set of 25. Two training videos were viewed together, then eight were coded separately and the assigned values were compared. Agreement values were low in the first
iteration of the codebook, so the language describing the behaviors was revised to be more explicit between scale values. During the revision of the coding rubric, the rating scale was expanded from three-points of low, moderate, and high, to five-points, incorporating scores of (1) very low to (5) very high (Appendix B & C). This was an attempt to more distinctly separate behavioral indicators along the scale that may not have been as clearly operationalized and documented in the three-point scale. For the categories that were not in exact agreement, we discussed our ratings and came to a consensus. For the responsive engagement dimension, 50% of the videos were coded with exact agreement. For learning strategies and opportunities, 88% of videos were coded with exact agreement. For directive engagement, 63% were coded with exact agreement. All values that were not in agreement before coming to a consensus were no more than one category off, for example, one rater coded high, and the other coded moderate.

Initially the construct of emotional affect was included in the responsive engagement dimension. Within the first use of the coding rubric and upon watching a sampling of videos, it became difficult to assign these elements together. For example, a rating of a high level of responsive engagement involves the adults oriented to the exhibit for the majority of the interaction, with their hands on the table, focused on the activity. During this time, they may not be verbally or nonverbally expressing warmth and enthusiasm during participation, similar to the affective talk as described by Allen (2002), but still engaged in a back and forth conversation. I could not justify giving a lower value to responsive engagement if there was evidence of behaviors listed in the higher category values. Therefore the component of affect was removed from the responsive engagement dimension. A sense of affect was noted for each family (positive, neutral +, neutral, neutral -, negative), but this was not linked directly to the three major dimensions. Emotional affect became more of a descriptive quality of the overall family
experience. Based on holistic review of the video, if there was evidence of both the child and
adult expressing an enthusiastic, warm tone of voice throughout the interaction or matching the
appearance of the other’s warmth, then the experience was rated positive. If the adults and
children had a cold tone, a lack of enthusiasm, or were matching in apathy then the interaction
was labeled negative for emotional affect. Neutral was a mixture of warmth and engagement,
with emotional engagement at times, but other instances there was a lack of connection between
the adults and children. Neutral (+) was assigned if the children and adults did not match, for
example the children were excited and the adults were neutral. If the children were neutral and
the parents appeared bored or disinterested, then neutral (−) was assigned.

Ratings for the eight randomly sampled double-coded videos were added to the SPSS
software program to calculate Cohen’s kappa (1960) for inter-rater reliability for each of the
coding dimensions. The dimension with a highest kappa value was learning strategies and
opportunities (κ = 0.75). The other dimensions were (κ = 0.27) for responsive engagement, and
(κ = 0.27) for directive engagement. Nonparametric bivariate correlations (Spearman’s rho, two-
tailed) were run with each dimension against the others to see if ratings for one dimension could
serve as a “proxy” or indicator measurement for the others. The results indicated weak positive
correlations and are discussed below.

Results

The family groups. Of the 25 families that participated in the August 2014 study, 64%
(n=16) were visiting from within the state of Oregon. The remainder were visiting from
Washington (n=5), Idaho (n=3), and Utah (n=1). About half of the groups that participated had
previously visited the HMSC Visitor Center (Yes, n=12). Considering the distribution of the size
of groups using the touch table, a majority of groups were using the exhibit in a pair or dyad
(n=14). Groups of three (n=5) and four (n=6) also used the exhibit together, having different mixtures of adults, children, and genders within the group. Of the 67 total participants, 39 were female, and 28 were male, ranging in age from 4 years to 58 years old (Table 2.1).

Table 2.1

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>28</td>
<td>42</td>
</tr>
<tr>
<td>Female</td>
<td>39</td>
<td>58</td>
</tr>
<tr>
<td>Total</td>
<td>67</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult (18 &amp; Up)</td>
<td>32</td>
<td>48</td>
</tr>
<tr>
<td>Child (17 &amp; Younger)</td>
<td>35</td>
<td>52</td>
</tr>
<tr>
<td>Total</td>
<td>67</td>
<td>100</td>
</tr>
</tbody>
</table>

Based on the responses post-use of the exhibit, 12% of the participants reported that they “do not have access to touch screen technology on a daily basis.” For those that reported the highest level of education a member of their group has completed, the most frequent response was “some college with no degree” (28%), followed by a graduate or post-graduate degree (24%) (Figure 2.2).

![Figure 2.2. Distribution of the education levels among the family group participants.](image-url)
The family groups describe their experience. Family groups were asked what attracted them to the exhibit and the most frequently mentioned response was involving the content on the table (n = 28; Table 2.2). The adult and child participants referenced specific images such as the boot and foot, the crab nebula, and the moon. They also mentioned the term “lights” and the x-ray phase of the spectrum. Responses related to affect, or a descriptive adjective about the exhibit, such as a “cool way to show images and information” or “interactive” and “visually appealing” (n = 27) had the second highest frequency. How the exhibit functions or how to use it (n = 24), such as “you can touch it” and prior knowledge or experience (n = 20) were other themes mentioned. Prior knowledge or experience focused on references to information or a prior encounter of similar nature outside of the immediate experience. Participants referenced seeing similar technology at Disneyland, the table was like an Apple iPad™, and they had observed use of these tables on television or in movies. The fact that the exhibit was technology, or an object not seen before, was not mentioned as often as these other themes.
Table 2.2

*Common Themes from Family Group Responses to Exhibit Attractiveness*

<table>
<thead>
<tr>
<th>Code Category</th>
<th>Definition</th>
<th>Example</th>
<th>Number of References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content</td>
<td>Reference to what is on the table, description or identification of content</td>
<td>Pictures of different lights, colors, specific image labels</td>
<td>28</td>
</tr>
<tr>
<td>Affect</td>
<td>Descriptive adjective</td>
<td>Neat, cool, fun</td>
<td>27</td>
</tr>
<tr>
<td>Function</td>
<td>How the table works, how to use the table</td>
<td>Spinning images, you can touch it, you can slide</td>
<td>24</td>
</tr>
<tr>
<td>Prior Knowledge or Experience</td>
<td>Reference to prior experience outside of the encounter, application of knowledge</td>
<td>Like an iPad, seen on TV, talked with kids about light/sound spectrum</td>
<td>20</td>
</tr>
<tr>
<td>Technology</td>
<td>Reference that the exhibit is electronic or in the format of technology</td>
<td>It’s an electronic, new technology, it was a computer</td>
<td>13</td>
</tr>
<tr>
<td>Child’s Experience</td>
<td>Adult response in connection to what child is doing or experiencing</td>
<td>Interactive for kids, seeing boys interested</td>
<td>13</td>
</tr>
<tr>
<td>Novelty</td>
<td>New object to the respondent</td>
<td>Never seen before</td>
<td>13</td>
</tr>
<tr>
<td>Appearance</td>
<td>How the table physically looks</td>
<td>Looked high-tech, looked cool</td>
<td>9</td>
</tr>
<tr>
<td>Identity</td>
<td>Reference to a description of self</td>
<td>Like technology, into board games</td>
<td>7</td>
</tr>
<tr>
<td>No Answer</td>
<td>Did not provide an answer, answer was not relevant to the question</td>
<td>I don’t know</td>
<td>5</td>
</tr>
<tr>
<td>Social</td>
<td>Presence of others at exhibit</td>
<td>Others using it</td>
<td>1</td>
</tr>
</tbody>
</table>

In response to the question asking the group to describe their experience using the tabletop, the most frequent theme was about function of the exhibit, including actions of manipulation, what it does, or how the table works (n = 55; Table 2.3). Families mentioned moving pictures through the different regions, flipping pictures over, seeing things differently under different wavelengths. Content was the second-highest mentioned theme with visitors
indicating what they saw or naming specific content (n = 44). This included the identification of different parts of the spectrum by name, specific images present in the exhibit. Comments related to emotional affect were the third most frequently mentioned response, or feedback on the experience as either positive or negative (n = 26). Examples of this included that the images were big and fun, and they wanted more interactive displays. A few responses were related to performing an activity, such as reading, playing, looking, or learning. There were two instances of an adult explicitly referencing the child’s experience and watching them or trying to get them to read.

Table 2.3

<table>
<thead>
<tr>
<th>Code Category</th>
<th>Definition</th>
<th>Example</th>
<th>Number of References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>Actions of manipulation of exhibit, what it does, how it works</td>
<td>Moving things, making finger swipes, touching</td>
<td>55</td>
</tr>
<tr>
<td>Content</td>
<td>Identification or naming specific content</td>
<td>Normal, alarm clock, different colors</td>
<td>44</td>
</tr>
<tr>
<td>Affect</td>
<td>Feedback on experience, good/bad</td>
<td>Liked X-ray, images, big and fun</td>
<td>26</td>
</tr>
<tr>
<td>Activity with specific content</td>
<td>Performing activity to accomplish task or manipulate, interpret content</td>
<td>Crab nebula discussion, look at moon through X-ray</td>
<td>19</td>
</tr>
<tr>
<td>Activity</td>
<td>Exhibit interaction</td>
<td>Read, play, look, learn</td>
<td>17</td>
</tr>
<tr>
<td>Novelty</td>
<td>Unfamiliar, new to participant</td>
<td>Size, never used</td>
<td>8</td>
</tr>
<tr>
<td>Connection to other experience</td>
<td>Recollection or association</td>
<td>Like a dinner table, seen on video</td>
<td>6</td>
</tr>
<tr>
<td>Child’s experience with exhibit</td>
<td>Adult comment of kid use</td>
<td>Watching child</td>
<td>2</td>
</tr>
<tr>
<td>Identity</td>
<td>Describe self</td>
<td>Amateur astrophotographer</td>
<td>2</td>
</tr>
</tbody>
</table>

Out of the eight adults who provided their contact information, four adults participated in a post-visit interview approximately six weeks after their trip to HMSC. When asked what they
remembered about their recent visit, all four discussed use of the touch table. Three of the adults mentioned the live animal exhibits, whether it was “animals,” “touch tank,” or “shells.” Two adults referenced the hands on exhibits and displays, and two mentioned the octopus. There was one mention of the tsunami table. When the participants were asked to describe the exhibits they remembered, the octopus encounter was mentioned, as well as the tsunami wave exhibit and the general hands-on activities at the site. Three participants specifically mentioned elements of the touch table, referring to “wavelengths of light,” “images from visible to x-ray,” “waves and energy,” and “move images on [the] table.” Two participants mentioned discussing the table with their family group right after leaving the visitor center, one indicated a few times, and one mentioned telling another friend about the table who wanted to see it for themselves. The participants were asked if they had visited HMSC since the date in August when they were there and one out of four had returned, this person living locally. While this very small sample on post-visit recollections cannot provide any strong conclusions, memories of the table content did stay with some of the participants in the form of basic general knowledge and vocabulary about the electromagnetic spectrum.

**Video coding results.** Out of the 25 observations, the average time adults and children spent interacting together was 3 min 25 seconds (SD=95.2 seconds). The longest amount of time a group of adults and children spent together at the table was 7 minutes 13 seconds. Among the distribution of time that adults and children used the exhibit together, 60% of the family groups spent between 2 to 4 minutes together (Figure 2.3). In review of the emotional affect demonstrated by the family groups, there was an overall sense of enjoyment using the touch table, with 40% assigned a positive rating. No family expressed apathy, boredom, or a cold tone while using the exhibit.
A moderate rating was observed for 68% (n = 17) of the 25 groups within the responsive engagement dimension. A moderate rating indicated that the adults or children spent approximately an equal amount of time focused on the exhibit or turning away and looking around. It also means that in a majority of instances the adults and children appear to be listening to each other by acknowledging comments or questions the other group members make. Out of 25 family groups, 60% were rated at moderate for learning strategies and opportunities. A moderate rating for learning strategies and opportunities indicates that on a few instances, adults and children reference the content of the exhibit, there may be one or two questions about exhibit content, and one or two references about prior knowledge or events outside of the immediate exhibit experience. For the directive engagement dimension, 56% of the groups demonstrated low levels, or less explicit instruction by the adult as to how to use the exhibit or perform specific tasks at the exhibit.

Responsive engagement. Family groups were most frequently rated at moderate for their observable behaviors in the responsive engagement dimension (n = 17; Figure 2.4). This reflects a mixture of users looking around at the surrounding gallery while at the touch table,
participating in use of the exhibit and watching others. A rating of moderate also indicated that
the users would step back or walk around the table, meaning their body was not always oriented
up against the exhibit during interaction. Families demonstrated a mixture of utterances or
responses to comments made by other members of the group, along with no explicit
acknowledgement of hearing what others were saying.

![Rating distribution for the Responsive Engagement dimension.](image)

_Figure 2.4_ Rating distribution for the Responsive Engagement dimension.

Two family groups were rated at _very high_, meaning that throughout the interaction the users did
not turn or look away from the exhibit and though they may have moved around the table, they
were consistently using the touch surface. The adult and child were also engaged in a regular
back and forth of communication and were in close physical proximity to each other and the
exhibit. The following sample reflects this responsive acknowledgement through verbal
communication as an adult and child have a back and forth conversation about use of the exhibit.
The adult and child were near each other at one corner of the table.
Adult female (41 years) and young female child (4 years):

**Child:** “Eh, this won’t move” *Child is trying to drag a content window, located along edge of the table, upwards.*  
**Adult:** “Oh this. You have to touch the arrow for it to go down.” *Completes action for child.*  
*Child says something indistinguishable in response.*  
**Adult:** “Oh, those stay. Those are…those are information about the different lights. See this is the x-ray, ultraviolet, that’s visible, and that’s infrared. See look, the moon.” *Adult is referencing the content boxes containing text along the edge of the touchscreen.*  
**Child:** “Ah, it’s red!” *Child reacts as adult pulls the moon into the infrared section.*

As the child expresses frustration with an action that is not taking place, the adult responds to support the situation. The adult is paying attention to the behaviors of the child as she makes physical gestures, but also to what she is saying. If the adult had chosen to ignore the child and use the exhibit independently, this would have resulted in a lower rating on the scale for the responsive engagement dimension. No group rated very low for responsive engagement, but two were rated low indicating that an adult or child was watching more than using the exhibit, walking away and coming back within a short period of time, and making limited acknowledgement of another group member’s statements.

*Learning strategies and opportunities.* For the learning strategies and opportunities dimension, 15 out of the 25 families rated moderate, with the remainder trending downward (Figure 2.5). Families were referencing content at a level of identifying the image such as “This is the crab nebula,” verbalizing where the image was located along the spectrum, or noting details within images. Adults and children were using the vocabulary within the exhibit, reading text aloud, narrating the movement of the image along the table, and making one or two references to prior knowledge or experiences.
In at least half of the groups observed, there was a reference to the use of prior knowledge connecting to current content as a form of identification or description. Questions were asked within 10 of the groups that were using the table, often related to identification or clarification of what they were looking at. For example “What’s infrared?” “What is that?” or “So do you know which is a shorter wavelength – infrared or ultraviolet?” There was repeated interest in the placement of photos under the X-ray section of the table. Family members would notice and point out the details in the boot image such as the bones in the foot, the nails within the shoe, or the eyelets for the boot laces. With regards to the vocabulary used, for the “visible light” section of the spectrum, adults and children referred to this as “how we see normally” a very everyday description. There was one example of an adult verbally questioning the validity of the content on display. Upon reading the text provided for ultraviolet light and connections to the size of a water molecule, the adult asked to himself aloud “What can be the size of a water molecule? I don’t get that.” Three family groups were rated very low due to observations of no talking or limited verbalization of the exhibit content. In two of these instances the children never mentioned the exhibit’s content and in the third, the adult made very few verbalizations during

Figure 2.5. Rating distribution for the Learning Strategies and Opportunities dimension.
the time spent at the exhibit. Here the adult was primarily observing the child’s use of table. In
these instances there was also no evidence of questioning or integrating the content with prior
knowledge. On the other end of the scale, two families rated *high* while no family rated *very high*
(Figure 2.5). The two families that rated high frequently referenced the content on the table, and
the adults would describe or explain content without being prompted by a question from the
child.

*Directive engagement.* For the directive engagement dimension, 14 out of the 25 family
groups were rated *low* (Figure 2.6). A *low* rating indicates less direction by the adult telling a
child how to perform tasks at the table.

For five of the groups, the child was explicitly showing adults how to use the exhibit, which
would also reflect in a lower rating. The premise of this dimension is that the adult is leading or
facilitating the experience to show child what to do or how to manipulate the touch table. This
rating was defined by adults and children connecting at least once as they performed tasks or
action at the table. The adults may verbally be instructing or demonstrating how to perform tasks
for the child. This was frequently the situation for the two family groups that were rated *high*, the
child participants in these instances were between four and six years-old. Adults were observed performing a task such as dragging a picture across the screen, and modelling this for other members of the group, but they were not often using explicit verbal instructions such as “take your finger and move the image this way.” The verbalizations were a narration of the activity performed, such as “this is what it looks like under ultraviolet rays” Adults would also do the action for the child, such as when they were trying to access the text content. The adult would tap on the information icon for the child. For the two families rated very low, the interaction was dominated by independent exploration. For the family groups that ranked high (n=4) or very high (n=2) in responsive engagement, four of the groups were rated moderate for the learning strategies and opportunities category. Therefore, while there was a high interaction level and hands-on participation between the adults and children, there were a few instances of the family group referencing exhibit content and asking identifying questions. For the two families that ranked high in the learning strategies and opportunities dimension, both ranked low for directive engagement, meaning there was less explicit instruction by the adult on how to use the exhibit. A high rating indicates that frequent reference to the content and use of the exhibit vocabulary is occurring, questions are being asked, and there may be some connection to external experiences as a way to interpret the content.

**A high ranked family group’s activity.** An adult female and female child, approximately nine years of age, used the table together for 3 minutes and 17 seconds. Their interaction was rated high for responsive engagement, high for learning strategies and opportunities, and low for directive engagement. The adult and child were in close proximity through the interaction and the adult and child took their hands off of the table briefly. There was
a call and response pattern to the conversation, meaning when either the adult or child said something, the other acknowledged with feedback. The following is a sample of their interaction.

**Child:** “Mom? What’s infaired [sic]?”  
**Adult:** “Infrared is uh, it’s not doing an image, it’s doing the heat put off by the image.”

**Child:** “Interrupts at end” “Whoa” Child is looking at the moon in X-ray  
**Adult:** “The crab nebula” Adult is looking at the underside of the image while child is looking at boot image.  
**Adult:** “Look at that.” Adult enlarges the image and text. “Trying to make it smaller.”

**Child:** “Ultraviolet? That’s a weird boot.”

**Child:** “Whoa, the moon…look.”

**Adult:** “Wow.”

**Child:** “In X-ray the moon is that color.”

**Adult:** “Wow! So that’s radiation coming off of it.” Child moves moon image and they share the image with their hands moving it across screen. “Ultra-violet light.”

**Child:** “Here, you have the moon.” Passes image over to adult.

**Adult:** “…visible…ah, okay.”

**Child:** “I just gave you the moon!”

**Adult:** “She gave me the moon…and I gave her the star.” Adult drops crab nebula image in front of child.

Specific content on the table was frequently mentioned and the adult described and explained her response to the question posed by the child. The adult was not explicitly directing the child how to use the table, and the child was also exploring the features on her own, but they both came together to discuss the content.

**A typical family group’s activity.** In this interaction an adult female in her 30s, and a six-year old male child used the table together for 3 minutes and 25 seconds. This particular interaction was rated *moderate* for all three dimensions.

**Adult:** “What is this? This is the crab nebula, bright white dot. We can also learn about the moon.”

*Child refers to clock image.*

**Adult:** “I like this one here. Oh a clock? Oh that’s really cool, here. Let’s look at the clock.”

*Child pushes images out of the way.*

**Adult:** “Yea, we gotta get these to go away. What do you want to learn about?”

**Child:** “I’m learning about this.” *Child has hands on crab nebula.*

**Adult:** “Crab nebula?”

**Child:** “I don’t know.”
**Adult:** “Here, while you do that, I’m gonna look at the clock.”

**Child:** “I’m gonna try out the crab nebula.”

With regards to responsive engagement, approximately half of the time the adult and child were at the table with their hands at the surface using it, and at other times they had stepped back or were watching with their hands resting on the edge over the course of the interaction. There was fairly consistent acknowledgement when someone would say something, but at times the group members would be focused on what was in front of them. There were a few instances where the use of the exhibit vocabulary was verbalized, as well as questions that were not directly related to building concepts, but a “What do you think?” form of question. For this interaction there was not an example of an explicit reference to prior knowledge. With a moderate rating for directive engagement, there is some instruction as to how to complete a task, such as how to flip an image to access text content or demonstration of moving images across the screen, but the facilitation role is not the main focus for the adult.

**A low ranked family group’s activity.** An adult female and female teenage child were together at the exhibit for 3 minutes and 26 seconds. The interaction was rated low for responsive engagement, very low for learning strategies and opportunities, and low for directive engagement with the lack of adult involvement. During a 30-second interval, the child referenced the content on the table:

**Child:** “This is how it normally looks.” Child has the boot image in the visible section of the spectrum and moves image to ultraviolet light where she pauses.

**Child:** “Almost the same, ultraviolet.” Child drags image to the X-ray section.

**Child:** Whoa, so that’s like if you were to X-ray your bone.” Child drags the boot image over the other direction, but brings it back to X-ray.

**Child:** “Oh, you can see the nails.”

The adult did not make any audible verbalizations during the interaction while watching the child use the exhibit. This was the extent of verbalization by the child over the course of the time at the
table. On a couple occasions the adult tapped the table, but also spent time several steps back from the table watching the child or looking around the gallery. The child appeared to direct more of the engagement despite interaction with the adult. The child independently identifies elements of content in the exhibit and makes the connection regarding the X-ray. In the remainder of the time at the exhibit, there were no questions asked, and little to no talking about the exhibit or in general.

**Adult-led directive engagement versus child-led directive engagement.** In at least five groups where directive engagement was rated at the lower end of the scale, there was demonstrated facilitation by the child to direct the adult on the use the exhibit. Depending on the category that the clips related to (whether the child was observed to direct the engagement or the adult was doing more of the facilitation) I reviewed the verbal statements and physical behaviors by the adult and child participants to see if patterns of specific strategies occurred.

Similar to the analysis methods used by Ash (2003), representative dialogic units (RDS) in addition to the corresponding contextual behaviors were pulled from overall video transcripts for a focused review in directive engagement. Examples of exclusions are comments made on whether the user “liked” the table, thought the exhibit was “cool,” or actions performed independently in relation to the individual’s interest, such as reading silently to oneself. I applied the method of open coding described by Berg and Lune (2012) to the RDS creating coding categories originating from the data. I converted the verbalization, at word or phrase level, and physical behaviors, into themes and sorted them to look for patterns (Berg & Lune, 2012). For phrases, if in a string of complete thought, it counted as a collective unit. If there was a pause, such as the end of a sentence, or an utterance that fell under a different category, this split a phrase into more than one unit to be counted. For physical behaviors, if the action was
continuous, such as dragging an image back and forth between the different spectrum sections, this was counted one time within that event. This process was done for both groups of videos, the directive engagement led by the child, and directive engagement led by the adult. Therefore, if the video fell under the child-directed engagement set, only behaviors done by the child were considered, and vice versa for the adults. The thematic codes were reviewed and compared quantitatively between all of the videos.

For the videos where a child expressed a high level of direction, all of the children were between the ages of 11 years to 17 years. There were two males and three females. In three of the videos, children had time to explore the exhibit on their own prior to the adult joining them. There were 51 instances of verbalization related to directing activity at the exhibit in comparison to 22 behavioral instances of guidance (Table 2.4). The most frequently used method of verbal guidance by children was instruction or direction (n=20) with statements such as “look,” or “…for information, just check…,” or “you don’t slide them, you click.” Identification of objects was the second most used strategy (n=15) with utterances such as “this is how it normally looks,” or “this is visible light.” Calling attention to the adult participant was another strategy to direct their attention to what the child was doing (n=6) using words such as “hey” or using the title of the adult, such as “Mom.” Children used physical demonstration to indicate the functionality of the exhibit by showing the adult how to tap, click, drag, rotate, or resize the images. This behavior occurred more often by children than when adults directed the engagement (Table 2.4).
Table 2.4  

*Strategies of Directive Engagement Demonstrated by Adults and Children*

<table>
<thead>
<tr>
<th>Verbalization Category</th>
<th>Example</th>
<th>Child</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instruction/Direction</td>
<td>Here, Move, Look, If…then, Come here, Watch</td>
<td>20</td>
<td>34</td>
</tr>
<tr>
<td>Identification</td>
<td>[Image name], This is what it looks like under [wavelength], This is how it normally looks</td>
<td>15</td>
<td>34</td>
</tr>
<tr>
<td>Calling Attention</td>
<td>Hey, [Title]</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Acknowledgement</td>
<td>Response to question of exhibit function</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Desire</td>
<td>I wanna, I want to</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Explanation</td>
<td>So it’s like heat, So that’s like if you were to X-ray your bone; <em>(Beyond what the content states)</em></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Read content aloud</td>
<td>Read text directly from exhibit</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Seek Input</td>
<td>Should we bring it…? Do you know what to do?</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>51</td>
<td>76</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Behavioral Category</th>
<th>Example</th>
<th>Child</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demonstration of exhibit function</td>
<td>Drag, turn, rotate, enlarge, shrink, tap, click, share hands on image</td>
<td>20</td>
<td>12</td>
</tr>
<tr>
<td>Gesture</td>
<td>Point</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>22</td>
<td>13</td>
</tr>
</tbody>
</table>
None of the dimensions were strongly correlated with the other dimensions. There was weak positive correlation between responsive engagement and learning strategies and opportunities, though the correlation was positive, $r(23) = .25, \ p = .23$. Directive engagement does not serve as a strong predictor of measurement for learning strategies and opportunities, $r(23) = .09, \ p = .68$. Finally, there was a weak positive correlation between responsive engagement and directive engagement, $r(23) = .19, \ p = .36$.

**Discussion**

In museum and science center spaces, visitors have the freedom to choose what objects and exhibits they have interest in and want to spend time at. They may first approach an object because of their curiosity or interest depending on their intrinsic motivations (Csikszentmihalyi & Hermanson, 1995). The intrinsic reward must reach a high enough level of satisfaction for “intellectual or emotional changes to occur” (Csikszentmihalyi & Hermanson, 1995; p. 69). Sandifer’s (2003) research on forty-seven visitors’ attraction and holding power across 61 different types of exhibits in a science center, found that technological novelty and open-endedness were contributing factors to the variance in average visitor holding time. In the Visitor Center, the tabletop exhibit is a novel object surrounded by several other tangible items and live animal displays to engage with. In the post-exhibit use interview, the most frequent response by family groups when asked what attracted them to the table was the content (Table 2.2). Family groups identified specific elements of the electromagnetic spectrum like the X-ray, images such as the boot or crab nebula, and the “different lights” or colors that they saw on the table. The fact that the exhibit was technology was mentioned less as often as an attractor as the content (Table 2.2). Responses involving emotional affect, or a descriptive adjective of the exhibit was another attractor. Families described the table as “fun,” “cool,” “neat,” and “a cool way to show images
and information.” The frequency of these responses provides some evidence that the content has an element of attraction to encourage use of the exhibit. It is unclear how strong of a role the content plays in attracting compared to the type of exhibit, so further research would be required to determine the strength of appeal that the appearance of the exhibit or the technology provides versus the content. Families were also attracted to their ability to touch the exhibit and that the images could move. While the specific factor of interest for why groups stayed on average of 3 minutes and 25 seconds is not known, this was a longer dwell time than was seen in Block et al. (2015). Under the naturalistic conditions within their study 60% of all groups were engaged with the touch table exhibit for less than 2 minutes. The touch table content is different in each of these studies, but this provides some insight as to how long participants will stay at this type of exhibit. A long period of time at the exhibit does not necessarily indicate that a high level of social engagement will occur. A short interaction time for one family at the exhibit had rich engagement during the minute and 34 seconds they were there.

Among the four museums Borun, Chambers, and Cleghorn (1996) compared, the most frequently observed behaviors by families at exhibits was the “hands-on” action at exhibits. In this study there were 17 families out of the 25 groups that were rated moderate for the responsive engagement dimension. This rating was reflected by a balance of family members with their hands on the table manipulating the content and spending time observing the other group members use it. The way that families oriented themselves around the tabletop allowed for social engagement, whether they were standing across from each other or side to side, they were in close proximity during the interaction to observe and engage. A moderate rating for responsive engagement also indicated that members of the group would walk around the table or that they were not always oriented directly towards the table throughout their time together, while looking
around the gallery to other exhibits. This indicates that there was an interest to use the exhibit together, but individual members would satisfy their own interests to remain physically and cognitively engaged (Csikszentmihalyi & Hermanson, 1995; Hilke, 1989).

In other studies of adult and child interactions at exhibits, adult presence and acknowledgment helped foster engagement as the physical presence of the adults can provide an opportunity for guided participation by the adult (Crowley and Callanan, 1998; Hilke, 1989; Rogoff, 1990). The *moderate* rating also reflected that not every instance of verbalization by a member of the group was acknowledged by the other members, which could reflect some element of individual focus on the exhibit. There was some back and forth conversation which indicated acknowledgement and presence of family members during the activity, but there also may have been other forms of communication that were out of view based on the perspective of the video recording. This could include facial expressions to indicate a reaction to actions. Rogoff (1990) has described that young children reference and use emotional cues as methods of information as feedback signals. Altering the camera view in a way that gave the participants perspective could have indicated the types of facial expressions between family members. Future research could explore the time spent looking at the exhibit versus other members of the group to get acknowledgement of participation in the experience.

For the learning strategies and opportunities dimension, 15 out of the 25 family groups were rated *moderate*. This indicates that on a few instances adults and children referenced the content of the exhibit using vocabulary or terms that were part of the electromagnetic spectrum. This included reading text aloud or identifying the images by name. A *moderate* rating also indicates that there may have been one or two questions asked about exhibit content that could be open or closed in nature, and there may have been one or two references to prior knowledge or
events that integrated with this particular experience. Adults and children employ a variety of strategies including conversation to understand the purpose or function of exhibit and how it links to real-world phenomena and formal scientific principles (Crowley & Callanan, 1998). This was seen at the table as both children and adults were verbally identifying the images or the sections of the spectrum as they interacted with the exhibit. This labeling helps and reinforces the development of the child’s culture (Ogbu, 1995; Rogoff, 1990). With some groups, the adult would narrate as either the adult or child dragged the images across the screen. The visible light portion of the table was referred to as “how we see normally” by more than one family group. There was also the use of the term “normal” may be an explanation used by adults to provide context or anchor to what the child already knows (Rogoff, 1990). During the post-use interview, participants used the language and vocabulary that was present on the labels to identify different elements of the exhibit, such as X-ray, and recall the specific images they manipulated, such as the boot or moon. They were also paying attention to what they were physically doing at the exhibit because they could describe their actions and the gestures they used such as swiping, sliding, and spinning. While I did not specifically ask the purpose of the exhibit, there was recognition that the pictures were different along the range of the spectrum.

Though not observed by every family group, the questions that were asked were in the format of clarification, such as “What is infrared?” posed by children to the adults. The adults would respond with a definition, but did not take the conversation further. Questions asking why or further discussion beyond the identification was not observed in family use of the table. Ash (2004) found that families used a variety of questioning strategies that were open and closed in nature as they viewed realistic dioramas in a natural history museum. These questions were used to encourage children to participate in the construction of meaning on a social level. There was
some evidence of both open and closed forms of questions in this study, questions were not asked by someone in every family group. There was reference to the table being similar to an Apple iPad™ or Microsoft Surface™, or seeing this type of exhibit at Disneyland. While this is not specific to the content on the table, this type of connection to prior knowledge about other forms of technology in popular culture is an example of family sense-making strategies seen in other research on science-center conversations (Zimmerman, Reeve, & Bell, 2010).

For the directive engagement dimension, a majority of families were rated low, meaning that the adults were not explicitly giving instructions to the children in the group as to how to use the exhibit or perform a task at the table. There were instances of independent free form exploration of the table by both the adult and child. The range of adult involvement with their child at the exhibit was apparent, specifically related to the directive engagement dimension. Two family groups were rated high meaning there were multiple occasions of adults instructing a child how to perform a task or demonstrating how to do an action, such as accessing the text behind the images. Astor-Jack et al. (2007) described in museum environments, specifically that “parents or teachers might read labels or tell the child what to do or how the particular exhibit component works” (p. 220). No groups rated very high, indicating that adults were not telling the child how to use the exhibit or perform task throughout the experience at the exhibit. Out of the 35 children under the age of 18 years, 82% were 12 years and younger. A lack of direct instruction, or management of the child’s experience, may be indicative that the children feel comfortable managing the exhibit experience on their own or the adults have the implicit goal to allow their children the freedom to explore the exhibit. This is similar to what Crowley and Callanan (1998) found analyzing collaborative scientific thinking between parents and children in a museum setting. In a collaborative model, the role of managing the learning experience is
not controlled by the adult nor child as the participants negotiate meaning during the interaction. This study used unobtrusive methods to observe adult engagement with children. If the adults knew they were being observed for the interactions, might they have rated higher on the scale for directive engagement? In observations of middle-class mothers and their children, less instruction takes place if the mothers think they are not being monitored than when they are (Graves & Glick, 1978). Again, it is important to remember the agenda of the family and the implicit purpose of their experience.

Reflecting on the instances where children led more of the engagement at the exhibit, based on the frequency counts children took more of an action approach or would perform the task rather than talk the adult through the activity (Table 2.4). For the adults, they used verbal strategies more often as a form of instruction with their children. These observations relate to Rogoff, Matusov, and White (1996) and their discussion that compared and contrasted different models of teaching and learning, with examples of one-sided control versus mutual participation in the experience. The traditional knowledge transmission model that is demonstrated in many Western classrooms are that adults have control of presenting information or determining the direction of the learning experience (Rogoff et al., 1996). The cultural norms of teaching and learning in the museum context are different. There is no formal curriculum or primary instructor, which creates a unique opportunity for the shift of roles within the family group. As the caregiver, adults might see their natural role as one to help provide information to their child, but some of the children in this study took ownership of the experience when they saw the adults did not know what to do or how to use the table.

Considering the interactions between these dimensions, bivariate correlations between ratings of behavior for one dimension were performed to determine whether one dimension
could serve as a predictor for the others. The results of the correlation indicated that there was no significant relationship between the dimensions. All three correlations were weak positive correlations. While one might consider the presence of the adult and the child together at the table and rating high on the responsive engagement scale might predict a higher level of learning strategies and opportunities, this was not the case. The spectrum of adult and child behaviors at the exhibit, some having consistent back and forth conversations and asking questions about the content, to very little verbalization despite being physically present gives some indication as to why the correlation might be weak. Refining the codebook, increasing the sample size, and focusing on specific group sizes, or ages, might narrow the study to provide more clarity on the overlapping relationship between these dimensions.

There were similar verbal and non-verbal behaviors seen in this study when compared to the other research studies on touch tables and touch surfaces, as well as family learning studies with non-digital exhibits. I found behaviors similar to that of Block et al. (2015) with pointing, statements about content, questions, negotiating use, and how-to manipulate the exhibit. With regards to the “how to” talk, family groups spent a period of time talking about how to use or do a task as a way to orient themselves to the experience. As adults and children described their experience using the exhibit, they frequently mentioned terms related to functions, gestures, and manipulations. For example, participants mentioned “enlarging,” “flipping,” or “sliding pictures,” “making finger swipes,” “moving different pictures over lights,” and seeing “how pictures change visually.” Mai and Ash (2012) referred to this as a strategy of scaffolding, or laying a social foundation prior to investigating the content, which is then interpreted in their own way. The use of “how to” talk gets the learners comfortable and prepared for the next levels of interpretation (Mai & Ash, 2012). This “how-to” talk was represented during the post-use
interview not only during the video observations, but during the post-exhibit interview as family groups described the use of the exhibit by naming the gestures that they used.

Hornecker and Nicol (2011) observed adults supported young children in their navigation of the exhibit, but in this study adults provided the freedom to explore the touch technology rather than a consistent facilitation by the adult as indicated by a low rating for directive engagement. Parents were observed reading the content aloud to their children which was seen in other touch table reviews (Hornecker & Nicol, 2011), but is also a performance indicator of family learning with exhibits that are not digital interactives (Borun, Chambers, & Cleghorn, 1996). Davis et al. (2013) noted children talking about content and observing others using the technology and in this study, both adults and children were doing similar behaviors. Davis et al. (2013) also noted that there were limited instances of the child dyads taking the content to higher-orders of thinking through the integration of the content with prior knowledge or application to other experiences and examples. In this study, I also found evidence of this as the questions often involved identification of an exhibit element, but did not proceed to making further connections with other examples.

Borun, Chambers, and Cleghorn (1996) argued that with the presence of family behaviors such as having their hands on the exhibit, reading aloud, and talking about the content, learning can be inferred. In their research among informal science settings with exhibits, families were rated “moderate” or demonstrated the learning levels of “one” or “two” on their performance indicator scale (Borun, Chambers, & Cleghorn, 1996). A rating of this value indicated that while families were using exhibits, they were primarily identifying and describing elements of the exhibit and content. Interpretation and application is a higher-order level of thinking that includes “multiple word answers, correct statement of concepts behind exhibits, and the
connection of concepts to life experiences” (Borun, Chambers, & Cleghorn, 1996, p. 126). A smaller number of families were demonstrating this level of learning behavior, which was similar to what was found in the learning strategies and opportunities dimension during interactions at the touch table. I observed the presence of verbal indicators that identified and described the images and text, but limited instances of integrating that knowledge with prior experiences and questions of inquiry. This might relate to the nature of the content and the affordances it provides as a style of exhibit that is primarily one-dimension and browsing image changes and text. There also has to be consideration for the agenda of the family group using the exhibit. Perhaps their interests only lie within the levels of how to manipulate the exhibit and identify or describe what they are looking at. It would also be presumptuous to assume that for families that didn’t talk as much were not necessarily learning, nor to impose beliefs about the goals of the group in their development (Rogoff, 1990). This could be the strategy they are comfortable with (Ogbu, 1995). Personal interpretation is taking place in the presence of others on a social level, but learning is individual and framed uniquely to them.

This research study was framed around a sociocultural theoretical framework, that human cognition is connected to the social, cultural, and historical situations of the external environment (Wertsch, Del Rio, & Alvarez, 1995). Vygotsky (1978) indicated that the socially shared activities can be internalized becoming the foundations for cognition, while joint activity provides an opportunity for different members of the group to provide their understanding with the group through language and practical action. From this perspective, the touch table is a cultural tool that mediates an activity, or the opportunity to discuss science content in the context of the informal learning environment. In the development of the engagement assessment rubric, I considered both verbal and non-verbal behaviors as strategies that adults and children use to
negotiate meaning and to make sense of the presented content. The physical presence of adults and children using the exhibit together allowed the opportunity for social interactions to take place. Language was used as a tool to label, identify, describe, and ask questions. These were strategies to make meaning of the science content on display. In reference to the directive engagement dimension, direction and facilitation of this activity by the adult was low. This could relate to Vygotsky’s (1978) construct of the zone of proximal development. As a strategy to support and scaffold development, adults could be rapidly assessing the proficiency of the child and their ability to perform a task independently (Vygotsky, 1978). Though the adult might not consciously recognize they are doing this, there was evidence of adults stepping in if they saw their child struggling to access part of the touch table exhibit, a feature of much apprenticeship types of teaching and learning in non-school and non-western contexts (Rogoff, 1990). The experience would have been different if either the child or the adult were using the exhibit on their own, but the table allows for input and exploration by many users. Each family member had a chance to attend to the exhibit in the way that they wanted and interpreted the content in a way that was personal to them. The collective experience points back to the sociocultural perspective that the sum is greater than the individual parts.

Limitations

There are limitations to consider with regards to this study and applying it to other situations of family learning strategies or with touch table exhibits. For example, this study made use of purposive sampling of adults and children visiting Hatfield Marine Science Center. The education level of the participants was high, with a majority having some college-level education, therefore a more diverse group of families using the exhibit could demonstrate different strategies of engagement or interpretation of content. It was also a small study focusing
on 25 groups. By expanding the sample, and examining the number of families that passed in the sampling period that did not meet the requirements would be useful in the future.

The rubric will need to be refined going forward, especially for the responsive engagement and directive engagement dimensions in order for the tool to be applied on additional cases. While rubrics and quantitative scales are often applied in behavioral research to assess interactions because of their ease of use, there are necessary considerations to achieve reliability and validity (Boehm & Weinberg, 1997; Pianta, La Paro, & Hamre, 2007). The values within the codebook have to be explicitly operationalized for observers to categorize behaviors, for example defining mutual exclusivity. While the use of broader chunks of behavior which may influence reliability and resulted in lower absolute observer agreement, the authors claim that could “be making a more meaningful and useful interpretation” (Boehm & Weinberg, 1997, p. 73). The rubric for this study could be improved by refining each code value more explicitly or by separating some of the behaviors out into more dimensions. This could improve the agreement between observers and improve inter-rater reliability. Additional observers and increasing the sample of videos reviewed may also prove useful for improving inter-rater reliability. Having the participants review the video footage so that they could apply their interpretation of the experience could improve validation of the interaction.

Finally, the affordances of the touch table and the software creates a boundary for what can be accomplished at the table for users while investigating the content. The experience is not truly open-ended for the user as they cannot take the content to a level of their personal interest and motivations. They are limited to the design, the specific images and text. While the purpose of this study was not to evaluate the effectiveness of the usability or whether achieved learning outcomes were accomplished for the electromagnetic spectrum program, a different type of
program could alter the engagement levels for each of the dimensions. Therefore the results of this study cannot be generally applied to all programs installed on multi-touch table platforms used as exhibits in informal science spaces.

**Overall Summary and Insights**

There is power in verbal and non-verbal communication and how it contributes to learning. As indicated in the sociocultural perspective, individual learning is influenced through social engagement. An intergenerational cultural group, such as the family, plays off the knowledge of adults and children as they navigate different experiences in daily life to accomplish activities and goals. These everyday activities and conversations between family members can extend into the informal science setting, or the museum, science center, or aquarium. Digital interactives such as multi-touch tables are increasing as a form of exhibit, but what depth of engagement on a social level is occurring in these public science settings? Documenting the natural family behaviors and strategies that are used to make sense of exhibits, including multi-user touch tables, can provide evidence to support the design of content for group interpretation. In this study, families expressed an attraction to the content as a motivator for using the exhibit. Upon a holistic review of behaviors on different dimensions, the most frequent rating that families aligned with were *moderate* in responsive engagement, *moderate* in learning strategies and opportunities, and *low* in directive engagement. Families were talking at a level of identifying and describing content elements, but there was limited integration and application of content knowledge to personal experiences. While this is a snapshot of behavior in the context of the museum experience and within one day of a lifetime, the behaviors observed in this research study have been seen in other studies on family learning and the use of multi-touch tables in other environments. The patterns of behaviors that were expressed by the family group
should be considered in the design of future software for touch tables that are planned for informal science settings to allow for meaningful engagement with the content.
References


Chapter 3: DEVELOPMENT OF THE CYBERLABORATORY

As part of the National Science Foundation sponsored project #1114741 “Cyberlaboratory – Exploring Customization and Continuity,” a suite of observation tools have been installed in the existing infrastructure of the Visitors Center of the Hatfield Marine Science Center (HMSC) in Newport, Oregon. Affiliated with Oregon State University and Oregon Sea Grant, the Visitors Center at HMSC consists of live animal displays, hands-on exhibits, and interactive technology, all of which serve as a way to communicate scientific research, concepts, and information. A combination of off-the-shelf surveillance and facial recognition cameras, coupled with audio recording and computer use tracking software have allowed us to create a non-invasive system for the collection of linked video, audio, and other data for research on visitor interactions and behavior in an informal learning environment. The project has two goals. The first is to create a system that allows for the collection of large amounts of data on visitor activity for both quantitative and qualitative analysis for researchers affiliated with the university. The second is to make the a system available to researchers worldwide which allows remote access to visitor data in the same way that a large, shared resource such as an astronomical observatory allows access to data to a large community of users. Recognition of the ethical and privacy concerns that may arise from filming visitors in a public place has received significant consideration as part of implementation, and approval of a protocol with the Institutional Review Board at Oregon State University is in place. This paper focuses on the considerations for use of video in the behavioral sciences and a description of the audio and video recording tools implemented into a learning lab within a public science center and aquarium space.
Historical Use of Filming in the Behavioral Sciences

Mondada (2012) claimed that video “still seems to be under-utilized in the social sciences as a means of gathering data concerning everyday social interaction” (p. 257). Use of video recordings to collect data in the behavioral sciences field has increased over the past several decades, partially in relation to the reduction in the cost of the process, and the size of technology has improved feasibility (Heath, Hindmarsh, & Luff, 2010). In the mid-1950s, researchers at the Center for Advanced Study in the Behavioral Sciences at Stanford University conducted one of the first systematic attempts to analyze video footage of simultaneous verbal and nonverbal social interaction with sound cinema film (see Leeds-Hurwitz, 1987; Erickson, 2011, p. 180). Video has been used extensively for over 20 years in classroom explorations of teacher pedagogical strategies and communication with students (Erickson, 2011). It is also another tool to support reflection on teacher performance and training, how meaning is communicated, and how students organize their activity (Erickson, 2011). At the same time, since the late 1990’s video has been used in a variety of ways to study learning and family activity in museums (e.g. Gutwill, 2003; Kisiel, Rowe, Vartabedian, & Kopczak, 2012; Mai & Ash, 2012; Rowe, 2002). This represents a larger focus on using video in educational research which goes along with an increased interest in discourse and activity analyses. Since the turn of the 21st century, interest has grown in what has come to be called the “learning sciences” (Sawyer, 2006). Learning sciences researchers pay close attention to the design and use of learning environments, and video has been an important tool in that work (Goldman, Pea, Barron, & Derry, 2007). Our own idea to instrument an entire museum space is aligned with similar efforts across the learning sciences to instrument classroom settings (see Purdue
Application in the Informal Science Setting

Observations of human behavior in the museum context give some insight to the cultural values, learning strategies, and steps that visitors take to make meaning of the content that is presented to them through exhibits and simulations of science phenomena. Video is a natural tool in some sense for studying family and group interactions in museums for several reasons. The first is pragmatic: museum learning is characterized by social interaction with complex spaces including text, objects, in some cases animals, and technologies. Capturing how all of these are activated as affordances in activity requires close observation which is facilitated by video. From a theoretical perspective, we know that learning involves the appropriation of mediational means as part of socially meaningful activity (Vygotsky, 1981; Wertsch, 1998). Observation of this process of appropriation is facilitated by the ability to observe activity over and over again at multiple scales (Wertsch, 1985; Rogoff, 1990). Moreover, video analysis may help to identify, describe and quantify some aspects of interaction such as rhythm (Scollon, 2005), the flexibility of moving in and out of individual and group activity (Kisiel et al., 2013), and the use of multi-modality (Norris, 2011) for communication and interaction whether it is between familiar visiting groups or visitors and museum staff.

There is power in the data that video recording can provide, but considerations for the advantages, challenges, and logistics of incorporating video data as a strategy needs to be weighed against the proposed evaluation or research question. On a basic level, visitor timing at exhibits and tracking through a space can be documented in video footage. When the number of human data collectors are limited, the cameras can provide an automated “eye” that has the
capacity to cover larger galleries and spaces. Human observers may also be overwhelmed by trying to accurately note all of the conversations between visitors in a busy and noisy environment and audio coupled with the video recording can improve the transcription of the conversations (Callanan, Valle, & Azmitia, 2007). The footage also provides multiple layers for analysis from a broad overview of behaviors in a defined timeframe to a zoomed in moment-by-moment progression of verbal and non-verbal expressions, and may uncover unanticipated research questions (Callanan, Valle, & Azmitia, 2007). Recordings preserve these interactions in a sequential order, which the researcher can refer back to and supplement with other methods of documentation such as interviews with the filmed participants or field notes (Knoblauch & Schnettler, 2012). Having access to recordings of the behavior at a later time gives the researcher the ability to review the minute details at a slower pace increasing the accuracy of capturing conversations or subtle movements, while incorporating the analysis of additional reviewers that may not have been present for the live action observation.

It is important to recognize the context to which the interaction takes place and that the researcher is providing an interpretative layer despite the best intentions to remain as objective as possible (Knoblauch & Schnettler, 2012). The use of multiple camera views and angles can be useful to capture different perspectives of the participants and over the course of the time in the space (Luff & Heath, 2012). A thoughtful plan for the analysis of video is also necessary to define early on otherwise the researcher merely has massive amounts of footage with no direction. The use of coding schemes may come from the research question or develop upon review of a sample of footage. Regardless of the categories or codes used, the assessment tool will need to be tested for reliability and validity (Angelillo, Rogoff, & Chavajay, 2007).
The researcher also has to keep in mind whether the videotaped action is representative of everyday action and if the presence of cameras could be influencing the participant’s behavior (Callanan, Valle, & Azmitia, 2007). Callanan, Valle, & Azmitia (2007) found in their research on family conversations in a children’s museum that the groups were more conscious of human observers than of the cameras, and they quickly forgot that the cameras were there. Block et al. (2015) compared visitor behaviors during use of a multi-touch table top exhibit and found that consent procedures immediately prior to entering the exhibit area of filming significantly affected group engagement as it altered the flow of visitors to the exhibit that was partitioned off. Block et al. (2015) recommended obtaining consent early on in the museum experience to allow time and space between consent and interaction with the exhibit under video observation. This is something we have accomplished in the design of the learning lab since the entire public gallery has recording devices installed.

**Observing Visitors in a Public Marine Science Center**

When visitors enter the Visitor Center at HMSC, there are multiple ways they are informed that they are entering an area that is being recorded. A large sign has been placed at the entrance that outlines the scope of research and contact information for the principal investigator. This information is provided in three different languages including English, Spanish, and Russian to reach the audience that visits the site (Figure 3.1).
Figure 3.1. Research protocol information signage located at the entrance of the HMSC Visitor Center.
There are additional signs in the gallery near the touch pools, as well as signs on each of the housings that contain the facial recognition cameras indicating their purpose (Figure 3.2).

Figure 3.2. Signage on facial recognition camera housings.

All staff members and volunteers have been informed of the camera systems, and have been instructed to provide the contact information of the principal investigator should a visitor have further questions about the research project and use of the footage. Information on the nature of the research project has also been included on the HMSC website for those that use this resource to plan their visit. Consent is inferred if people voluntarily enter the Visitor Center. Should any visitor express concern about their personal experience being recorded, they can request that the
footage not be used or accessed at a future time. Upon recruitment for research involving adult and child interactions around a multi-touch table exhibit at HMSC, each potential participant was informed that footage of their use of the exhibit would be paired with post-use interview data. Upon a review of the research protocol with the family groups, no adult declined participation, or expressed concern or unawareness of the camera system or its use (East, 2015).

**Surveillance system.** The observational cameras that have been installed on-site are models that are readily available for consumer purchase. Up to 35 cameras have been placed in multiple locations around the Visitor Center for overhead views and close-up shots of specific exhibits (Image). The use of video management software allows for the configuration of several cameras and the storage of footage on servers. The cameras are scheduled to record continuously during the hours when the center is open. Other configuration options include the ability to adjust the frames per second and image quality to maximize data while considering the bandwidth of the network. The number of days that recorded footage can be stored for specific camera views and can be adjusted for future access. Once the archival retention time passes, the video footage is deleted from the system unless a researcher has extracted it for analysis.

Administration privileges allow for the control of user access to the client software, restricting access to views, the live feed, and the ability to download archived footage. Upon assigned privileges, researchers can log-in from the client software program and access footage from anywhere they have an Internet connection. The footage can either be stored to an external hard drive or network cloud services. Care is taken to maintain privacy and confidentiality of records as stipulated in the Institutional Review Board protocol with raw video data where visitors could be identified.
**Audio detection and recording.** Several models of the surveillance cameras have built-in microphones to capture audio within a wide area. In an effort to get the best audio data possible for detection of conversation in specific locations, omnidirectional microphones are plugged into an amplifier and then linked to a specific camera. In a multi-touch table exhibit, microphones were installed into finished pieces of wood that were attached along the long edges of the table. The four microphones were connected to an amplifier which then linked to a camera with an overhead view of the tabletop exhibit. This set-up allowed for the simultaneous recording and archiving of both video and audio of actions and conversations made by visitors while they use the exhibit.

**Facial recognition software.** To complement the surveillance footage, facial recognition cameras and software were also installed for the use of automated timing and tracking. There has been over 30 years of research on this technology and the publics’ awareness of it has increased as the technology has become commercially available and from use by law enforcement at border crossings and airports (Zhao, Chellappa, Phillips, & Rosenfeld, 2003). Biometric technology is the recognition of faces, whether still or video images, that depending on design is cross-referenced to compiled images from linked cameras or a database of stored images from another source (Zhao, Chellappa, Phillips, & Rosenfeld, 2003). Biometric technology recognizes measurements and dimensions on the face, represented as measurements in pixels or the distance between the eyes, and between the eyes, nose, and mouth to support detection and matching. Several variables can influence the recognition and matching of faces including the illumination of the surrounding space, a person’s pose in the direction of the camera, and the person’s distance from the camera’s field of view, to which the software has to calculate the pixel distance determination for the biometric components.
In the museum space, the desire is to understand how to improve the personal experience and customize content to the learner’s motivations and interests. At HMSC’s Visitor Center, the cameras have been strategically placed at locations that capture the traffic moving through galleries or approaching specific exhibits. Mounting structures for the facial recognition cameras (Figure 3.3) were developed through the use of 3-D printing technology to allow for the customization of mounting the cameras to unique exhibit platforms, as well as to prevent visitor access to the internal camera and lens.

![Figure 3.3. Housings and mounts for observation technology.](image)

Consideration of the height of camera installation, illumination of the coverage area, and width of view contributes to the success of facial matching software. Cameras are sensitive to light and the speed that the person is moving through the space, which can cause the resulting image of the face to be of low quality. Other physical parameters to consider are the facility’s network bandwidth that is streaming multiple cameras, whether basic surveillance or facial recognition. Configuration settings link the camera streams to video servers, which are then linked to video scan software that detects whether a face is present in the frame and if it matches a face that has passed by other cameras in the space. An alpha-numerical identification is generated for the face and stored to a database, comparing to other images that have been detected and stored. Data that
is provided by the software used on-site is an estimation of age, sex, and ethnicity. The ability of the software to recognize and match a face is variable given many environmental conditions and limited by the ability of the software. Reporting on this data, we are interested in tracking the path that a visitor takes through the Visitor Center in reference to time stamps indicated by the camera but also dwell time at exhibits. Reports would also have the ability to search on specific metrics to support the researcher’s question.

**Considerations for Implementation**

Our experience over this project has pointed out again and again to the idea that prior to implementing a networked observation “lab” in a public space, several design elements need to be considered. Depending on the space to be filmed and the budget allowance, the type of camera and installation procedures can vary. Handheld video cameras that can be placed on a tripod can be used, but cameras have become smaller and can continuously record as they are powered over the Ethernet. The camera view desired will influence where the camera will be installed and will depend on whether the infrastructure of the space can support it, for example if a power source is located nearby. This is also related to the purpose of the recording. The types of questions researchers and evaluators are trying to answer as that could inspire a review of final camera installation. Whether a small or large number of cameras are planned, a review of the site’s current network infrastructure and whether it has the bandwidth to support large quantities of video data will be necessary.

The software management of streaming and storing the footage is another consideration. Several camera brands come with video management software or can be used with independent programs that support specific camera models. To maintain confidentiality and privacy, the footage must be handled appropriately to protect human subjects. There also must be a
thoughtful plan for the transition between footage and the research question to provide useful answers whether in qualitative or quantitative form. The design, configuration, and implementation of the facial recognition software requires some training to successfully install and configure depending on the software brand selected. Recognition of the limitations of the software is also necessary because what is detected to be a face might not actually be a face. Therefore, proactive validation comparing what the software is detecting to what is actually detected is a step to incorporate in the research process.

Obtaining Consent

Acquiring the conventional model of informed consent for every visitor that enters a public space, specifically a museum, can create challenges and potentially undermine a visitor’s experience (Heath, Hindmarsh, & Luff, 2010). The Exploratorium used an augmented signage method that explicitly indicated that recording was taking place for research purposes, while placing these signs in multiple locations, including the entrance of exhibit spaces (Gutwill, 2003). In an effort to document evidence of whether visitors knew they were being recorded, they surveyed 200 visitors and found that 197 visitors were aware they were being recorded (99 percent). The three who were unaware were not bothered by the filming process (Gutwill, 2003). Within this project, it was found that the most effective was a sign at the entrance to the exhibit space (Gutwill, 2003). Meisner et al. (2007) conducted research on co-participation and interactions around computer-based exhibits at London’s Science Museum while using video recordings of behavior to support analysis. For this study, strategies similar to Gutwill (2003) were used to gain implicit consent, and no visitors expressed concern to recording process (Meisner et al., 2007). The videos are recording what one might reasonably expect a stranger to observe and it always remains the visitor’s choice to enter and stay in that setting. Information
that is provided to visitors via signage indicates the freedom to alert research team members and staff regarding their preference to opt-out of participation or delete any footage that they may be present in. Providing visitors with explicit information regarding the purpose of the recordings coupled with cameras that are un-obtrusive and seen in several different settings outside of the museum environment, may appease any questions or curiosity about the presence of cameras.

**Summary**

There are both advantages and important decisions related to the use video observation systems to capture human interactions. A major advantage is the rich amount of data to analyze that can be accessed long after the immediate recording for future reference. The interactions observed through unobtrusive filming can provide useful evidence for understanding human behavior in context. Thoughtful research design and planning are necessary for transitioning the data from video format for the purpose of analysis, aiming for high levels of validity and reliability, and an accurate presentation of findings. Decisions involving logistics such as the manner of installation, software choices, and data management should all be incorporated in the planning process. Ensuring that the video recording process is transparent to participants so that they feel fully informed or comfortable asking questions about the nature of research is of utmost importance, as they have a significant role in the behavioral and learning sciences research.
References


Audio and Video Recording Tools Used in Cyberlaboratory

Overhead Surveillance

- Axis Cameras
  - M10 Series
  - M32 Series
- Audio recording technology
  - Omnidirectional microphones
  - 2-channel and 4-channel mixers
  - Microphones plug into Axis cameras (M32 Series)
- Milestone XProtect Management Application
  - Manages the Axis camera views
- Milestone XProtect Smart Client
  - Downloaded to desktop, laptops, or tablet for viewing of video streams

Facial Recognition Technology

- Point Grey Research, Camera Hardware
  - "Blackfly" camera model
  - "Flea" camera model used in areas of changing light and exposure values
  - Specific lenses are ordered based on physical site’s field of view lighting set-up
- Cognitec Software
  - FaceVACS facial recognition software
  - Video servers feed to video scan server which compiles data in database
Chapter 4: DISCUSSION AND CONCLUSION

Summary

Our view of the world and the value we place on objects is shaped by our environment and the interpretations we make in moment-by-moment situations. Through social interactions we talk, discuss, and question our experiences in an effort to make meaning. This is significant to human culture. Individuals are a combination of what they inherit from their ancestors and the skills they develop through engagement with caregivers and peers (Rogoff, 1990). The surrounding culture can influence what is learned as well as the values and strategies that are applied to making decisions, evaluating problems, and developing tools and technologies to remedy those challenges (Ogbu, 1995; Rogoff, 1990). As individuals attempt to solve the challenges in front of them, there is a connection to the “social and societal values and goals, tools, and institutions in the definition of the problems and the practice of their solution” (Rogoff, 1990, p. 61). In the presence of their peers and family group, children learn and acquire skills in daily activities so that they can perform those skills independently. The strategies they use are reflected in the ways that have value in their cultural context. As we accumulate knowledge and experience over the course of our lifetime, we use that information to make decisions that impact our daily lives on where we live, work, and spend our leisure time. These decisions also have impacts on our environment. Our society faces several challenges involving natural resource management with the intersection of human and ecological systems. A collaborative effort to make strides in negotiating these challenges will involve an understanding of basic science concepts and the connections between systems. Individuals will need an ability to ask critical questions, test assumptions, and use information to help make decisions.
Recognizing that science learning takes place beyond the classroom walls is important to the overall accumulation of science knowledge and integration with everyday activities.

Family groups spend much of their time interacting or learning from each other where there are no formal learning outcomes, other than to perform an activity or have an experience. These activities can occur in the home, in nature, at the grocery store, or in cultural institutions such as museums. Some families visit museums, aquariums, and science centers during their leisure time as a meaningful relationship-building experience, to learn more about a topic of interest, or to promote a learning experience for their children. The museum visit is one occurrence that fits into an overall lifetime of learning opportunities both inside and out of a formal education setting. Through the use of exhibits, family members make personal interpretations of the information presented, while also being influenced by what other members point out or discuss. For the families that access these environments, they share this social experience while they explore exhibits using verbal and nonverbal strategies to communicate. These strategies can be pointing, verbally identifying an object, reading aloud, asking questions, or explaining. From this individual and social learning is taking place as the group makes meaning of the content they are interacting with.

Digital table surfaces are another platform for communicating information, such as science content, in a museum, aquarium, or science center. Interactive tabletops are appearing as exhibits yet there are unanswered questions as to visitor interactions and behaviors while using these as exhibits in informal science learning environments. The types of behaviors they demonstrated are reflected in other research on family experiences in other settings (e.g. Ash, 2003; Borun, Chambers, & Cleghorn, 1996; Crowley & Callanan, 1998), but the affordances of the exhibit content, the agenda of the family user, and the prior knowledge that relates to their
interest may play a role in the level of engagement that family members participate in. This study focused on families at Hatfield Marine Science Center and the behaviors they expressed within the social group while using a digital interactive. Digital interactives are not new to the museum environment (Geller, 2006), and can range in size and scale from single user desktop kiosks to multi-user touch walls. To understand how families use this technology together, I asked the following question: what levels of interaction and engagement are expressed between adults and children at a multi-touch table exhibit installed in a public marine science center? What degree were interaction indicators framed as responsive engagement, learning strategies and opportunities, and directive engagement expressed between adults and children while using the exhibit?

Through a combination of in-person observation, interviews, and video recording analysis, I investigated the engagement levels of 25 families using the touch table exhibit together in August 2014. I developed a codebook in the form of a rubric that used similar categorical terms outlined by Piscitelli and Weier (2002), titled responsive engagement, learning strategies and opportunities, and directive engagement. These dimensions incorporated verbal and nonverbal behavioral indicators that increased in complexity along a numeric scale. Upon observation of the video segments where adults and children were using the exhibit together, a value between (1) very low, (2) low, (3) moderate, (4) high, (5) very high that most closely matched the operationalized definitions for each category were assigned. These codes were based on a holistic or macro-level review of engagement using instances of conversation or nonverbal gestures as justification for the code given. To determine inter-rater reliability for each of the three dimensions on the eight double-coded videos, Cohen’s kappa statistic was calculated. The dimension with a highest kappa value was learning strategies and opportunities
(κ = 0.75). The other dimensions were (κ = 0.27) for responsive engagement, and (κ = 0.27) for directive engagement. Nonparametric bivariate correlations were calculated between dimensions to see how closely they could serve as a proxy measurement for the other dimensions. Results of this study provides evidence for the depth of engagement a select group of families expressed while using a multi-touch table exhibit and strategies they used to make personal meaning of science content on a social level. This data can provide design considerations for exhibit developers implementing digital tabletops in an informal science learning environment.

Revisiting Results and Discussion

In the post-exhibit use interview, the most frequent response by family groups when asked what attracted them to the table was the content. The “hook,” or what may have initially sparked initial curiosity was the tabletop platform, connected to an interest in the presented content (Csikszentmihalyi & Hermanson, 1995). Family groups identified specific elements of the electromagnetic spectrum like the X-ray, images such as the boot or crab nebula, and the “different lights” or colors that they saw on the table. Families were also attracted to their ability to touch the exhibit and that the images could move. As adults and children described their experience using the exhibit, they frequently mentioned terms related to functions, gestures, and manipulations. For example, participants mentioned “enlarging,” “flipping,” or “sliding pictures,” “making finger swipes,” “moving different pictures over lights,” and seeing “how pictures change visually.”

In this study there were 17 families out of the 25 groups that were rated moderate for the responsive engagement dimension. This rating was reflected by a balance of family members with their hands on the table manipulating the content and spending time observing the other group members use it. The way that families oriented themselves around the tabletop allowed for
social engagement, whether they were standing across from each other or side to side, they were in close proximity during the interaction to observe and engage. This rating also indicated that members of the group would walk around the table or that they were not always oriented directly towards the table throughout their time together, while looking around the gallery to other exhibits. There was some back and forth conversation which indicated acknowledgement and presence of family members during the activity, but there also may have been other forms of communication that were out of view based on the perspective of the video recording. This could include facial expressions to indicate a reaction to actions.

For the learning strategies and opportunities dimension, 15 out of the 25 family groups were rated moderate. This indicates that on a few instances adults and children referenced the content of the exhibit using vocabulary or terms that were part of the electromagnetic spectrum. This included reading text aloud or identifying the images by name. A moderate rating also indicates that there may have been one or two questions asked about exhibit content that could be open or closed in nature, and there may have been one or two references to prior knowledge or events that integrated with this particular experience. Adults and children employ a variety of strategies including conversation to understand the purpose or function of exhibit and how it links to real-world phenomena and formal scientific principles (Crowley & Callanan, 1998). This was seen at the table as both children and adults were verbally identifying the images or the sections of the spectrum as they interacted with the exhibit. This labeling helps and reinforces the development of the child’s culture (Ogbu, 1995; Rogoff, 1990). With some groups, the adult would narrate as either the adult or child dragged the images across the screen. The visible light portion of the table was referred to as “how we see normally” by more than one family group. Use of the term “normal” may be an explanation used by adults to provide context or anchor to
what the child already knows (Rogoff, 1990). During the post-use interview, participants used the language and vocabulary that was present on the labels to identify different elements of the exhibit, such as X-ray, and recall the specific images they manipulated, such as the boot or moon. They were also paying attention to what they were physically doing at the exhibit because they could describe their actions and the gestures they used such as swiping, sliding, and spinning. While I did not specifically ask the purpose of the exhibit, there was recognition that the pictures were different along the range of the spectrum.

For the directive engagement dimension, a majority of families were rated low, meaning that the adults were not explicitly giving instructions to the children in the group as to how to use the exhibit or perform a task at the table. There were instances of independent free form exploration of the table by both the adult and child. The range of adult involvement with their child at the exhibit was apparent, specifically related to the directive engagement dimension.

The results of the correlation indicated that there was no significant relationship between the dimensions. All three correlations were weak positive correlations. While one might consider the presence of the adult and the child together at the table and rating high on the responsive engagement scale might predict a higher level of learning strategies and opportunities, this was not the case. The spectrum of adult and child behaviors at the exhibit, some having consistent back and forth conversations and asking questions about the content, to very little verbalization despite being physically present gives some indication as to why the correlation might be weak. Refining the codebook, increasing the sample size, and focusing on specific group sizes, or ages, might narrow the study to provide more clarity on the overlapping relationship between these dimensions.
Limitations and Suggestions for Future Research

Mai and Ash (2012) stated that “ways of being, doing, and thinking are not, however, tangible items that we can easily label” (p. 113). Assessing human behavior can be challenging and requires thoughtful research design. There are limitations to this study that need to be acknowledged and areas where the research design could be improved. While the focus of this study was to qualitatively assess interactions and engagement by adults and children, the development of the rubric was created as a way to measure those interactions. Rubrics and quantitative scales are applied in behavioral research to assess interactions because of their ease of use, but there are necessary considerations to achieve reliability and validity (Boehm & Weinberg, 1997; Pianta, La Paro, & Hamre, 2007). The values within the codebook have to be explicitly operationalized for observers to categorize behaviors consistently. Two of the proposed dimensions, responsive engagement and directive engagement, had low exact agreement between coders and calculated Cohen’s Kappa values. The rubric will need to be refined for additional analysis, specifically to rate interactions related to those dimensions. Spending more time with multiple coders after making the definitions more explicit in their operational definitions could improve the inter-rater reliability. Another improvement to the rubric could be splitting each dimension into sub-categories. For example, within responsive engagement, there could be separate ratings applied for physical proximity to the table, consistency of acknowledgement, and emotional affect could be included. These would be rated independently of each other, so if a behavior such as physical proximity was higher than how often adults and children responded to each other, the rating would not affect the value of the other sub-categories. While the use of broader chunks of behavior, as was the case in this study, may influence reliability and result in lower absolute observer agreement, the authors claim that
could “be making a more meaningful and useful interpretation” (Boehm & Weinberg, 1997, p. 73).

This study also made use of purposive sampling of adults and children visiting Hatfield Marine Science Center with a small sample size. The education level of the participants was high, with a majority having some college-level education, therefore a more diverse group of families using the exhibit could demonstrate different strategies of engagement or interpretation of content. By expanding the sample, and examining the number of families that passed in the sampling period that did not meet the requirements would be useful in the future. The size of the family group was not a controlled variable. While many of the groups were adult-child pairs, an increased number in family size could influence the engagement dynamics. In future research, limiting the requirements of participants to a specific group’s size could illustrate those dynamics. Finally, the affordances of the touch table and the software creates a boundary for what can be accomplished at the table while investigating the content. The experience is not truly open-ended for the user as they cannot take the content to a level of their personal interest and motivations. They are limited to the design, the specific images and text.

**Implications and Recommendations**

Considerations for what visitors, specifically families, do in museums is relevant to the development of exhibits and facilitating learning (Ash, 2004). The multi-touch table is a tool for presenting science content to public audiences in a way that fosters distributed meaning-making and social engagement. People were talking about what they were exploring on the multi-touch table, as a way to show others what is interesting to them or to guide them through use of the content. There was a basic level of discussion of content or repeating the text and vocabulary
presented. From this level of usability, can elements within the content design be expanded so that higher-orders of thinking and integration of prior knowledge are promoted?

The value of good usability design should not be lost on attractive digital interactives. Having prior knowledge and experience with specific technology, like touch surfaces on smartphones, could influence the length of time it takes the visitor to figure out what the purpose is, or how to use an exhibit (Gammon & Burch, 2008). With the increasing presence of touch technology in daily life, guests may recognize the functionality of these exhibits quickly due to an established mental model (Gammon & Burch, 2008; Norman, 2002). A high number of family groups (88%) reported access to touch surface technology on a daily basis which could point to the familiarity with gestures as they approach the touch table exhibit. Visitors should not spend more time trying to determine how to navigate or use the exhibit because it could prevent them from reaching a connection with the intended content (Allen, 2004).

Bitgood and Patterson (1987) suggested several characteristics that relate to the physical design of the exhibit that are relevant to the table, including the incorporation of multiple senses, how demographic characteristics may influence visitor reactions, and the element of social influence. The current state of the touch table at the Visitor Center appeals mainly to the visual sense. While it responds to touch input, this is different that if there were more tactile components to the table surface. Having only a visual feedback does not support those with visual challenges. Designers should consider features that stimulate other senses but in balance to not overwhelm the user. An older adult demographic group was also absent from this study, with the oldest participant was 58 years of age. Further research is necessary to understand their attraction, motivations, and use (or avoidance) of digital interactives so that diverse visitor needs are addressed, beyond the family group. Finally, I observed that while each family group used
the table, only on limited occasions did unrelated visitors join to use the exhibit at the same time, and it was briefly. Is there a social norm that prevents participation with others outside of the family group? In the touch table research by Block et al. (2015) it was pointed out that not only families use the exhibit so the experience has to be meaningful for groups of different sizes, including a single user. Block et al. (2015) suggested focusing on the experience for dyad use, versus groups of threes or fours, as partners stayed longer and were more engaged than larger groups. In a space where people move around in an unstructured manner, they may approach exhibit when not in initial state, so the design has to incorporate a reset over an interval of non-use or a way to join the program in a fluid fashion.

Borun (2002) made several recommendations related to exhibit characteristics that foster family engagement. Exhibits that are multi-sided, multi-user, accessible, multi-outcome, multi-modal, readable, and relevant can facilitate learning (p. 255). The touch table meets some of these characteristics, for example it is multi-sided, multi-user, and accessible to some degree, but there are areas where the touch table can be improved from both the hardware and software design. Referring back to Borun’s (2002) characteristics, the experience with the electromagnetic spectrum exhibit might be considered multi-outcome in that there is not a prescribed progression of steps to interact with the content. It is still limited in the way the images are presented under specific wavelengths and available text, so the outcome in some ways is determined by the designer. The results of this study showed that adults and children were exploring on their own while coming together to point out elements of interest or show each other how to access text or manipulate images. One recommendation is to take advantage of the multi-user and collaborative strategies that families do use while incorporating science content. For example, the program could be designed so that users depend on the input or decisions of others to progress, accessing
other levels or solving a task. A possible way to support the development of strategies involved with inquiry-based learning is a program that allows users to manipulate variables in the simulation of an environmental model. This could be a way to test assumptions and see how their decisions influence the results. Another way to increase the physical tactile element and promote playful learning and collaboration is through the use of tangible objects that react with digital table displays (Price, Rogers, Scaife, Stanton, & Neale, 2003; Price & Pontual Falcao, 2011). Price & Pontual Falcao (2011) studied a tangible tabletop that was designed to simulate behaviors of light based on reaction with common objects at the table’s surface. Price & Pontual Falcao (2011) found that children were testing the different inputs and re-arranging objects while discussing concepts that underlie the physics of light. Expanding the use of this form of technology in the museum field could generate new ways for visitors to view science properties and models. Something to keep in mind is that while there are good intentions for exhibit designs, it is important to remember that these intentions might not align with the motivations of the visitor or group and what they take away from the experience (Meisner & Osborne, 2009). There is value in studying visitor use for future design decisions and innovations.

**Sociocultural Learning Strategies and Science Communication**

Wertsch, Del Rio, and Alvarez (1995) stated that a sociocultural approach considers the link and overlapping interaction between the individual’s cognitive functioning and the cultural context in which functioning takes place. The purpose of this study was to explore the social learning strategies between individuals, specifically adults and children or a related family group, and their natural methods for making sense of the content presented on a multi-touch table. I was curious about the depth of engagement that was occurring between familiar family members, and this study provided evidence as to the types and levels of social learning strategies. For both
responsive engagement and learning strategies and opportunities a level defined as moderate, and for directive engagement a level of low. The communication strategies took the form of both verbal and non-verbal methods of acknowledgement, response, and feedback. Pointing to a sociocultural theoretical perspective, Vygotsky (1978) argued that a pivotal moment in development is the use of speech and practical activity together (p. 24), and both of these behaviors took place, often at the same time. Non-verbal methods included pointing, manipulating images along the screen together, and orienting their bodies towards other family members while at the table. Verbal methods involved the identification of objects displayed on the touch table, descriptions to clarify questions, and limited reference to prior experiences. Children looked to adults to answer their questions as they had their hands on the table, and at times parents would question their children to assess their knowledge. Vygotsky (1978) also described how children use communication strategies to accomplish tasks with their speech, hands, and eyes. These behaviors contributed to the overall shared experience that is personal to the family group. Within the interactions of a majority of the family groups, the individuals were talking within the group, thus an overlap of interpretation on the individual and group level. The statements families provided post-use of the exhibit demonstrated their attention to the content and the experience on a basic level of identifying images and elements of the electromagnetic spectrum. Understanding social learning strategies is more than whether the family could recite the knowledge presented on the touch table. Crowley and Callanan (1998) pointed out that what is gained from the museum experience is the development of processes of “forming expectations, evaluating evidence, and constructing explanations” (p. 12). The development of these processes are important as the child goes forward because they will rely on these skills to assess, make, and communicate actions in their daily lives.
Communication connects people socially and through the context of cultural goals are they interpreted by the individual, whether it surrounds science content or another topic (Hansen, 1979; Rogoff, 1990). It includes the process of transmission, receipt, decoding, and interpretation. The receiver of the message contains a collection of cultural knowledge and personal experience that are recalled upon to make sense of the transmitted information (Hansen, 1979). Through conversation there is a gradual modification of shared understandings, and what we know about science is shared and refined over time through cultural contexts in various forms of communication (Hansen, 1979).

Bandura (1986) stated that “understanding how new ideas and social practices spread within a society, or from one society to another, has important bearing on personal and social change” (p. 142). The development of knowledge from scientific research has changed societies on dramatic levels, for example humans are living longer partly due to a better understanding of health and medicine. The communication of scientific research has also had significant impact on behavioral choices, from the food we eat for our health to our use of natural resources to satisfy our needs and wants (Nowotny, Scott, & Gibbons, 2001). This is not just a one-way transmission from scientists. Nowotny, Scott, & Gibbons (2001) argued that “science is now ‘listening,’ in part because the boundaries separating science and society are becoming more porous” (p. 53). Platforms such as social media are one way that people join in the conversation on a diverse range of topics and the message can change rapidly. While it may be easier for some to access science on the Internet, physical sites where science content is their platform, such as museums and science centers, remain as a resource for those who are motivated to seek it out. With the many different ways to access or learn about science, the ways that people make sense of it or
share that information is a necessary component to the conversation on the value of science to society.

Reflecting on the use of social learning strategies and science communication leads to another question: what role do museums and science centers have to promote or facilitate science literacy as part of their mission? Rather than a transmission model and authority over content, could this space be seen as one that allows for a dialogue that is open to visitor input? Institutions have considered the museum as a way to foster public engagement by providing a meeting place or forum that encourages a more in-depth learning experience for adults. One example that had a positive response reported by participants was at the Museum of Science in Boston where a dialogue surrounding nanotechnology was interactive between visitors and researchers (Bell, 2008). This project was known as the NISE (Nanoscale Informal Science Education) Network (Bell, 2008). The public had access to subject matter experts and could express their thoughts on topics that have societal implications (Bell, 2008). With the interplay of social values and ethical controversies, museums could be a safe space to foster these conversations. The audience could be limited to those who already visit these settings, so thoughtful consideration for including a broader audience will be required.

Understanding science conversations and social learning strategies is also connected to how society moves forward with challenging decisions related to natural resources and their management. For science educators, communicators, and mediators that are in the position to translate science topics to diverse audiences, having an awareness that previously generalized strategies may not necessarily work for all groups and stakeholders is important as they tailor their message. This idea is similar to what Hein (1998) stated “If learning is a matter of making connections in a network then research on this learning must be devised that can ascertain
degrees of connections, not knowledge of isolated facts” (p. 87). This includes a recognition that prior knowledge, beliefs, and values play into the perceptions of how people view science and the environment. In order to make tangible gains in conflicts surrounding natural resources, starting from this viewpoint can facilitate conversations. Historically science has been the “go-to” to make decisions of point to solutions (Nowotny, Scott, & Gibbons, 2001). Creative solutions to challenging environmental issues are dependent on the interaction and collaboration between those that develop knowledge from scientific research, as well as those that can apply it, and depends on a feedback loop between cultures (Nowotny, Scott, & Gibbons, 2001).

Science Understanding and Marine Resource Management

The theories behind sociocultural learning can be applied to practice, and there is evidence of its use while implementing natural resource management. A review of research in natural resource management by Cundill and Rodela (2012) found that incorporating social learning supported better decisions due to a combination of better relationships, an understanding of connections between humans and the environment, and effective problem-solving strategies. This engagement of stakeholders required the exchange of information in an inclusive environment but also with persistent negotiation at a social level (Cundill & Rodela, 2012). Whether it is the ocean or other habitat, humans have learned to take advantage of their environment and fulfill needs that support survival including food, shelter, and water. Humans are interpreting and responding to the world around them, receiving constant feedback from the external environment and adapting that information to make sense of it. That knowledge is used to make decisions and act on basic needs. Coupled with natural variation in the environment, use of resources is reflected in the current state of pressure (McLeod & Leslie, 2009). What was once a situation where humans believed that natural resources were of unlimited amounts, is no longer
the case. Humans have to make use of evolving information in an effort to make decisions going forward for both the human and ecosystem domains.

Rudd and Fleishman (2014) surveyed 375 managers, policymakers, advisers, scientists in United States to rank research priorities and questions that were “most or least likely to increase the effectiveness of policies related to the management of natural resources in the United States” (p. 220) on the timeframe of 5-10 years. While the priorities varied among these individuals, the top three questions involved the investigation of changes to environmental parameters and the accessibility of resources, the tradeoffs and benefits ecosystem services, and the increasing impacts to coastal communities such as sea level rise (Rudd & Fleishman, 2014). These challenges cannot be addressed without an interdisciplinary approach that integrates knowledge from the fields of natural and social sciences. This involves an understanding of how people learn and the social strategies that are implemented to deal with complex issues. While an understanding of the physical processes of the Earth is important, how humans apply that information is also significant.

Berkes (2012) referenced resource management as a “wicked problem” (p. 3) as each place is unique and there is no simple, direct, solution. The path is nonlinear and is influenced at many scales. Human learning is comparable to this. There is no single way to provide information to a learner. They may move through an experience in a particular place in a nonlinear manner but to appease individual motivations while spanning scale. A majority of a lifetime is spent acquiring skills and knowledge that has been acquired through free choice, yet the field of studying learning outside of the classroom environment is still in its infancy. It will take the collective buy-in of a variety of disciplines to see the value of research in domains beyond the natural sciences.
Conclusion

Conversations and the interpretation of science content are occurring in the informal science learning environment. People will decode and translate content along personal and social levels within their family group that fits their cultural frame of mind. This takes place in everyday activities, and in the museum environment where families learn from each other. This happens at the exhibit interface where there are objects and tools offered up for use. The focus by the family may not be on accumulating specific facts or knowledge of science but the process of asking questions, making observations, testing assumptions, and using evidence to explain reasoning plays out. Knowing this, designing exhibits to scaffold the development of inquiry skills is a worthy process to support the use of these strategies for application in the future.

This study focused on what was occurring between the adults and children collectively, rather than as isolated learners. Observing family groups at the touch table exhibit, there was a mixture of strategies that incorporated verbal and nonverbal methods. The presence of multiple users allowed for multiple individual experiences that contributed to the collective experience. From the continuing research on learning behaviors in museums and objects such as multi-touch tables, we can build our understanding of how people use technology together and the ways they make sense of the information presented to them. This is helpful for reviewing the strategies that are used to communicate science to broader audiences that are playful and engaging.
References


APPENDICES
Appendix A: Interview Questions

Participant ID Number:_____

1. Have you previously visited the Visitor Center at Hatfield Marine Science Center?
   Please circle one: Yes  No

2. Do you have access to or use touch surface technology on a daily basis? For example, this could be a smartphone or tablet.
   Please circle one: Yes  No

3. Please write the age and sex for each person in your group that used the touch table exhibit:

4. Overall for your group, what is the highest level of school completed or the highest degree achieved?

Please select one:
   □  Less than high school degree
   □  High school degree or equivalent (e.g., GED)
   □  Some college but no degree
   □  Associate degree
   □  Bachelor degree
   □  Graduate degree

5. What is your zip code? (Please write response) ______________

Thank you.
Participant ID Number:______

Follow-up interviews will occur 6-8 weeks from now over the telephone. If you choose to participate in the interview (lasting no more than 20 minutes), your name and phone number may be listed below.
What about the touchtable made you want to use it?

Can you describe or talk about what you were doing while you were using the exhibit?
Appendix B: Coding Rubric

**Dimension of Learning Behaviors:**  Responsive Engagement [Nondirective]

*Degree to which the adult(s) and child(ren) remain within physical proximity and recognize the comments and questions of others through verbal or behavioral actions.*

Behaviors: Adult(s) and child(ren) maintain proximity with each other and the exhibit. Adult(s) and the child(ren) listen to ideas, acknowledging they have been heard and respond. The adult may encourage or praise the child with positive remarks. Adult(s) and child(ren) may express positive physical indicators, emotions (e.g. smiling), or enthusiastic behavior during interaction.

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Very Low:</strong> Adult(s) or child(ren) may walk several feet away or spend more time turned away from each other or the exhibit. The hands of the adult(s) or child(ren) may only be on the table for a few seconds. There is no verbal acknowledgement or response between the adult(s) and child(ren) when they speak.</td>
</tr>
<tr>
<td><strong>2. Low:</strong> Adult(s) or child(ren) may turn away frequently, adult(s) or child(ren) have their hands on the table for a brief period of time. Adult(s) and child(ren) may acknowledge or respond each other’s comments or questions once.</td>
</tr>
<tr>
<td><strong>3. Moderate:</strong> The adult(s) or child(ren) spend an equal mixture of time turned away from the exhibit or with their hands on the table. More than once, but not in all of the instances do the adult(s) and child(ren) appear to be listening to each other or acknowledging or responding to comments or questions.</td>
</tr>
<tr>
<td><strong>4. High:</strong> Most of the time adult(s) and child(ren) are in close proximity and oriented to the table, but they may briefly step back or turn elsewhere, and hands come off the table briefly. There are a couple of instances of acknowledgment and response between the adult(s) and child(ren) to comments/questions.</td>
</tr>
<tr>
<td><strong>5. Very High:</strong> Adult(s) and children are in close proximity and their bodies are always oriented to the surface. They never walk away or turn away throughout the experience, their hands on the exhibit almost always. There are consistent responses to comments or questions made by the adult(s) and child(ren).</td>
</tr>
</tbody>
</table>
**Dimension of Learning Behaviors:** Learning Strategies and Opportunities

*Degree to which the adult(s) and child(ren) engage in sharing information about concepts, questioning content, and recalling and integrating this experience to external events or the outside world.*

Behaviors: Adult(s) and child(ren) verbalize and share information by asking or answering questions, describing or providing examples, and reading exhibit content aloud. Adult(s) and child(ren) use questioning strategies that are either open or closed in nature. Adult(s) and child(ren) reference events that are external to exhibit use, an example of recalling and integrating information. This could include verbalizing prior memorable experiences or knowledge.

<table>
<thead>
<tr>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td><strong>1. Very Low:</strong> Adult(s) and child(ren) have little to no verbalization about the exhibit content. There may be little verbalization entirely. There are no questions. There are no points of reference to events outside of the immediate exhibit experience.</td>
</tr>
<tr>
<td><strong>2. Low:</strong> There are one or two instances where adult(s) and child(ren) reference the content of the exhibit. There may be a reference to prior knowledge or events outside of the immediate exhibit experience.</td>
</tr>
<tr>
<td><strong>3. Moderate:</strong> On a few instances, adult(s) and child(ren) reference the content of the exhibit. There may be one or two questions asked about exhibit content. There may be one or two references to prior knowledge or events outside of the immediate exhibit experience.</td>
</tr>
<tr>
<td><strong>4. High:</strong> Adult(s) and child(ren) frequently reference exhibit content. There are one or two questions related to building knowledge of concepts. Prior knowledge is often referenced or events that are outside of the immediate exhibit use.</td>
</tr>
<tr>
<td><strong>5. Very High:</strong> Adult(s) and child(ren) are only making comments on exhibit content. There are multiple occasions where questions are asked, either of open or closed format which could lead to further understanding of concepts. There are multiple instances where there is verbal recollection of prior knowledge or experiences that are outside of immediate exhibit use.</td>
</tr>
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</table>
**Dimension of Learning Behaviors: Directive Engagement**

*Degree to which the adult(s) and child(ren) participate in demonstration, instruction, or direction as related to the facilitation of an action during use of the exhibit.*

Behaviors: Adult(s) show(s) the child(ren) how a task is done to help the child(ren) acquire that behavior. Adult(s) instructs or passes information on to the child(ren) or gives guidance on how to perform an action. The adult(s) guide(s) the child(ren)’s behavior in order to facilitate the manipulation of content.

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Very Low:</strong> Adult(s) and child(ren) strictly use the table independently and on their own. There is no direction or guidance is provided by the adult(s) to perform an action on the table. There is no evidence of the adult(s) and child(ren) working together or sharing an action to perform a task.</td>
</tr>
<tr>
<td><strong>2. Low:</strong> Adult(s) and child(ren) connect at least once as they perform tasks or actions. Adult(s) may verbally instruct, demonstrate, or show the child(ren) how to perform an action.</td>
</tr>
<tr>
<td><strong>3. Moderate:</strong> There are a couple of occasions of adult(s) instructing or telling (a) child(ren) how to perform a task. There may be an instance where the adult(s) and child(ren) work together to proceed through an activity at the table verbalizing their actions.</td>
</tr>
<tr>
<td><strong>4. High:</strong> There are multiple occasions of adults instructing or telling a child(ren) how to perform a task. The adult frequently demonstrates how to do an action (look, see, how). There are a couple instances where the adult(s) and child(ren) work together to proceed through activity at the table verbalizing their actions.</td>
</tr>
<tr>
<td><strong>5. Very High:</strong> Adult(s) is (are) primarily directing or guiding the child(ren) on how to manipulate content on the table. Adult(s) and child(ren) are frequently working together to proceed through an activity, verbalizing their actions.</td>
</tr>
</tbody>
</table>
Appendix C: Video Coding Sheet

ADULT and CHILD INTERACTIONS AT TOUCH TABLE

**Dimension of Learning Behaviors**

<table>
<thead>
<tr>
<th>Responsive Engagement [Nondirective]</th>
<th>Video ID</th>
<th>Video Code Period: Start (    ) – Stop (   )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree to which the adult(s) and child(ren) remain within physical proximity and recognize the comments and questions of others through verbal or behavioral actions.</td>
<td>(1) Very Low</td>
<td>(2) Low</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Learning Strategies and Opportunities</th>
<th>Video ID</th>
<th>Video Code Period: Start (    ) – Stop (   )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree to which the adult(s) and child(ren) engage in sharing information about concepts, questioning content, and recalling and integrating this experience to external events or the outside world.</td>
<td>(1) Very Low</td>
<td>(2) Low</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Directive Engagement</th>
<th>Video ID</th>
<th>Video Code Period: Start (    ) – Stop (   )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree to which the adult(s) and child(ren) engage in demonstration, instruction, or direction as related to the facilitation of a task or action during use of the exhibit.</td>
<td>(1) Very Low</td>
<td>(2) Low</td>
</tr>
</tbody>
</table>

Affect:

Notes: