Chapter 25
In Search of an Articulated and Coherent Theoretical Framework to Inform Research and Evaluation of Learning in Science Centers: A Tale of Two Research Challenges

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25.1 Introduction

Frank Oppenheimer, founder of the Exploratorium, perhaps the first interactive science center, famously pointed out, "No one ever flunked a museum" (Semper, 1990, p. 52). Indeed, there are no high stakes tests to flunk in science museums; however, if that is true, how do museum professionals and others recognize learning in such settings? The question, Do people learn in science museums? has confronted and confounded museum professionals since museums evolved from "curiosity shops" to their current position within the infrastructure of society's cultural, educational, and academic institutions (Abell & Lederman, 2014; Andre et al., 2016; Association of Science-Technology Centers, 1996; Horr & Heimlich, 2016; Roberts, 1997).

The field of informal science education had considerable movement over the last decades. Literature from and about informal organizations shows a shift around their attitudes concerning their role in science education and what constitutes learning. They moved from a stance where museum education departments were in the basement (a telling decision as to organizational attitudes about their importance), to a more vital interest in the process of learning and their desire for increasing recognition as a legitimate and integral part of the greater educational infrastructure. We witnessed a change in thinking about museums and learning (Hein, 1998, 2006, 2012). In the mid 1990s, a call to establish a research agenda for informal science institutions, supported by the American Association of Museums and the National Science Foundation, helped promote a self-examination around the unique character and opportunities for learning in science museums (Falk & Dierking, 1995). As a result, through this examination, informal science research gave rise to a deeper

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understanding of the visitor experience and effective ways to present science in these settings. However, questions about the process of learning in informal science settings are still very current (Corin, 2017; Falk & Dierking, 2019).

Literature well documents the quest for, and challenges faced over the last century in actually identifying and even defining learning taking place in science museums (Andre et al., 2017; Leinhardt et al., 2002; Dierking et al., 2004). Professionals stimulated much of this research when faced with the question, "Yes, visitors have fun in museums, but what do they really learn?" (Allen, 2002, p. 262). Those who fund and support museums are particularly intent on validating their investments, an intention that motivates requirements for inclusion of evaluation in many grant-funded exhibits or programs. These policies support a sizable and expanding body of research. Much of this research, however, is specific to particular exhibits or programs. Although they contribute to knowledge in the field, gaps remain for researching these visitor-centered, and for the most part, unprescribed and/or unpredetermined experiences. Particular gaps remain around ascertaining effective and appropriate ways to recognize, document, and assess *learning* during experiences in informal education settings.

The museum experience is complex because the museum does not exist in isolation. It serves as a crossroad for multiple communities, which include the museum itself, the audiences it seeks to serve, and the communities, culture, and contexts in which it exists and receives support, and upon which it focuses. Falk and Dierking explore these ideas in their related volumes from 1992 and 2000. They articulate a model for the museum experience and visitor learning from the perspective of the museum visitors. They posit that to understand learning in the museum setting, we must not only rely on learning theories developed in contexts outside the museum setting, but also consider the critical aspect of the museum experience itself with the important roles the personal, social, and physical contexts play in learning (Falk & Dierking, 1992, 2000). Falk (2009) expands on some of these ideas as he describes the differing agendas and identities each visitor brings to their museum experience. A transactional view of museum experience was put forth by Paris and Mercer (2002). Their research evoked a perspective that visitor experience with exhibits and their associated objects can have a transformative effect on the visitor, evoking "tangential, unintended or novel responses and might change the knowledge, beliefs, or attitude of the visitor" (Paris & Mercer, 2002, p. 401).

As human knowledge and associated understandings are always susceptible to modification and change, my own mental models have been influenced by theories and paradigms around learning. In my work in both informal and formal education, I continue to draw upon a suite of ideas, perspectives, and conceptual frameworks, which together inform my understanding of learning and offer a rich way to think about how people learn. As I gain exposure to new ideas, I consider how they resonate or perhaps conflict with my prior conceptions of learning. This collection of ways of thinking about learning includes constructivism, experiential learning, and sociocultural and social-emotional theories around learning (Fosnot, 1996a, 1996b; Hein, 1998; Kirshner & Whitson, 1997; Kolb, 1984; Lave & Wenger, 1991; Ogbu, 1995a, 1995b; Perry, 2012; Schauble et al., 1998; Senge, 1990; Senge et al., 1994;

Sprenger, 2020). These ideas, under which theories and associated postulates arise, come from a wide array of disciplines including psychology, human development, cognitive science, education, sociology, anthropology, and organizational development. I perceive them to be complementary in relation to learning in informal settings because no single theory addresses the complexity of learning and researching in such settings.

This chapter shares the tale of my own foray toward investigating this question, Is learning happening in science museums? It is a story about a search for an approach and theoretical and/or conceptual framework for researching learning in informal science settings.

For informal science educators and researchers, researching learning in informal environments opens associated questions such as: How do we identify learning in informal science settings? What does it mean to learn science? Ideas about learning have become increasingly complex, moving from an initial perspective focused on a simple accumulation of science content knowledge and methods, to one that includes and considers its social, emotional, and cultural components (Birney, 1986; Davidson et al., 2020; Fenichel & Schweingruber, 2010; National Research Council, 2009; Serrell, 1990). This broader and deeper way of looking at science learning has a profound influence on the ways we think about examining science learning in informal settings (Allen, 2002; Falk & Dierking, 2019; Gutwill, 2016; Kelly, 2003; McManimon, 2021; McManimon et al., 2020; National Research Council, 2009; Price & Applebaum, 2022; Schauble et al., 2002; Tal & Dierking, 2014). This enhanced way of looking at learning prompts innovation toward recognizing, assessing, and understanding learning in informal science settings.

My work in the museum field ranges from being a developer and implementer of museum programs to being an evaluator and researcher of museum programs, exhibits, and organizations. My prior work in formal education with young children provides a grounding for thinking about how children learn and develop in those settings. This diversity of perspectives and experience allows me to view the field of education from both a practitioner's and a researcher's point of view. I conclude that although distinct differences exist between formal and informal learning environments, many ideas and theories about learning are relevant for both environments. It strikes me as unrealistic to think about informal learning, as a separate process. Informal learning is part and parcel of the total learning and development of each person (Crane, 1994). The key for me is to think of the learner as the main focal point for investigation and to look at how the context and situation of that learning opportunity affects that experience. Recent literature discuss a science-learning ecosystem, an idea that resonates with how I perceive the learner's movement across the landscape of available science learning opportunities (Corin et al., 2017; Falk & Dierking, 2019).

Perhaps I eventually will come upon, or possibly contribute to, a greater "learning theory," which can apply across contexts, including museums. In the meantime, I will approach challenges, such as proving learning is taking place in informal science education settings, by investigating the question at hand with methodologies feasible and perhaps innovative for that setting, keeping in mind the unique culture and context of informal learning environments.

25.2 Applications in the Literature

25.2.1 Constructivism

The most profound influences on my research in learning are the ideas of constructivism, a paradigm of concepts about both knowledge and learning, which describe both what "knowing" is and how one "comes to know" (Fosnot, 1996a, p. *ix*). This self-regulated process is relevant around museum's exhibits and programs because visitors bring their personal models of how the world works and further negotiate meaning-making, new representations and models, via their actions and social interactions (Fosnot, 1996b).

Hein has done considerable work focusing on how constructivism relates to learning in museums (Hein, 1998). Hein's ideas on constructivism in museums developed over many years and are informed by the thinking of many others, including Dewey and Freire. Hein believes, as did Dewey and Freire, that we must consider knowledge within the context of the reality through which it arises (Dewey, 1938/1998; Freire, 1970/2017; Hein, 2012). Hein's constructs took shape by closely examining theories of knowledge (epistemologies) and theories of learning, and applying this to a model of how these theories pertain to informal education settings like museums.

Hein maps theories of knowledge and learning on two continua, each representing a range of beliefs people hold, or associate with, the ideas of knowledge and learning. One end of the continuum for theory of knowledge is, knowledge is independent of the learner. The other extreme of this continuum is, knowledge is in the mind and constructed by the learner. On the other continuum, the theory of learning, one end is the belief that learning is incrementally absorbed by the learner overtime. The opposite end of this continuum is the belief that active participation of the mind leads to a restructuring of the mind. These continua "extend from the more formal, structured, and hierarchical to the less formal, more network-like, and more holistic" (Hein, 1998, p. 78). If we intersect these continua they sort themselves into four ways of thinking about different kinds of museum learning environments, each reflecting a different stance as to how those responsible for designing that environment perceive knowledge and visitor learning. These four domains are: Didactic, Expository; Discovery; Stimulus–Response; and Constructivism (Hein, 1998, p. 25, Hein, 2001, pp. 10–11). Differing frames of reference about knowledge and learning lead to distinctly different educational approaches in the museum exhibits, physical arrangement, and programs. For example, Hein (1998) explains a constructivist museum environment reflects the belief that knowledge is constructed by the learner either personally or socially. In a setting designed with these beliefs about learning and knowledge, experience and active learning are key, and exhibits and programs designs are toward interactivity. Visitors receive encouragement to make connections with things they already may "know," and make meaning through interpretive methodologies that enable them to construct their understanding. Hein posits that when researchers are determining their research methods for researching and evaluating museum exhibits and programs, they should consider the museum's stance on learning and knowledge. Researchers should be sensitive to the belief systems and world views that inform the context they examine, to best understand that context (Hein, 1998, 2001).

Viewing learning from a constructivist stance in museum settings, requires recognition and appreciation of the importance of the social context of these settings. Leinhardt and Knutson (2004) pose their concept of learning in museums as conversational elaboration. They view their concept as distinct from a purely constructivist discussion of meaning making in museums. Instead, they emphasize that the museum situation and cultural role is part and parcel of the learning that takes place. They posit that "learning is influenced by conversation, especially conversation that provides explanatory engagement in the exhibition. Both learning and explanatory engagement are influenced by the design features of the environment and by the identities of the visiting groups" (p. 19). Falk (2009) expands on these ideas, by focusing on the variety of identities that visitors might bring with them to any museum visit. Identities are not static, as an individual's identity will change at different times, according to need and situation (Falk, 2009).

25.2.2 Experiential Learning

The concept that learning connects to experience ties to the intellectual work of Dewey, Lewin, and Piaget (Crain, 1992; Dewey, 1938/1998; Falk & Dierking, 1992; Hein, 2012). Although each offered different models and ways to think about the learning process, they all saw experience as a basis for learning. These ideas flow into the concepts in Kolb's (1984) experiential learning theory. As Kolb explains, this theory does not seek to replace behavioral and cognitive learning theories. Grounding his work in the intellectual ideas of Dewey, Piaget, Lewin, and others, Kolb suggests instead that experiential learning theory is "a holistic integrative perspective on learning that combines experience, perception, cognition, and behavior" (Kolb, 1984, p. 21). Experiential learning theory describes learning as a continuous process where ideas form and reform through experience. It conceives learning as a process grounded in experience, requiring reflection and resolution, and transaction and interaction between the learner and the environment. Kolb's (1984) working definition of learning is, "Learning is the process whereby knowledge is created through the transformation of experience" (p. 38). Informal science education venues have become increasingly experiential in their approach to exhibits and programs as they become more about engaging people in educationally enjoyable and perhaps transformational experiences such as affecting science identities (Cohen & Heinecke, 2018; Falk &

Dierking, 2000; Hein, 1998, 2001; National Research Council, 2009; Piscitelli & Penfold, 2015; Rennie & Johnston, 2003; Roschelle, 1995; Shaby & Vedder-Weiss, 2020; Tal & Dierking, 2014; Tal & Dallashe, 2021).

25.2.3 Sociocultural and Emotional Theories of Learning

Situated learning theory came out in 1991 in one of the seminal discussions around the sociocultural aspects of learning. Lave and Wenger (1991) proposed this theory, which focuses upon a re-thinking about how people learn. Lave and Wenger (1991) posit that there is a relational interdependency of agent and world, activity, learning, and knowing, making it critical to look at learning within the context of human activities and social interactions. They presented the concept of "community of practice." Wenger further discussed communities of practice in later writings (Wenger, 1998). Lemke (1997) also discussed these ideas, explaining that our participation and cognition is generally bound up with those of others (Lemke, 1997). Engeström and Middleton (1998) explored this perspective in the context of a variety of work situations (Engeström & Middleton, 1998a, 1998b). In his related discussion of situated cognition, Clancey (1997) posits that "human knowledge is located in physical interaction and social participation" (Clancey, 1997, p. 344).

Because perception and action arise together, and learning occurs within human behavior and interaction, ideas of situated learning are most applicable when investigating interactive contexts, such as science centers and children's museums (Callanan et al., 2017; Dohn, 2011; Engeström 2016; Falk & Dierking, 2000, 2019; Falk & Storksdieck, 2005; Fenichel & Schweingruber, 2010; Hackett et al., 2020; Letourneau et al., 2017; National Research Council, 2009; Nesimyan-Agadi & Ben-Zvi-Assaraf, 2022). Engeström (2016) explains that ideas and ways we think about learning are expanding. Contexts for museum-generated learning are moving beyond the museum walls as museums reach out to broadened audiences through outreach programs and on-line connections (Engeström, 2016). Situated learning is also very much a part of the learning experience for those who work in and with museums, and something I personally experienced and subsequently researched in my doctoral dissertation examining how museum teacher educators build their expertise within their practice at the museum (Bailey, 2003, 2006). Others continue to discuss and investigate this area of inquiry, and associated literature show situated learning to be an important part of their work and findings (Adams et al., 2008; Allen & Crowley, 2014; Bevan & Xanthoudaki, 2008; King & Tran, 2017; McLain, 2017; McManimon, 2021; Patrick, 2017a, 2017b; Tran, 2007; Tran et al., 2013).

Ideas of socially constructed learning have been an important feature in museum learning models over the last few decades. In these settings, people learn together as they share ideas and perspectives. They participate in a process of joint meaning-making where they build on each other's knowledge and understandings (Fienberg & Leinhardt, 2002; Schauble et al., 1998; Wertsch et al., 1984). Mastusov and Rogoff (1995) perceive learning in settings like museums as a participatory process and one that brings together communities of learners. Following Dewey's definition of an educational institution as an opener of the sociocultural environment of its participants, Mastusov and Rogoff posit we can assess visitor's learning by observing changes in learner's participation in different communities and practices. These researchers explain that a community of learners forms in the museum through an interface of three participating communities: the staff, the exhibits, and the visitors (Dewey, 1916; 1938/1998; Mastusov & Rogoff, 1995; Wenger, 1998). The degree to which each of these groups holds the responsibility for the learning process, and the motivations of the respective groups, influences the character and practices of the museum's mission, exhibits, programs, and participants (Hein, 1998, 2001; Simon, 2010).

Wertsch (1991) explains a sociocultural approach to mind theorizes that "human mental functioning is inherently situated in social interactional, cultural, institutional, and historical context" (Wertsch et al., 1991, p. 86). Therefore, we cannot just look at the individual in terms of their learning, but must view them in their sociocultural context. This also gives rise to the idea of distributed cognition: the idea that when people work together, their coordination of efforts involves a distribution of cognition around the task, as well as cognition around their coordination (Hutchins, 1991, 1995). Cole (1991), in considering the emerging theories of socially shared cognition, says the view that cognition can be shared does not break down the basic distinction between the individual and the social. Socially shared cognition does not need to challenge standard psychological theory, rather it can extend this way of thinking into potentially useful areas of education practice, under conditions when children are working together. Cole points out that when we talk about the categories of the individual and the social we also are talking about the context of human culture within which both reside. Thus, when we speak of socially shared cognition, we must not ignore the cultural component (Cole, 1991). Each individual in an informal science public context is likely to have access to the behaviors of others around them. Therefore, the ideas, prior experience, and culture of those around them can affect, inform, and influence a visitor's museum experience. There is evidence in the museum literature, of a broadening perspective on the sociocultural aspects of the museum experience. Outreach into the community, participatory engagement, and partnerships with groups not traditionally involved, moves the sociocultural aspect of learning to new levels. These shifts are motivating new perspectives about the museum learning experience and an influence on how museum professionals think about their work and actions (Falk & Dierking, 2019; Fraser & Switzer, 2021; Simon, 2010; Spitzer & Fraser, 2020).

Beyond the sociocultural aspects of the visitor experience, the emotional, or affective aspect of learning is also significant to that experience (Csikszentmihalyi & Hermanson, 1995; Friedman, 2008; Gardner, 1991; Hein, 1998; Falk & Deirking, 2000; Paris & Ash, 2000; Semper, 1990). Findings from traditional visitor tracking studies conducted in the early and mid-twentieth century highlighted the decidedly individual nature of visitor's museum experience, and stimulated interest in better understanding this phenomenon. The more naturalistic observations conducted in the late 1970s and early 1980s increased documentation of visitor's affective behaviors and engagement with exhibits and programs, providing a more comprehensive story of the visitor experience (Hein, 1998; Falk & Deirking, 2000; Semper, 1990).

Ideas connecting emotion and learning, can be seen beyond the museum field. Csikszentmihalyi and Hermanson (1995), in a discussion of why people want to learn in museums, note psychologists began to write about intrinsic motivation in the late 1950s. In the later part of the twentieth century and early twenty-first century, research and discussions around social-emotional learning are increasingly visible in the literature from multiple fields such as psychology, neuroscience, formal education, and organizational learning (Davidson et al., 2020; Deci & Ryan, 1985; Friedman, 2008; Immordino-Yang, 2016; Immordino-Yang & Damasio, 2007; Immordino-Yang et al., 2019). Recognition of the critical connection between the emotional and cognitive functions of humans has triggered this interest. In neuroscience, researchers Immordino-Yang and Damasio (2007) posit that "the relationship between learning, emotion and body state runs much deeper than many educators realize and is interwoven with the notion of learning itself" (Immordino-Yang & Damasio, 2007, p. 3). In the formal education field, researchers and leaders advocate an emphasis on social-emotional learning for both students and professionals (Frey et al., 2019; Knight, 2022; Sprenger, 2020). In the museum world, advances in technology such as heat maps, eye-movement tracking and skin conductance are offering researchers non-traditional ways to document and measure emotional responses in visitor's museum experience, and consider how such findings can inform learning outcomes (Tinio, 2021). Strategies used to support social-emotional learning (SEL) are moving into the museum literature. For example, Eppley (2021) describes how the trauma of the pandemic and racially charged issues of 2020 motivated at least one museum to become familiarized with SEL research to better support their partner schools (Eppley, 2021). Additionally, museum experts presented research-based principles for supporting families during a health crisis that paid close attention to the social-emotional aspects of learning (Dierking et al., 2020). Luke et al. (2021) has conducted research to document evidence of preschoolers social-emotional behaviors in museums and compare this with their playground behaviors. Their research findings suggest a need for reinforcement of professional development for museum educators toward recognizing developmentally appropriate social-emotional skills for young children, and additional attention paid to these needs in exhibit design.

25.3 Examples of Author Use

The learning theories I discussed above help inform the research design, process, and methods I use to investigate visitor's learning. Although I utilize both qualitative and quantitative methods, I am most interested in pursuing the "whys" and "hows" of the visitor experience. I am very interested in recognizing the process of learning, and if, and how, that process demonstrates itself during an informal learning experience. A naturalistic approach to research in informal settings is very helpful toward finding answers to these questions. Methodologies that consider the context and culture in which the visitor's current experience takes place, including the social and physical aspects of that context, help to build our understanding of learning in these settings.

Typical exhibit evaluations in my field often are based on a particular exhibition or program, where the exhibit and program have a theme and/or message with clearly defined goals or objectives. However, the concept of determining and/or measuring visitor learning always has been a thorny topic for museum researchers, and one with which they have wrestled for many years. An interest and need to verify that learning is taking place in informal science environments continues across the field (CAISE, 2010; Gutwill, 2016; Hackett et al., 2020; Letourneau et al., 2017; McManimon et al., 2020; Panos & Ruiz-Gallardo, 2021; Pattison et al., 2018; Puvirajah et al., 2020; Tal & Dallashe, 2021). Defining learning and capturing evidence of learning within and as a result of an informal experience is a challenge I increasingly confront. A free choice environment, especially one designed for very young children holds particular obstacles when tackling this question (Hackett et al., 2020; Letourneau et al., 2017; Zosh et al., 2017).

It is difficult to draw a single line from what we see visitors do in science museums to any particular characteristic, influence on learning, and/or learning theory. Part of the challenge of conducting informal learning research is to be able to recognize and identify learning moments in progress within the tangled weave of the many things taking place, often simultaneously, during the museum experience.

What follows is a discussion of two evaluations I conducted about a year apart at two very different science centers, which provided opportunities and gave rise to a new approach in researching the idea of learning in science centers. Characterizing both evaluation projects were requests to identify and show that learning takes place for visitors as they interact with exhibits in these science centers. The first was at a small science center for children in the United States and the second at a large science center in Germany. Hurdles my team and I encountered and surmounted in the first project resulted in informing new approaches in the second project. From this second project's inception, my team and I thought about and discussed observable behaviors that were associated with learning. Together, we designed data collection methods which would document these behaviors as well as other behaviors we might observe among visitors in the galleries.

Informing the research design and associated data collections for both projects were the learning theories that have guided my work over the years, most specifically perspectives around learning held by constructivism, experiential, and sociocultural and social-emotional theories of learning. Constructivism applies because the visitors were in a self-regulated process as they interacted with the museum's exhibits. Experiential and sociocultural and social-emotional theories were employed because we were gathering information about the visitor's experience in the context of the science centers, getting details about how that experience transpired, and observing behaviors and interactions, which could provide evidence of the visitor's learning process.

25.3.1 Application 1: Small Science Center Research Project

A small science center for children, to show donors that their young visitors were learning in that science center, requested us to conduct a “proof of concept” study. To accomplish this, we designed and conducted four studies. In the first study, the Exit Interviews, we approached families as they exited the museum, and invited them to answer some questions about their visit experience. We collected a sizable amount of data from these interviews, which included questions around learning. The second study, the In-depth Observations, were detailed documentation of individual children exploring the museum exhibit(s). During these observations, we looked for evidence of visitor engagement with exhibits, including the time they spent at these exhibits and many other details around their actions, behaviors, and interactions. Additionally, we conducted follow-up interviews with the young visitor’s caregiver, asking them if they noticed certain behaviors in their children and, if so, to what degree. The third study was a Group Interview with parents of children attending the museum’s summer day camp program. In this interview, I asked parents about connections they may have noticed between their child’s museum camp experiences and other experiences, such as occurrences at home and/or on excursions. In the fourth study, I observed the museum’s outreach program conducted at a local public school.

In a more typical evaluation with clearly stated exhibit, program, or attitudinal goals, similar collected data likely would provide answers to our evaluation questions. However, after careful analysis and review of our data from this project, in the light of our primary research question to determine if learning was happening, I felt that we had limited pertinent data providing evidence for whether or not young visitors experienced learning as they interacted with the museum’s exhibits and programs. I thought deeply about this problem, and discussed it with my team. What was missing? As we pondered, we realized the question “Are children learning from their exhibit experiences?” was less about a specific learning outcome and more about identifying or verifying that the process of learning was taking place during their experience.

The learning theories I adhered to in the past were still relevant, but more from an educator’s perspective toward exhibition and program design. These theories were proving less helpful toward informing our research analysis process, at least for this investigation aimed at identifying something as complex and seemingly internal as visitor learning. After considerable thinking and discussion with others, I came upon a potential solution to this problem. I needed to better define and describe what we were researching. The resolution to my conundrum became increasingly clear—because we were asked to identify if learning was taking place, then we needed to look for, define, and identify more specific visible and auditory indicators of the learning process. What were observable behaviors, which might be signs of, or characteristic of, learning, which visitors might present during their museum experience? Once we identified such observable behaviors, would our collected data include pointers or markers for such behaviors?

The appropriate next step was to go back into the cognitive development literature of young children. I reviewed this literature with a specific eye toward finding what this research offered in terms of observable behaviors that investigations have shown to be associated with the learning process. Aside from researching and reading the literature, I also had discussions with colleagues pursuing similar questions about learning in informal settings.

I revisited our collected data, this time with an eye for those observable behaviors gleaned from the literature. I looked at behaviors our observations had documented in the galleries and during outreach events, and/or behaviors reported during our interviews with families and parents. I considered these data points to see if they did or did not align with the observable behaviors in the literature. As I did this, I realized our data had the evidence which we sought. I was able to see alignment between many of the behaviors described across the cognitive development literature with behaviors we had documented in our studies. I was pleased to realize we had collected observable data relating to the question of whether these young visitors were experiencing some moment in their process of learning. I was able to re-code the collected data to highlight observed behaviors, which aligned with findings on cognitive development. With this evidence, I was able to build a case that many of these young visitors were demonstrating behaviors characteristic of learning. I was able to suggest in my report to the small science center that because we documented behaviors characteristic of learning occurring at the center's exhibits and programs, that some process of learning was likely in progress for these visitors, at those moments.

In my report, I presented our findings, supported by data, for the following categories: watching and imitating, communicating, making connections, focusing, exploring with senses, critical thinking, adult supporting and scaffolding learning, self-directed engaged learning, and taking on challenges. The narrative of my report drew connections between what we observed and what the literature says about cognitive development of children, with particular emphasis on observable behaviors characteristic of cognitive development. Therefore, I concluded that the center's exhibits appeared to support visitors experiencing and displaying these learning characteristics, and that the center was an environment where learning was likely to spark and take place. I provided a brief literature review in our report, but due to a short time frame for report production and submission, I considered this review only a beginning of what I hoped to develop. I felt motivated to ultimately develop this brief literature review into a more comprehensive review of that literature, so I could feel more confident toward crystallizing this approach for identifying learning in similar science museum settings.

This research path did not shift my thinking and beliefs about learning and the learning theories which informed them, but it did cause a modification in my thinking of how to approach my research projects. It also sensitized my interest in finding other studies that might be taking a similar approach. For example, Barriault and Pearson (2010), a Canadian study, researchers developed a tool that utilized observable visitor behaviors to distinguish three stages or levels of visitor engagement: initiation, transition, and breakthrough (Barriault & Pearson, 2010). Another useful study was the research work of Letourneau and colleagues, which focused on caregiver's observations of children's behaviors in a museum (Letourneau et al., 2017). Although these studies had somewhat different research questions and goals from those I was pursuing, this literature informed my thinking and subsequent research design.

25.3.2 Application 2: Large Science Center Research Project

The opportunity to build further on these ideas came a few years later. A large science center in Germany asked me to conduct an evaluation for two galleries of exhibitions. This science center had similarities to those with which I was accustomed, and its visitors tended to be the familiar groups of families and school groups. One of the galleries attracted mostly young visitors, under the age of 10, generally accompanied by adults. The other gallery attracted teens and adults. There were 122 exhibits in all. Among the primary goals for this evaluation was to provide "a comment" about the learning happening at the exhibits in these galleries. I realized this would be an excellent time to apply the approach of identifying observable learning behaviors that I had developed for the small science center. However, in that prior evaluation, this approach had emerged during the data analysis process, after the research design and data collection phases. For this new evaluation and much larger complex study I would be able to incorporate this approach much earlier in the research design and data collection phases. Therefore, from the outset of this project, my team and I systematically went about developing a flexible but more focused approach that deliberately would look for these observable behaviors associated with learning. To gather the information needed to answer the evaluation/research questions, we identified three studies to conduct in the two galleries. Within two of these studies we used direct methods to focus the data collectors to look for and document nine particular observable behaviors associated with learning.

We informed these studies by the same learning paradigms for which we informed the small science center research: constructivism, experiential, sociocultural, and social-emotional learning. Because half the project team was from the U.S. and less familiar with the German science center's audience, it was especially important to collect detailed information around the sociocultural aspects of the visitor's experience. Experiential and situated learning theories were important for researching in this interactive setting, because the visitor's experience was associated strongly with the context of the science center, its exhibits, and its visitors.

Our initial methodology had data collectors pay particular notice to nine things/behaviors which visitors might show: observing, thinking aloud, trial and error, repeating, explaining discoveries to others, explaining handling to others, being frustrated, being satisfied, and being concentrated. As other visitor behaviors might also prove pertinent, my team utilized several data collection methods, both quantitative and qualitative, including timing and tracking, exit interviews with individuals and groups as they left the gallery, and in-depth play-by-play observations of individual visitor's interactions at a sample of target exhibits, followed by a short, associated interview and a data-collector-completed summary sheet.

The timing and tracking study was primarily quantitative and looked at the path and duration of exhibit stops made by 50 visitors in each gallery, 100 visitors in total. The team conducted 50 exit interviews, 100 exit interviews in total, to gain reactions, recollections, and motivations from a sample of visitors just as they exited each of the galleries. The exit interviews were both quantitative and qualitative, with many questions permitting open-ended responses.

My team and I selected 20 target exhibits, 10 from each gallery, for in-depth study. The methodologies used to investigate these in-depth exhibit interactions were primarily qualitative, with some quantitative components. We alerted data collectors to look for the specific nine behaviors and capture any other behaviors they observed. Most of the data collection was in German. As they watched visitors, data collectors made audio recordings of a play-by-play description of what they were able to see, hear, and feel. We intended this to capture, as far as possible, all the aspects of that visitor's experience, including their expressions, communications, and interactions with the exhibit, other visitors, and museum staff. At the point the visitor appeared to be finished interacting with the exhibit, data collectors approached the visitor and invited them to respond to a short interview. If they agreed, the data collector asked them a series of questions, including spontaneous questions to get clarification and/or understanding of what the data collectors had observed. After these observations and interviews, data collectors filled out a summary sheet. This sheet included those nine behaviors and the degree to which, in their recollection, they had observed the visitor demonstrate. Data collectors transcribed the audio recordings and interviews and those data collectors fluent in both English and German subsequently translated them into English. The team collected these data for at least 25 visitors at each of the 10 target exhibits per gallery, thus a total of 250 observations.

Data analysis permitted us to look for patterns and behaviors across the studies. Other team members analyzed the primarily quantitative data from the timing and tracking and exit interviews. I focused on the analysis of the qualitative data from the in-depth observations of the target exhibits. I looked at behaviors reported in the play-by-play descriptions of visitor's experience, including behaviors we initially did not identify. We all conferred on our respective findings and on report development. Findings from these studies show many instances of visitor behavior characteristic of learning-in-progress. We also were able to distinguish differences across the specific target exhibits as to the form and degree of learning-related behaviors each of these exhibits encouraged.

25.4 Learning Characteristics and Influences on Learning

I learned many lessons along the way over the course of the large science center research project. Perhaps most important was the emergence and refinement of a set of Learning Characteristics and Influences on Learning. During my analysis and coding process of the in-depth target exhibit study data, I was moved to reorganize the original nine behaviors into a more functional grouping. Most of the original nine behaviors remained; however, I reshuffled and/or merged them into five new categories, four of which I labeled "Learning Characteristics," and the fifth labeled "Influences on Learning." Each of the main categories have associated sub-categories derived from observations, which help discriminate among the various ways and conditions under which visitors exhibited these behaviors.

A full discussion of these Learning Characteristics and Influences of Learning, along with the supporting research literature, is beyond the scope of this chapter. However, to illustrate how others might use this tool in pursuing similar research interests, I offer a brief review of these Learning Characteristics and Influences on Learning and examples of how I applied them in the two research projects applications described above. First, I provide a list of the categories and subcategories that emerged during coding and organizing of findings of the in-depth observation study data collected in Application 2, the large science center research project. Second, I present quick descriptions and explanations for the main categories of Learning Characteristics and Influences of Learning, and follow these descriptions with examples of representative data coded for that Learning Characteristic and/or Influence of Learning. Third, I present a sample of literature used to support and develop these Learning Characteristics and/or Influences of Learning, with particular attention towards their relevance for researching learning in museums.

25.4.1 Learning Characteristics and Influences on Learning Coding Categories with Sub-categories

I have found the following set of *learning characteristic*s and *influences on learning* to be a useful tool toward collecting, sorting, coding, and analyzing data to identify behaviors characteristic of, and associated with, the process of learning at science museum exhibits. Below are the full list of main categories and subcategories I developed during Application 2, the large science center research project:

Learning characteristic—Utilizing executive functioning skills (EFS)

EFS: Attraction to and initial interaction with the exhibit.
EFS: Focusing, concentrating, and paying attention to the exhibit.
EFS: Joint attention-attraction and focusing at the exhibit.

Learning characteristic—Utilizing communication skills

Form of Communication: Utterance at the exhibit.
Form of Communication: Statement at the exhibit.
Form of Communication: Signaling discovery at the exhibit.

Form of Communication: Explaining and/or describing discoveries at the exhibit.
Form of Communication: Directing and strategizing at the exhibit.

Learning characteristic—Utilizing observational skills

Observing: Visitors independently using their senses to gather information through direct interaction with the exhibit.
Observing: Visitors receive guidance to use their senses to discover at the exhibit.
Observing: Visitors informally gathering information through watching and listening at the exhibit.
Observing: Visitors imitating and/or building on the ideas of others at the exhibit.

Learning characteristic—Utilizing critical thinking skills

Critical Thinking Skills: Repeating-comparing-testing at the exhibit.
Critical Thinking Skills: Grasping the concepts at the exhibit.

Influences on learning

Influences on Learning: Affective aspects of visitor experience at the exhibit.
Influences on Learning: Sociocultural aspects of visitor experience at the exhibit.
Influences on Learning: Mechanical and operational aspects of the exhibit.

25.4.2 Quick Descriptions of Main Categories of Learning Characteristics and Influences on Learning, with Examples

Learning characteristic: Utilizing executive functioning skills

Executive functioning skills are the skills people employ to manage situations, such as our attention, emotions, and behavior, to reach goals. Executive functions of the brain interweave social, emotional, and intellectual capacities. The team looked at visitor's highly observable behaviors of attention, focus, and engagement and noted if the attention to something was a solo behavior or was "joint attention" involving additional individuals.

Example *Learning characteristic—Utilizing executive functioning skills (EFS).*

The following is an excerpt of data from Application 2, coded as:
Learning characteristic -Utilizing executive functioning skills.
Subcategory-Focusing, concentrating, and paying attention at this exhibit.

Observation 14, M19, below is an example of a male visitor, estimated to be 19 years old, demonstrating sustained focusing at an exhibit about using your senses. He appears to be thinking carefully as he chooses and interacts among the components. M19's first behavior was to apparently conduct an overview of the exhibit's components, after which he approached and interacted with the hearing component, and moved on to explore the touch component.

Representative data excerpt: Observation 14, M19: M19 arrives at the exhibit and first looks at the different stations. Then he goes to the hearing center and puts on the headphones. Now M19 slowly moves the controller back and forth. M19 listens very carefully and attentively to the sounds. He lets the controller stand completely on the right and looks very concentrated.... Then he again looks at the other theme sections of [the exhibit] and decides for "What feels most comfortable to you?" M19 strokes from left to right across the different surfaces—first with his left and then with his right hand. He performs this movement slowly and deliberately..... {Full duration 6 min 54 secs}.

25.4.2.1 Learning Characteristic: Utilizing Communication Skills

Humans can conduct communication through verbal means and via body language, such as facial expressions and gestures. The team looked for instances of communication in visitors and documented details, both auditory and visible, of those communications.

Example *Learning characteristic—Utilizing communication skills.*

The following is an excerpt of data from Application 2, coded as:
Utilizing communication skills.
Subcategory: Explaining and/or describing discoveries.

Observation 2.12, F10 below is an example of a female, about 10 years old, communicating what she's done and discovered. As F10 leaves the exhibit, she also appears to explain how this station works, to the next visitor.

Representative data excerpt: Observation 2.12, F10:... F10 places another stone under the microscope and only now discovers the control slides on the microscope... She is visibly surprised by the result the controllers have created... she enthusiastically calls the woman [the group's supervisor?] to her and joyfully points to the big screen. With the same control setting F10 places the white shell (open side to the lens) under the microscope and examines this result with enthusiasm... F10 puts the shell away, stands up and wants to walk away. But then she turns around again and explains to the boy from earlier what he can do there and what function the controls have. Finally, F10 leaves the exhibit. {Full duration: 7 min 15 secs}.

25.4.2.2 Learning Characteristic: Utilizing Observational Skills

Observational learning, or modeling, is learning through observation and imitation. Visitors use their senses of sight, hearing, touch, smell, and taste to gather information. People use these senses to figure out how things work and often do so by watching other people's interactions. Sometimes visitors guide or encourage other visitors to utilize their observation skills. The team gathered observable behaviors of visitors using their senses, noting if they imitated things they observed other visitors do.

Example *Learning characteristic—Utilizing observational skills.*

> The following is an excerpt of data from Application 2, coded as:
> Utilizing observational skills.
> Subcategory: Informal information gathering through watching and listening.

In Observation 5.12, M9, two boys and an adult male, perhaps all related to each other, guide each other in an investigation of the braking mechanism of giant lever designed to lift a heavy ball. All *use their senses to investigate the lever*, they *watch and listen* to each other, and appear to influence each other's attention toward scrutinizing the air brake.

Representative data excerpt: Observation 5.12, M9: M9 comes to the station and pushes the lever down. Another boy (his brother?) comes and pushes the sphere on the other side. Now the other boy goes to M9's side and pushes there, too. After pushing down, M9 lifts the lever [and watches it].... The father now joins in and helps M9 push. Both observe the delayed re-upward movement of the lever.... The father seems to explain something to M9. M9 pushes the lever down again. He lets go and watches the delayed re-up again. M9 then walks away. {Full duration: 0 min 57 secs}.

25.4.2.3 Learning Characteristic: Utilizing Critical Thinking Skills

According to the research literature, *critical thinking* has similarities to the scientific method: determining the issue to be addressed, posing hypotheses, conducting unbiased experiments to test the hypotheses, and drawing conclusions. The process of critical thinking draws on many other skills including focusing, self-control, making connections, communicating, and perspective taking (considering how our solutions affect others). Critical thinking involves meta-cognition, or thinking about thinking, as people reflect, analyze, plan, and evaluate. The team looked for observable behaviors associated with utilizing critical thinking, including experimenting, testing things out, trial and error behaviors, exhibiting curiosity, investigating, repeating actions, making connections between cause and effect, modifying actions, and conducting problem solving. We looked for evidence that visitors were grasping the concept upon which the exhibit focused. Post-observation interviews provided the most informative data towards identifying visitor's conceptual understanding. However, during some observations, comments overheard and/or behaviors noted provide clues concerning visitor's grasping the concept.

25.4.2.4 Learning Characteristic—Utilizing Critical Thinking Skills

The following is an excerpt of data from Application 2, the large science center, coded as:
Utilizing critical thinking skills.
Subcategory: Repeating-comparing-testing at the exhibit.

In Observation 3.23, F6, a young girl is observed to demonstrate *problem solving*. F6 appears to want to get air coming through a hose to blow into a wind tunnel. She tries different hose configurations, and shortly figures out how to locate and arrange a hose that is long enough to work at the wind tunnel.

Representative data excerpt: Observation 3.23, F6: F6 comes to the [Wind Games] exhibit with her grandmother. The air system goes on and she immediately takes the hose away from the flower. With the hose, she goes to the wind tunnel and tries to hold it underneath. But the hose is too short. So she takes the hose away from the cactus [inflatable cactus-shaped-balloon] and connects her hose there instead. She now takes the tube, that was connected to the cactus before, to the wind tunnel. Now the length is sufficient. {Full duration: 2 min 31 secs}.

25.4.3 Influences on Learning (Affective Aspects, Sociocultural Aspects, and Operational and Mechanical)

The *influences on learning, affective aspects, and sociocultural aspects,* draws on the research indicating the interrelatedness among the cognitive, sociocultural, and affective, emotional aspects of the human learning experience. Observational data relevant to these aspects includes *facial expressions, body language, vocalizations,* and *interactions (both with the exhibit elements and with other people).*

The following is an example from Application 2, with data coded as:
Influences on Learning.
Subcategory: Affective aspects of visitor experience at the exhibit.

Observation 1, M6, is an example of how different emotions can be demonstrated during an exhibit interaction at the interactive about moving air [Wind Games}. When parachutes get tangled, support comes from M6's grandmother. M6 subsequently displays happiness as he carries on with other investigations. He also asks his grandfather to witness his activity.

Representative data excerpt: Observation 1, M6:... M6 now has discovered the wind tunnel. He is looking for something to put in. He discovers the parachutes and sets them up. He blows two parachutes upwards until they get twisted into each other. They do not fly upwards. M6 takes them out and wants to disentangle them. He does not make it. His grandmother helps him. M6 starts playing with the hose and the flower [inflatable] figure… The grandmother gives him a parachute again. M6 takes the parachute and puts it into the wind tunnel. He lets it fly. He is happy and calls his grandpa to have a look… {Full duration: 6 min 20 s}.

25.4.4 Sample of Literature for Recognizing Behaviors Characteristic of, and Influences on, Learning

25.4.4.1 Learning Characteristic: Utilizing Executive Functioning Skills

Brunner summed up the critical connection between motivation and learning by stating, "motives for learning must be... based as much as possible upon the arousal of interest in what there is to be learned" (Brunner, 1960, 1977, p. 80). Duncan et al. (2007) examined what skills or knowledge children acquired early in life matter most to children's later success when they entered school. These researchers concluded that three skills were related strongly to later success in reading and math, including the less obvious one of "attention skills." They found that the more penetrating our attention, the richer and deeper our learning (Duncan et al., 2007). Motivation is key to paying attention and research has shown that supportive environments such as science centers and museums can rekindle the natural motivation and desire to learn. In conjunction with the 1995 American Association of Museums conference convened to establish a research agenda to investigate learning in museums, Csikszentmihalyi and Hermanson (1995) wrote an influential paper on "intrinsic motivation" as it relates to what drives people to want to learn in museums. Csikszentmihalyi and Hermanson connect what psychologists and other researchers know about what motivates learning with learning experiences in the contexts and cultures of science museums. They include ideas of curiosity and interest, and "The Flow Experience" (Csikszentmihalyi & Hermanson, 1995, p. 69; Csikszentmihalyi, 1990). In the formal school environment, Gregory and Kaufeldt (2015) investigate student motivation as informed by research from neuroscience and psychology, citing researchers such as Ryan and Deci, Maslow, Glasser, and Bandura. Gregory and Kaufeldt propose strategies to improve student motivation, and advance ideas such as first hand experiences, choice and self-directedness, and group flow (Gregory & Kaufeldt, 2015). Ryan and Deci's research on intrinsic motivation, highlight people's inherent psychological needs of competence, self-determination and relatedness (Deci & Ryan, 1985; Ryan & Deci, 2000). The museum literature show researchers and practitioners in the museum community are making connections to these inherent psychological needs to address issues around motivation and a sense of belonging, for both visitors and staff (Allen & Crowley, 2014; Dohn, 2011; Gutwill, 2016; Price & Applebaum, 2022).

Focus and self-control involve many executive functions of the brain, including paying attention, remembering the rules, and inhibiting one's initial response to achieve a larger goal. These functions connect significantly to our ability to learn (Diamond, 2013; Jensen, 1998; Rueda et al., 2005; Sylwester, 1995). Zelazo, in a 2016 report for the U.S. Department of Education, explains most current researchers generally agree that human executive functions are characterized by a specific set of regulatory skills including cognitive flexibility, which involves thinking about things in other ways; working memory, which involves keeping things in mind; and inhibitory control, which involves the ability to suppress attention from distraction (Zelazo et al., 2016). All of these functions are applicable to the museum experience, but attention is a visible behavior, which can be observed and documented in visitors.

Vygotsky (1938/1978) recommends that experts support learning by creating a "scaffold" between what they know and what the learner knows and understands. He labeled this space between the knowledge levels of expert and learner as the Zone of Proximal Development (ZPD). This scaffold enables achieving a higher level of understanding of a given concept or learning goal (Crain, 1992; Vygotsky, 1938/1978; Wertsch, 1995a, 1995b). Ash (2003) examined the detailed content of family dialogue and the co-construction of knowledge taking place among the group members of different ages. Her research of family conversations at several science centers were considered through a Vygotskian ZPD perspective (Ash, 2003). *Joint attention*, especially between parents or other caregivers and children, is a powerful means of supporting learning and development (Pan et al., 2005; Rogoff & Gardener, 1984; Rollins & Snow, 1998; Snow & Beal, 2006; Wertsch et al., 1984). Pursuits such as working together on an activity or problem, or interacting around an exhibit, can provide a setting for focused conversation and/or engagement. Joint attention is commonly observed in research studies conducted in science museum settings (Callanan et al., 2017; Fenichel & Schweingruber, 2010; Gutwill & Humphry, 2005; Patrick, 2014; Patrick & Moorman, 2021; Tunnicliffe, 1998).

25.4.4.2 Learning Characteristic: Utilizing Communication Skills

Rittle-Johnson et al., (2007) investigate the transfer of knowledge. Researchers found that having a listener, even one who does not respond, helped children's problem solving and their ability to transfer learning to a new situation (Rittle-Johnson et al., 2007). Adults can provide what Hart and Risley (1995) labeled as "extra talk." Hart and Risley's studies showed adults posing questions such as *What if?*; *Remember?;* and *What do you think?*, highly correlate with their children's performance on IQ tests at three years of age and achievement tests in third grade (Hart & Risley, 1995; Sulzer-Azaroff, 1997).

In 2002, Allen studied in-depth learning through documenting visitor conversations, or "learning-talk," at an exhibition on frogs at the Exploratorium science center.

For this study, she defined learning as, "an interpretive act of meaning-making, a process rather than an outcome, and a joint activity of a group rather than being attributable to one of the people only" (Allen, 2002, p. 262). In her analysis of conversations, she distinguished five overall categories for talk: perceptual (identifying, naming, pointing out feature, quoting a label), conceptual (simple inferences, statements, interpretations), connecting (connections with exhibit and personal experience), strategic (how to use and manipulate the exhibit), and affective (Allen, 2002; Fenichel & Schweingruber, 2010, pp. 69–74). Allen concludes that tracking visitor conversations is worth the considerable effort it takes by bringing "the researcher into the heart of the learning 'action' of the museum visit, and emphasizing learning as process rather than merely outcome" (Allen, 2002, p. 301).

Parents and other caregiver's looks and gestures help children direct their attention to what these adults think is important. *Pointing*, for example, one of the most familiar of gestures, is a signal to children and from children. Children begin to *point* around eight months of age or later, an important milestone in the development of communication skills and a first step into language. Children communicate feelings through expressions and tones even before language can do so, and learn language through the filter of feelings (Fernald, 1993; Galinsky, 2010; Goldin-Meadow, 2007; Kuhl, 2010). Borun et al. (1996) and Borun and Dritsas (1997) explored how conversations among families in science museums can influence the learning process. They found alterations in exhibits made a difference in terms of supporting learning and encouraged development of "family-friendly exhibits" (Borun & Dritsas, 1997; Borun et al., 1996).

25.4.4.3 Learning Characteristic: Utilizing Observational Skills

We observe by making use of our senses to learn about the world (Bransford, et al., 2000; Wolfe, 2001). Meltzoff (2009) identified three channels for learning and development: individual discovery, trial and error, and observational learning. Observational learning often is associated with imitation. Meltzoff points out that imitation is faster than individual discovery and trial and error (Meltzoff et al., 2009). Modeling, learning through observation and imitation, is a powerful tool for childhood learning. In some cultures, modeling has been the traditional, fundamental way to teach children (Bauer & Pathman, 2008; Falk & Dierking, 2000; Rogoff & Lave, 1984). Bauer and Pathman (2004) posits learning is physical; therefore, we must remember the properties of objects in order to communicate their relationships. The researchers found that memories are preserved better under some circumstances than others and that direct experience is more likely to promote memory than passive observation. Beginning in infancy, children learn best through direct experience (Bauer & Pathman, 2008; Bauer et. al., 2004). Additionally, Kolb's work around learning puts experience at the center of learning and development (Kolb, 1984). Kolb's ideas help connect theory to practice in science museums and many of the behaviors he discussed in his theory of experiential learning we can observe as visitors of all ages interact with exhibits.

25.4.4.4 Learning Characteristic: Utilizing Critical Thinking Skills

Galinsky (2010) defines the core of critical thinking as "the ongoing search for valid and reliable knowledge to guide our beliefs and actions" (Galinsky, 2010, p. 204). In Galinsky's view, critical thinking skills can be placed among the higher-order skills among executive functions of the brain, and involve things such as reflection, metacognition or, thinking about our own thinking. Zelazo et al.'s (2016) definition of reflection closely aligns with Galinsky's (2010) definition of critical thinking. Zelazo et al. define reflection as "To pause, consider the options, and put things into context prior to responding" (p. 141). Definitions of critical thinking have and continue to vary over time. Research of this term reveals differences according to when the definition was presented, the disciplines from which it emerged, and the geographic regions where the definitions arose. In 2007, the Journal of Museum Education presented a full issue that offered a variety of perspectives around the idea of critical thinking and if, and how, it ought to relate to museum education (Herz, 2007). More recently, this conversation is taking place around art and history museums (Hubard, 2011; Martinko & Luke, 2018). Use of the actual term "critical thinking" is less is evident in the emerging literature from informal and formal science education, although ideas around cognition, learning, new technologies that support critical thinking, programs and exhibits that encourage making informed decisions, crossing borders between school science and everyday science, and critically reflecting on ethical museum research practices, are still very much in the current literature (Gutwill & Allen, 2010; Knipfer & Wessel, 2011; Lee et al., 2020; McManimon, 2020; Fenichel & Schweingruber, 2010; Spitzer & Fraser, 2020).

Kuhn (2010) discusses scientific thinking development in children. She explains young children have a natural curiosity that can be supported by encouraging their observations, questions and ideas (Kuhn, 2010). There is a growing body of research that looks in particular at parent's and caregiver's role in supporting children's scientific thinking in museums. Callanan and Oakes (1992) found that parents played a strong role in promoting children's scientific reasoning in everyday activities. Using video recordings of conversations at Children's Discovery Museum in San Jose, she concluded that children were engaged more in the exhibit if they explored it with parents rather than alone. In a later study Callanan et al. (2017) found that parents varied in their sense-making talk and in connection to the nature of the exhibit. Moreover, parental engagement was predictive of children's engaged conceptual talk (Callanan & Oakes, 1992; Callanan et al., 2017). Other researchers have found parent's support promoted their children's scientific thinking, in that this support helped children focus on the evidence, gather new evidence, and interpret the evidence (Ellenbogen et al., 2004; Gelman, et al., 1991; Gutwill & Allen, 2010;). Pattison and Dierking (2019), in collaboration with science museums, have researched and described science-related interest development in young children from low income families. They found important variations across families related to parental expressions, involvement, and approaches to re-engaging children's interest (Pattison & Dierking, 2019). To develop parental support, the Providence Children's Museum and Brown University, conducted research to identify ways to encourage parental interaction with their children by increasing caregiver's understanding about how play connects with learning (Letourneau et al. 2017). This research included studies in which caregivers were invited to observe their children at play in the museum. The caregiver's activity sheet focused them to look for specific behaviors. This sheet also incorporated explanations of those behaviors in terms of children's learning. For example, the behavior of *repeating over and over* was explained on the activity sheet as "Kids are exploring cause and effect and practicing new skills" (Letourneau et al., 2017, p. 95).

25.4.4.5 Influence on Learning: Affective Aspects

Over the past three decades, research has paid increasing attention to the emotional and affective content of learning. This literature has emerged from a cross-section of fields seeking to better understand learning and brain-body connections with that process. We can enhance learning, in general, by the motivational and memorable nature of settings such as science museums (Crowley, 2002; Csikszentmihalyi & Hermanson, 1995). Paris and Ash (2000) emphasize the vital aspect of the affective domain in the science museum experience and the importance of further researching connections between enjoyment and learning. Recent advances in neuroscience highlight links between emotion, social functioning, and decision making that influence our understanding of affect in education and learning (Davidson et al., 2020; Elias, 1997; Golman, 1995; Immordino-Yang, 2016; Immordino-Yang & Damasio, 2007; Posey, 2019; Sprenger, 2020). Research shows that play is associated with learning. In 2017, the Lego Foundation published a white paper that pulled together a great deal of the research to date on children's play as a learning mode. They identified several characteristics of playful learning, including that it is socially interactive, iterative, joyful, meaningful, and actively engaging (Zosh et al., 2017). Moreover, Hirsh-Pasek and Hadani (2020) discuss the power of playful learning and conclude that skills and content are taught best in playful ways. They posit that playful learning advances the six critical skills of collaboration, communication, content, critical thinking, creative innovation, and confidence (Hirsh-Pasek & Hadani, 2020). Additionally, the Lego Foundation collaborated with the Harvard's Project Zero to design a pedagogy of play, which offers playful learning has three distinct overlapping categories: choice, wonder, and delight. Playful learning includes both subjective and objective dimensions with indicators representing psychological states as well as behaviors that are observable (Project Zero, Harvard University, 2016).

25.4.4.6 Influence on Learning: Sociocultural Aspects

Socially constructed learning is an important feature of museum learning models. In museum settings, people learn together as they share ideas and perspectives (Fienberg & Leinhardt, 2002; Schauble et al., 1998). Research findings suggest spontaneous conversation makes a difference in younger children's learning. Higher levels of parent mediation while examining dinosaur fossils in a museum were associated with children being able to identify more fossils than they could before these conversations. The researchers posit that authentic objects available in museums and the associated conversations around them, are likely more memorable due to their high-interest place-based setting (Crowley & Jacobs, 2002). Leinhardt and Knutson (2004) looked at learning as it connects to museum conversations and concluded conversations are critical to the learning that takes place in the museum (Leinhardt & Knutson, 2004). Moreover, Rogoff (1984) posits, "Cognitive activity is socially defined, interpreted, and supported. People, usually in conjunction with each other and always guided by social norms, set goals, negotiate appropriate means to reach the goals, and assist each other in implementing the means and resetting the goals as activities evolve." (Rogoff, 1984, p. 4). This behavior often is observable in the social interactions around museum exhibitions.

25.4.4.7 Influence on Learning: Mechanical and Operational Aspects

We can find one of the influences for learning in museums in exhibit design. Various aspects of exhibit design either enhance or inhibit learning behaviors. Museum researchers continue to study what aspects of exhibits to improve to increase the potential of learning. Gutwill and Humphry (2005) worked on identifying characteristics of exhibits that will extend the time visitors engage with exhibits. These included, (a) being immediately approachable hence supporting initial engagement, (b) have interactive elements that encourage prolonged exploration, and (c) that the presentation supports social groups through inclusion of multiple components, which are accessible for different developmental levels and interests. Moreover, visitor research and evaluation can inform improvement of exhibit design to enhance learning. An example of this research is that of Perry (2012), who conducted research on a way to improve the learning potential of an exhibit relating to colored shadows. She identified a need to signal visitors to look toward the source of the light. Changing this signage proved to be a highly effective way to increase visitor's conceptual understanding of mixing colored light (Perry, 2012).

25.5 Importance to Research

As the question "Is learning taking place in informal science settings?" is often asked, I believe the approach I developed toward investigating this question has value for the field. I will continue to refine what at this point I might call a theoretical framework for the *Learning Characteristics and Influences on Learning* (Camp, 2001). This framework and approach still are evolving and thus far has been helpful for two research ventures in informal science settings. However, I will be happy to see it evolve further.

Different realms of research examine many of the behaviors that take place in informal learning settings. Fields such as psychology, neuroscience, cognitive development, formal education, literacy development, sociology, anthropology, organizational development, and beyond all have something to offer. Although the findings come through seemingly disparate research paths, such as how the brain works, language development, and how humans interact and influence each other, they all relate to human learning.

This raises the notion that perhaps these paths are not so separate and in some instances, they converge and/or cross. Many chunks of qualitative data from informal education settings often present multiple and sometimes concurrent examples of behaviors associated with learning. To illustrate, the following is a brief excerpt of data between a boy, about four and a half years old, and a parent at a wildlife center:

Observation: Family moves into the raptor exhibit and immediately locates the bird up on a branch. Mom reads the signage aloud about the turkey vulture.

Mom: "Do you think the turkey vulture is watching those squirrels outside of his habitat?".

M4: "Yeah, I bet he wants to eat them."

This short exchange illustrates several things related to learning. One, the mother's question is an example of "extra talk" where her query extends the conversation, increasing the learning potential (Allen, 2002; Hart & Risley, 1995; Pan et al., 2000; Snow & Beal, 2006). Two, the response from the child suggests he is utilizing his critical thinking skills and is making connections around what he is observing and his prior knowledge (Callanan & Oakes, 1992; Callanan et al., 2017). Three, this child is using his executive functioning skills as he pays attention to what is going on (Diamond, 2013; Ruedea, 2005; Zelazo et al., 2003, 2016). Four, both participants are using their observation skills and having a direct experience with the objects in their setting. This data is an example of "joint attention" for this child and his mother around an exhibit and a situation where the interaction of people involved together around an activity, conversation, problem, can affect or change the dynamic of the learning and communication experience (Rogoff & Gardener, 1999; Rollins & Snow, 1998; Pan et al., 2005; Snow & Beal, 2006; Tunnicliffe, 1998). Finally, this experience is socially constructed. Thus, the sociocultural aspects of the situation, such as their relationship and the culture and context of the setting they are in, are influencing this experience (Fenichel & Schweingruber, 2010; Rogoff, 1999).

As this data example illustrates, drawing a simple inference from what we observe to evidence for learning is part of the challenge of researching in informal settings. Perhaps informal science research is not alone facing this challenge to understand the association between behaviors and learning. As I read the literature relating to how we learn, my perception is that theories about learning increasingly are migrating and cross-pollinating across fields. Could this mean that researchers are moving from the silos of their specific discipline and genre toward seeking a more comprehensive or inclusive way to research human behavior, interactions, and development? Engeström (2016), well known for his work around activity theory, or cultural historical activity theory (CHAT), points out the Learning Sciences are increasingly looking at learning outside of formal learning environments. Engeström posits that the *process* of learning has not received proper attention in recent years. He submits that an expanded view about learning is necessary (Engeström, 2016).

The process of looking inward and increasing our understanding of informal science learning remains important. Non-formal science organizations certainly have their unique opportunities to excite and stimulate the public toward science. As the Oppenheimer quote indicates, museums were and continue to be eager to hold onto their differences and distance themselves from the pressures traditionally associated with formal education. It has been an important goal and one they have achieved in many ways. Museums have attracted not only science geeks, but also science-shy visitors, into the world of science centers. However, by doing so they also have run the risk of becoming distanced from the positions and roles in our society held by the more establishment formal education institutions often characterized as "hallowed halls" of learning.

These insights motivate me to keep drawing from a range of disciplines to identify and document observable behaviors characteristic of the learning process. We can find relevance, intellectual merit, and, perhaps, inspiration from research studies emanating from other fields that hold an interest in the learning process. Connecting to the literature from other fields, such as cognitive development, neuroscience, sociology, and more, provides a fresh set of lenses through which to view our own informal science research (Falk, 2009; Falk & Dierking, 2000, 2019; National Research Council, 2009; Wertsch et al., 1995a, 1995b).

However, I propose that it does not need to be an either-or situation. Designing an approach toward recognizing evidence *that learning is taking place* in these informal settings—however challenging—is a meaningful step toward verifying the value and efficacy of informal science institutions, and an important quest toward solidifying and making more credible their role within society's greater educational infrastructure.

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