Small Stories for Learning: A Sociocultural Analysis of Children's Participation in Informal Science Education

by

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In the end, my story is very small, but I hope you all hear it very loudly: thank you.

ABSTRACT

This dissertation examines the ways children use language to construct scientific knowledge in designed informal learning environments such as museums, aquariums, and zoos, with particular attention to autobiographical storytelling. This study takes as its foundation cultural-historical activity theory, defining learning as increased participation in meaningful, knowledge-based activity. It aims to improve experience design in informal learning environments by facilitating and building upon language interactions that are already in use by learners in these contexts. Fieldwork consists of audio recordings of individual children aged 4-12 as they explored a museum of science and technology with their families. Recordings were transcribed and coded according to the activity (task) and context (artifact/exhibit) in which the child was participating during each sequence of utterances. Additional evidence is provided by supplemental interviews with museum educators. Analysis suggests that short autobiographical stories can provide opportunities for learners to access metacognitive knowledge, for educators to assess learners' prior experience and knowledge, and for designers to engage affective pathways in order to increase participation that is both active and contemplative. Design implications are discussed and a design proposal for a distributed informal learning environment is presented.

1. Introduction

1.1 The Space: Informal Science Education

This dissertation examines the ways children use language to construct scientific knowledge in designed informal learning environments such as museums, aquariums, and zoos, with particular attention to autobiographical storytelling. It aims to improve experience design (Carliner, 2000; Johnson, 1998; Norman, 1988/2002; Norman 2004; Shedroff, 2001) in informal learning environments (Eshach, 2007; Schugurensky, 2000; Vadeboncoeur, 2006) by facilitating and building upon language interactions that are already in use by learners in these contexts. Ultimately, this research contributes to ongoing efforts to improve science education through better understanding of the relationships, operations, and contexts where effective learning takes place.

The case has been made, time and again, that public understanding of science needs improvement. One reporter suggests that science education in the United States has been experiencing a "quiet crisis" (Feller, 2004, para. 2), and PISA (Program for International Student Assessment) science rankings for the U.S. have dropped from fourteenth in 2000 to twenty-first in 2006 (Bybee, 2009). Why is it so vitally important for our citizens to be scientifically literate? In speeches around the country, President Barack Obama has repeatedly noted that improving math and science education is essential to helping the U.S. to compete globally on an economic basis. "If we want to win the global competition for new jobs and industries, we've got to win the global competition to educate our people" (Obama, 2011, para. 6). But there is perhaps a better, more universal reason for strong science education. Physicist W. Michael Snow, when asked why he believes in scientific research and outreach, voices the belief of many:

> I slowly realized that the activity of science itself was perhaps the best thing that I personally could do to make the world a better place. In my view the most important overall political effect that science has on the world is that it establishes the facts about our world which any rational group of people must take into account if they are to be successful. So if it is listened to it constrains people to avoid doing things that are ridiculous. This is something. (personal communication, 2002)

This *is* something: a scientifically literate country has a citizenry that can make decisions based on the best available evidence, using critical analytical and reasoning skills.

While the President pushes for stronger science education in schools and better partnerships between businesses and schools, some science education researchers point out that average Americans spend less than five percent of their lives in classrooms, and that most science is learned outside of school (Falk & Dierking, 2010; Livingstone, 2000). What is this huge educational apparatus that allows average citizens to learn science outside of school? It is comprised of "a vast array of digital resources, educational television and radio, science museums, zoos, aquariums, national parks, community activities such as 4-H and scouting and many other scientifically enriching enterprises" (Falk & Dierking, 2010, p. 486). This is not to say that the main thrust of past science education improvement efforts – namely, better teacher training and support for in-school science – is misguided. It does suggest, however, that it is incomplete, and that public science understanding could benefit greatly from increased investment in these alternative venues.

There is no clear consensus on the terminology for referring to alternative education choices with finer distinction. This learning is informal because it does not happen in traditional school buildings; it is free-choice because there is no specified, teacher-directed curriculum. Beyond these distinctions it is unclear whether "informality" refers to locations, relationships, content, pedagogy, assessment, or anything else (Vadeboncoeur, 2006). The focus of the present research is science education in museums, aquariums, zoos, and other institutions (as opposed to digital and traditional media outlets). These spaces are "informal" and "free-choice," but they are also structured with the expectation that at least, there, a visitor will encounter opportunities to interact with science domain content.

1.2 The Problem: Design for Facilitation within Informal Education

1.2.1 An agenda for informal education research

If government and other social improvement funding agencies are to invest financially in alternative models of science education, there must be a similar investment of research effort to guide effective implementation of science programming. If the

cultural perception of alternative education venues is that they are "merely" entertainment or offer only shallow acquaintanceship with scientific principles and skills, then it is the imperative of designers and staff educators to offer additional value, and the duty of researchers to understand how that value is constructed. Over the past two decades, increasing interest in alternative methods of schooling has inspired researchers to examine in detail which factors result in more effective learning. It is unnecessary to reiterate all of their findings here, as that has been done well by others (see Falk, 2004, for example). The end result of this body of work, however, suggests only that there are myriad factors at play each and every time a visitor – a potential learner – arrives at a museum. Although there is still work to be done identifying the specifics of these factors, leading researchers have suggested that it is time to consider the question of effective informal science learning more holistically and with greater attention to the scope and scale of museum experiences (Dierking, Ellenbogen, & Falk 2004; Falk, 2004).

More concretely, the research agenda has turned from trying to isolate individual learning factors – such as prior experience, ability to orient within an exhibit space, or degree of interactivity offered – to trying to understand how all of these factors work together to influence a learner's experience. New research must also recognize that a museum visit is only one piece in a learner's ongoing acquaintance with science, and therefore researchers' attention would be well spent understanding factors external to the immediate museum context, such as how a family talks about science outside of a museum, the significance of time for reflection, and the influence of other informal science learning opportunities (media, hobbies, clubs) on a learner's motivation and curiosity. Rennie and Johnston suggest that the future research agenda should address three principles: a search for a wider range of learning outcomes, the use of a wider range of research methods, and a greater recognition of the significance of time (2004). Six specific strands of research are suggested, including 1) the study of motivation, curiosity, choice, interest, and expectations; 2) the investigation of authentic context and characteristics of exhibits and tools that are useful for learning, especially with reference to new learning about interaction coming out of the design and human-computer interaction disciplines (e.g. Norman, 1988/2002 and 2004); 3) the exploration of social

and cultural mediating factors, especially the family unit outside of museums; 4) the design of research programs that are longitudinal in nature, connecting dimensions of learning across a span of time; 5) the conceptualization of learning as a process, with attention not just to what is learned but also to how it is learned; and 6) the use of a variety of research methods, including conversation analysis, concept mapping, social learning network analysis, and hierarchical linear modeling (Rennie, Feher, Dierking, & Falk, 2003).

Recognizing that thoroughly addressing all of these strands constitutes a research career rather than a single study, this dissertation is responsive to the suggested agenda in both theoretical orientation and methodology. To account for the individual (strand 1), the material context (strand 2), and the sociocultural context (strand 3), I build my conceptual framework on the school of cultural-historical activity theory, or CHAT. The CHAT model is founded on the dialectical relationship between individual subject and object of interest as it is mediated by environmental artifacts (including symbolic tools such as language) and the sociocultural context (community) in which the relationship is located. Although this dissertation is not explicitly longitudinal (strand 4), the CHAT model is also a dynamic model, accounting for the way these relationships change over time (Roth, 2004). By turning my attention to learners' autobiographical memories and the stories generated by those memories, the study implicitly recognizes the way knowledge is constructed gradually and how participation changes over time. Finally, I have developed my research questions intentionally as attentive to process rather than product (strand 5), and draw on conversation analysis and interviews to begin to build answers to those questions (strand 6).

1.2.2 Research questions: stories and artifacts

Most generally, in this dissertation I ask first, how do children communicate in informal learning environments, and second, how do the artifacts and exhibits in those environments contribute to effective communication strategies? Other researchers have found the museum context a fruitful one in which to explore communication. Notably, Leinhardt and Knutson's study *Listening in on Museum Conversations* explores the ways different individual and group conceptions of identity play out in the informal education

environment (2004). Although focused on seemingly different questions – they concentrate on how identity concerns motivate and set the agenda for museum visits – Leinhardt and Knutson's work touches on many of the same issues that result from my attention to children's voices. They note, for example, that learning in a museum is a social process that results from the connections and collisions between individuals' historical experiences and their interactions with artifacts in the museum environment. In other words,

> Learning is influenced by three clusters of factors: the cumulative personal historical identities of the visiting group; the designed features of the environment with which the group interacts; and the explanatory engagement of the group with objects, ideas, and concepts in an exhibition. (Leinhardt & Knutson, 2004, p. xiii).

Their general understanding of the ways visitors converse in museums and engage with museum artifacts and curated exhibits will provide a valuable touchstone for my work as I strive to understand in more detail a subset of museum conversations: the stories told by children, and the responses from the people around them. Here I am particularly interested in *small stories* (Bamberg & Georgakopoulou, 2008): personal tales that are developed in a social and activity context, and represent an individual's moment-to-moment performance of self.

Listening in on Museum Conversations recognizes that communication is triggered by context, by "designed features of the environment." One of the features of informal learning environments that cannot be overlooked is the presence of cognitively and emotionally provocative objects and the opportunities for embodied interaction with those objects. In *The Necessity of Experience* (1996), Edward S. Reed argues that the experience of our senses is the most fundamental way that people learn, and to ignore this first-hand knowledge in favor of pre-packaged, second-hand knowledge does a disservice to our creative and scientific capacities. Tomie Hahn makes a similar point about learning culture through the experiences of the senses in her recent ethnography. "Not only do the senses orient us in a very real, physical way; they enable us to construct parameters of existence – that which defines the body, self, social group, or world" (2007, p. 3). This dissertation research begins from these concerns – a question of discourse, and a question of materiality. The work presented is necessarily informed by

my own experience as an educator in both school and museum contexts, and by my interactions with the community and artifacts of science in laboratories and in the natural world.

Specifically,

1. How do children use narrative language and experiences in informal science learning environments?
    a. How do children use stories to participate in their own science knowledge construction?
    b. Is autobiographical storytelling an effective way for children to communicate their implicit and prior knowledge?
    c. How, if at all, do educators and other learning facilitators (e.g. adults and older children accompanying a child) use children's storytelling to support the child's learning?
2. What is the narrative role of artifacts in informal science learning environments?
    a. What are the design implications that stem from children's uses of narrative?
    b. Is design that supports narrative interaction in conflict with design for other kinds of learning interactions?

By addressing these questions, I aim to contribute to the body of knowledge drawn on by educators and exhibit designers in informal learning environments and their corresponding digital environments in order to improve children's understanding of and enthusiasm for science. As discussed above, informal science education may provide alternative entry routes to higher learning in science. Better understanding of how children interact with exhibits and educators in these contexts will lead to better exhibit design that not only encourages learning, but also supports the development of future informal learning advocates. Although this dissertation is focused on the educational environments of children, it also suggests further avenues of inquiry regarding similar situations in which adolescents and adults work and learn.

1.2.3 Current conversations: assessment, metacognition, and affect

In particular, the research questions outlined above center on what children bring to the conversation in a learning exchange, and how educators can access – and enable children to build on – those existing knowledge structures. The necessary phase of assessing pre-existing knowledge is garnering increasing attention among education researchers. In 2007, the National Academy of Sciences published *Taking Science to School: Learning and Teaching Science in Grades K-8*, which draws on a comprehensive body of research to provide a portrait of contemporary science education in the United States. After repeating the argument that at no time in the nation's history has a scientifically informed citizenry been more important, the authors conclude, "It is thus critical that children's prior knowledge is taken into account in designing instruction that capitalizes on the leverage points and adequately addresses potential areas of misunderstanding" (p. ES-3). The phrasing of this statement is telling, as many researchers begin their tasks at this point: how to address and build upon learner's prior knowledge (e.g. Cook, 2006; Hewson & Hewson, 1983; Schmidt, De Volder, De Grave, Moust, & Patel, 1989). Practicing educators are aware of the need for adequate initial assessment (Gielen, Dochy, & Dierick, 2003; McTighe & O'Connor, 2005), but with some exceptions (Stoddart, Abrams, Gaspar, & Canaday, 1999), little research has been done to discern which are the most effective ways for educators to perform this assessment and to learn what comprises each individual child's prior knowledge.

The research summarized here addresses this problem of assessment directly, but is not tied to historically problematic traditions of standardized testing (Haladyna, Haas, & Allison, 1998; Lomax, West, Harmon, Viator, & Madaus, 1995; Paris, Lawton, Turner & Roth, 1991; Stake, 1995). By focusing on discerning the ways in which children's storytelling communicates their prior knowledge, and the ways that educators and designers can leverage that storytelling, my research leads to education design implications that are applicable both to informal learning settings and to traditional classrooms. Indeed, many websites written by teachers for other teachers offer advice and ideas to "turn the classroom into a museum" in order to motivate children's interest in learning. Rather than replacing classroom instruction, however, informal education settings like museums and zoos can complement the structured lessons of the

schoolhouse with teaching that meets children at their pre-existing levels of knowledge, ability, and interest.

Additionally, the observations presented here suggest that even when an educator is not present to facilitate children's experience of science, by telling autobiographical stories learners gain access to metacognitive knowledge about their own participation in activity. Other research has concluded that supplying cognitive aid without related metacognitive assistance is insufficient for effective learning in a design-based environment (Bhat & Kolodner, 2009), and that metacognitive skills account for a not-insignificant percentage of variance in learning outcomes (Veenman, 2011). Consequently, facilitating learners' and educators' recognition of metacognitive knowledge may help them to engage more fully in science literacy operations (Baird, Fensham, Gunstone, & White, 1991; Hartman, 2001; Schraw, Crippen, & Hartley, 2006).

Finally, because autobiographical memory is necessarily personal, the stories that learners choose to tell about themselves offer a window onto their affective pathways – that is, their motivations, interests, and self-perceptions (identity construction). Wolff-Michael Roth has presented compelling ethnographic evidence for the role of emotion in work-related learning, arguing for a theory of affect that complements cultural-historical activity theory. In Roth's formulation, emotion is "a constitutive element" of cognition through three dialectical relationships: individual maximization of positive valence activities, tacit and embodied effects of emotion (e.g. neuromuscular, biochemical, and neurological conditions), and the production and reproduction of collective emotion (mood) (2007). These interrelated faces of the emotional nature of cognition lead to and are reinforced by experiences of identity and motivation, and are reflected in any kind of learning. As noted previously, Leinhardt and Knutson's observations suggest that identity issues frame the reasons that visitors go to museums (2004). Other authors emphasize that identity construction is ongoing and constantly renegotiated (Wenger, 1998), that identification and learning are deeply interrelated (Brown, Reveles, & Kelly, 2005; Preston, 2004; Shen, 1989; Wortham, 2006), and that educators' own identity negotiations also affect the learning environment (Eick & Reed, 2002; Spillane, 2000). In other words, "learning is not simply about developing one's knowledge and practice,

it also involves a process of understanding who we are and in which communities of practice we belong and are accepted" (Handley, Sturdy, Fincham, & Clark, 2006, p. 644).

1.3 Chapter Descriptions

Several disciplinary strands and multiple research methods inform this dissertation. Consequently, each chapter bears some of the burden of connecting the present work to larger conversations about the relevant issues. In the next chapter, I present the conceptual underpinnings of my fieldwork: what is learning, and what does speech have to do with learning? Who is the speaker when a museum visitor engages with an exhibit, and how does dialogue shape the activity context? Why are artifacts so central to the operations of learning, and how do they support the interpersonal relationships that are essential to all human activity? In Chapter 3, the specific research methods of my fieldwork are presented, along with a thorough description of the research site and the techniques used to make sense of a large body of qualitative data. Chapters 4 and 5 are two sides of the same discussion. Chapter 4 summarizes the literal findings of the fieldwork; these are the patterns of communication, the sequences of operations, and my reflections on their relationships to one another. Here I also discuss my findings in light of recent literature by other researchers with similar concerns. Chapter 5 continues the work of making meaning from the data by describing the learning and design implications of the empirical observations, and concretizes those implications with a design proposal. This design proposal is situated with respect to other design-based research for the same target users. Finally, Chapter 6 describes the limitations of the present work, suggests avenues where it might be fruitfully extended, and highlights its contributions to ongoing scholarship.

2. Conceptual Framework

2.1 Overview

The research questions outlined in the previous chapter are grounded in my own observations of education in practice, and are guided by three broad theoretical relationships:

- cognitive development as a social and interpersonal process, explicitly reliant on communicative exchanges;
- cognitive practice and learning as context-dependent and environmentally-supported activity; and
- learning as it is constrained and enabled by embodied, material experience.

I locate my investigation at the confluence of several streams of disciplinary thought: psychological reflections on development and social cognition; rhetorical and literary theories about dialogic construction of meaning; and design practices of experience and material interaction.

From the disciplinary tradition of psychology, I build in particular on the work pioneered by Lev Vygotsky that emphasizes learning as a social process. Vygotsky's successors continue to develop and refine a school of understanding known as cultural-historical activity theory (CHAT). CHAT provides an ecological approach to analyzing the triangle of relationships between an individual learner, the social community in which the learner operates, and the tools and artifacts that mediate learning in the physical world. Within this model of cognitive practice, Lave and Wenger explores "what kinds of social engagements provide the proper context for learning to take place" (Hanks, 1991, p. 14), while the theory of distributed cognition inquires into the nature of the tools (including language) that support the thinking that takes place outside of individual human minds. Taken together, the theoretical positions that constitute the CHAT model indicate that we cannot understand an individual's educational experience without considering the social, physical, and emotional environments in which he or she is learning.

In particular, I am interested here in exploring the way language supports the interrelationships between an individual child, other people, and the artifacts within an

informal learning environment with the child. CHAT treats language as a tool deserving special attention, given its central role in mediating social interactions. In addition to highlighting the role of language coordinating activity, however, Vygotsky and his scholarly descendents shed light on how communication participates in problem solving, memory, and identity construction. All of these processes have bearing on the ways children gather knowledge in informal learning environments.

Finally, I would be remiss if I did not mention the work of Jean Piaget, who stresses that mental development occurs as a result of the interaction between internal and external influences. Although his ideas have been modified and extended in fruitful ways, the core propositions of Piaget's theory still provide a foundation for understanding the ways that children internalize skills and knowledge through the paired processes of accommodation and assimilation, processes that are accomplished through the activities of imitation and free play. While Piaget and Vygotsky are often studied in opposition to each other, both were prolific theorists, and I find that a comparison illuminates complementary as well as divergent thinking.

Two other disciplinary threads are complementary to CHAT itself for analyzing and understanding the social and material interactions that surround learning. With respect to social interactions, the tradition of rhetorical and literary theory suggests strategies for understanding dialogic communication. Although rhetoric has historically taken as its object of study extraordinary speech acts, some theorists have also turned their attention to everyday exchanges. In particular, the work of Mikhail Bakhtin celebrates the negotiation of truth through dialogue. Similarly, Roland Barthes and Julia Kristeva each add to my understanding of negotiated narrative by addressing the ways audiences bring meaning to a communicative act and experience texts in the full, rich contexts of their own lives.

Toward understanding the material interactions, the growing field of human-computer interaction offers a range of approaches to design research and to design *as* research. The works of Seymour Papert and Sherry Turkle, among others, illuminate the way learning is intimately related to the artifacts available in a learner's material and informational environments, bridging the gap between internal psychology and external objects. I take Papert's emphasis on microworlds and Turkle's compelling illustrations

of the power of objects to motivate and inform as a place to begin my own design inquiries. Bringing this inquiry full circle, Nathan Freier has begun developing a framework based on constructivist theories of human development that helps to organize my understanding of individuals' multifaceted interactions with technological environments. I also draw from the many inspiring examples by other technology designers who have grappled with issues of human interaction, usability, and experience in both formal and informal learning situations.

These disciplinary conventions, however, do not capture the richness of interrelated thought that has been conceptualized by the thinkers I will discuss. Therefore, after a discipline-centric overview, I will retrace the connections between these lines of thought about learning following thematic relationships about the locations of meaning-making, the internalization of meaning, and the contextualization of meaning-making. By revisiting this conceptual material, I am able to analyze some of the parallel themes and overlapping concepts promulgated in various academic conversations over the past century. Many of these theorists have articulated similar ideas but have applied them to different contexts: childhood development, literature, computing. In the course of my discussions of how this scholarship forms a necessary backdrop for my own work, I also develop language that is accessible to contemporary scholars in each of the disciplines I draw from.

2.2 Psychological Reflections

2.2.1 Learning as socially situated activity

Above all else, the disciplines of psychology and social cognition help us to understand what learning is, and how it comes to happen as an exchange between an individual and his or her environment - an environment that necessarily includes other people. The school of cultural-historical activity theory, or CHAT, founded in part on the work of Lev Vygotsky, emphasizes this socially situated nature of human activity. Vygotsky is perhaps best known for his formulation of a zone of proximal development, which represents the difference between what a student can accomplish alone, and what they can accomplish with the assistance of a more capable instructor or peer. Vygotsky proposes that the creation of this zone is an essential feature of learning, that when a

child is interacting with people in his or her environment the child engages in developmental processes that only later are internalized. In this conception, learning is not equated with development but rather results in the development of "culturally organized, specifically human, psychological functions" (1978, p. 90).

Development as culturally organized is a central tenet of CHAT. Vygotsky's experiments, continued and extended by his colleagues Luria and Leont'ev, demonstrated that cultural and physical artifacts mediate human enterprise, as shown in the partial activity theory diagram in Figure 1. (Note that in this model, the word "object" refers to the object of activity, which may or may not be a physical object. In the following pages, I therefore refer to the object of this model as the object/ive, and physical objects as artifacts, in order to clarify the dual word meanings.)

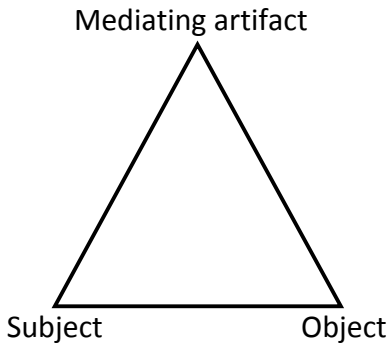

Figure 1: Partial model of activity, after Engeström (1987, 1999a)

In this model, mediating artifacts are products of culture. As Engeström (1987) explains, Vygotsky's formulation of activity in this model does not simply add a link to a stimulus-response [subject-object/ive] operation. The mediating artifact

> permits humans, by the aid of extrinsic stimuli, *to control their behavior from the outside*. The use of signs leads humans to a specific structure of behavior that breaks away from biological development and creates new forms of a culturally-based psychological process. (Vygotsky, 1978, p. 40, original emphasis)

Mediation (including both signs or language and tools) is not alone in constituting an activity, however. As Engeström's complete model makes clear, a human activity is also structured by the social context where it is located, a context including the other people

that comprise the larger community, the rules governing actions, and the historically-constituted division of labor within the community (Figure 2).

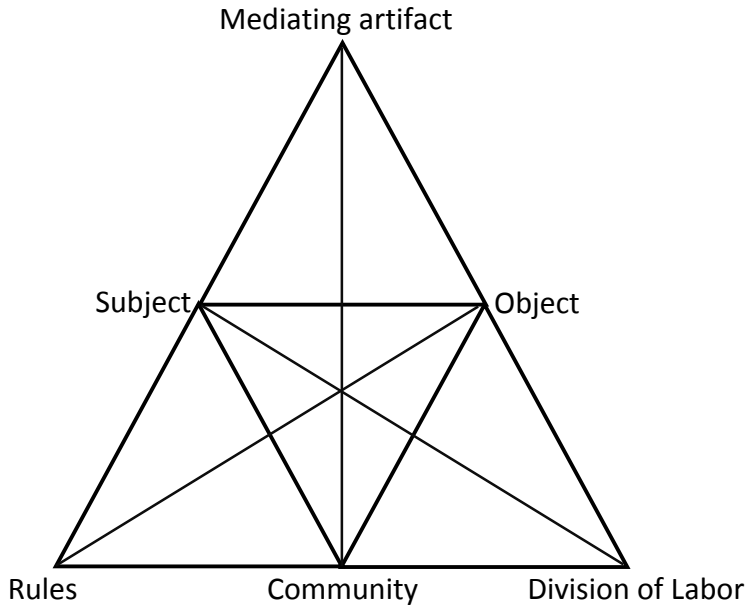

Figure 2: Structure of activity unit, after Engeström (1987, 1999a).

Ultimately, then, development is what happens to a person as a result of participating in human activities, and learning is the process of increasing or changing one's participation in an activity. This is the central assumption of Lave and Wenger's theory of legitimate peripheral participation, that "...learning is a way of being in the social world, not a way of coming to know about it" (Hanks, 1991, p. 24). Lave and Wenger's definition of learning as increased participation in a community of practice implies that a study of learning requires attention to the ways in which an activity is constituted by the relationships between persons, their actions, and the world (1991, pp. 49-50). It is not enough to simply ask what knowledge and skills should be the object/ives of study; "a learning curriculum unfolds in opportunities for engagement in practice" (Lave & Wenger, 1991, p. 93).

In his detailed examination of the coordination of a navigational team on the bridge of a naval vessel, Hutchins outlines how learning arises from engagement in practice. He focuses in particular on the way that division of labor enables individuals to gradually increase their participation in a task, even when the task is poorly understood initially.

Because the cognitive task of navigation is distributed among several persons, tools, and codified procedures, a novice participant can contribute to the task without necessarily understanding how his or her behavior assists with the task. In a consistently structured computational system such as this, the social structure and the tools constrain the behavior of the participants so that the socially appropriate thing to do is also the computationally correct thing to do. "That is, one can be functioning well before one knows what one is doing, and one can discover what one is doing in the course of doing it" (1996, p. 224). In other words, individual learning is a consequence of participating in a task; it is the change in internal organization that permits a participant to coordinate with the structured environment (Hutchins, 1996). This definition of learning as that which enables participation echoes Lave and Wenger's descriptions of apprenticeships among midwives, tailors, meat cutters, and Alcoholics Anonymous participants. "For newcomers then the purpose is not to learn *from* talk as a substitute for legitimate peripheral participation; it is to learn *to* talk as a key to legitimate peripheral participation" (1991, p. 109).

2.2.2 The role of speech in learning

Although talking is not the only kind of action relevant to distributed cognition, it certainly plays a central role as a primary means by which knowledge and action are coordinated and utilized. It is important to stress, however, that the role of language as a mediating tool is not limited to simple transmission of knowledge. Vygotsky's own experiments offer compelling evidence for the roles of speech in children's problem-solving tasks (and consequently in learning activity). He notes that speech not only accompanies practical activity, such as the task of figuring out how to retrieve a box placed on a high shelf, but also enables a child to carry out the activity. Vygotsky's empirical observations found that

> The more complex the action demanded by the situation and the less direct its solution, the greater the importance played by speech in the operation as a whole. Sometimes speech becomes of such vital importance that, if not permitted to use it, young children cannot accomplish the given task. (1978, pp. 25-26)

Vygotsky notes that speech not only enables a child to control external artifacts, but also to control his or her own behavior. As the child matures, speech gradually moves from accompanying the child's behavior to preceding the behavior in the form of an articulated plan of action, and finally to internal speech, or thought (Vygotsky, 1978, pp. 27-28).

In a socially situated learning model, speech similarly serves generative purposes and not merely to transmit tidy packages of knowledge. For example, Engeström writes about a variation on Vygotsky's zone of proximal development, wherein one participant in an organizational meeting might paraphrase and clarify the point of view of another, thus scaffolding the formation of a new idea (1999b). If an internal representation is still in the process of development, then speech from the perspective of socially situated cognition cannot simply be the translation or transmission of knowledge. Instead, it must serve as an action-oriented tool, intended to accomplish something in the social world. Wells demonstrates how, within the activity theory model, speech can constitute both the action (dialogue) and the outcome (e.g. meaning-making, theory-building) of an activity (2002). Whereas other tools operate directly on the object/ive, "discursive mediation…takes the form of a transaction between the human participants with respect to the object of their action" (Wells, 2007, p. 160).

Lave and Wenger, too, treats verbal meaning as the product of interpretive activity, defined with respect to relational contexts, and not merely as linguistic content. "Language is part of practice, and it is in practice that people learn" (1991, p. 85). Furthermore, Smith and Semin (2004) amasses evidence that communicative acts – from the perspectives of both speaker and audience – are sensitive to relationships, motivations, and other contextual clues. They offer as an example the way we might represent an artifact in the environment, "the car I am currently passing," as opposed to "the red pickup truck with license plate number such-and-such." The authors note that these deictic, or action-oriented, representations are not especially useful for creating objective models of the world, but they are useful for allowing us to participate in the world. Attitudes and affective responses, frequent components of artifact-oriented speech, are deictic representations that capture relationships and have implications for

the ways we perceive, act upon, and think about the artifacts in our environments (Smith & Semin, 2004, pp. 8-9).

2.2.3 The role of memory and autobiographical speech

For children, deictic representations may even be the primary means by which knowledge is organized. Vygotsky noted that very young children base their representations of the world on the recall of concrete instances, and not on abstract generalizations. Thus, memory (and accordingly autobiographical speech) is implicated in children's activity, and consequently in children's learning. Vygotsky's observations of the role of memory in children's thinking foreshadow the fieldwork described later in this dissertation:

> If you ask a child to tell you what a snail is, he will say that it is little, it slithers, and it sticks out its foot; if you ask him to tell you what a grandmother is, he is likely to reply, 'She has a soft lap.' In both cases the child gives a very clear summary of the impressions which the topic has made upon him and which he recollects. The content of the thinking act in the child when defining such concepts is determined not so much by the logical structure of the concept itself as by the child's concrete recollections. It is syncretic in character and reflects the fact that the child's thinking depends first of all on his memory. (1978, p. 50)

Vygotsky's observations are supported by recent research demonstrating that knowledge recall is highly dependent on context (see Bauer & Fivush, 2010, for an overview). Rather than being stable and invariant, our internal processes vary with environment and social context (Smith & Semin, 2004, p. 21). Furthermore, information in the current environment can activate related conceptual knowledge, just as conceptual knowledge may bring to mind situational information. This is a cognitively sound strategy: using situational knowledge during conceptual processing is likely to improve prediction of the environment, because concepts are likely to continue to be relevant in situations where they were relevant on past occasions (Smith & Semin, 2004, p. 22). Just as knowledge is distributed "in the world" through the use of tools, rules, and divisions of labor, knowledge is also distributed "in time." Current events are structured by imagined future outcomes and by remembered past experiences (Cole & Engeström, 1993).

Because both artifacts and community mediate activity, autobiographical speech is dually implicated in the CHAT model of development. By helping learners to organize concrete experience (situated knowledge) and also through its role in identity construction (situated self), autobiographical speech supports the relationships that form the skeleton of Engeström's triangle (see Figure 2 above). In other words, autobiographical speech is an essential feature of learning not only because it encapsulates concrete knowledge, but also because it is a performance of identity that enables learners to coordinate with others in socially constructed situations.

Miller et al. explore the variety of ways in which stories serve "as a resource for young children as they come to express and understand who they are" (1990, p. 294). One of the elements of that understanding is a sense of self-continuity, a perception of the self as a single entity that, although it exists at different points in time and changes from one time to another, is nevertheless a coherent being. Autobiographical memory, both in its construction and in its sharing, is discussed in detail by Katherine Nelson as a primary means to a sense of self-continuity in contemporary Western cultures. Nelson notes that changing economic and political arrangements[1] during the last three or four centuries of European history initiated a widespread occupational shift. With increasing frequency, an individual could no longer depend on the tradition or status of his or her family to determine social and economic place. Each was (and is) required to establish these based on an individualistic understanding of self, a self that is dependent on a record of unique lived experience – on autobiographical memory (2003b, p. 127-8). Beyond providing an individual with a static picture of a past self, however,

> [Autobiographical memory] expresses the self to others and establishes peer relations, at the same time that it provides ballast for maintaining identity within a somewhat fractured community, where in the eyes of some observers...there is no single self but rather many selves to be displayed on different occasions. (Nelson 2003b, p. 134)

Although there is a long tradition of narrative analysis, as Bamberg and Georgakopoulou have pointed out, the autobiographical stories that contribute to identity construction do not need to be "big stories," or "grand narrative" of the kind normally

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[1] I would add to these causal factors the parallel rapid changes in communication technologies; the printing press is the obvious example.

elicited in autobiographical interviews or writings. Instead, they suggest that we turn analytical attention to *small stories*, "an umbrella-term that captures a gamut of under-represented narrative activities, such as tellings of ongoing events, future or hypothetical events, shared (known) events, but also allusions to (previous) tellings, deferrals of tellings, and refusals to tell" (Bamberg & Georgakopoulou, 2008, p. 5). By considering these short, ephemeral moments of storytelling, this *narrative practice approach* takes into account local context, situated understandings, and the import of natural discourse. Recently, Bamberg has posited that short stories allow greater insight into identity processes because they account for how storytellers develop a "sense of self and identity in sequential, moment-by-moment interactive engagements" (2011, p. 8). These small stories highlight the way tellers construct identity in practice, as opposed to the ways that tellers represent identity to others (as in life-stories or the *big story* approach) (Bamberg, 2011).

For a complete sociocultural account of learning, this moment-to-moment identity construction must be taken into account:

> Different enactments of discursive selves may emerge in the space between their activities and their sense of participating in a community of practice. Multiple identities and different identification opportunities may open up to the learner in the void between his or her perception of activities and the professional practice and identity with which they are associated. (Vågan, 2011, p. 44).

In other words, if we wish to develop a holistic understanding of learning in situated activity, it is not sufficient to assume that individuals have a ready understanding of their social roles – research must also take into account the ways that individuals come to build, change, and reflect upon their position in the activity. Close analysis of the active performance of identity – and therefore of autobiographical speech, of small stories – is consequently an essential component of a model that understands learning to be increased participation in socially constructed activity.

2.2.4 Internalization of knowledge

Although this dissertation takes the Vygotskyan CHAT framework as its primary theoretical basis, it is instructive to turn briefly to another well-known school of developmental psychology, that of Jean Piaget. As other scholars have noted, much of

the conversation comparing the work of Vygotsky and Piaget has focused on their ideas about whether cognition arises from individual or social beginnings. This is in many ways a false dichotomy, as Piaget recognized the role of the social world in the construction of knowledge, and Vygotsky agreed that the individual has an active part in his or her own cognitive development (Cole & Wertsch, 1996, p. 251). Furthermore, both Piaget and Vygotsky recognized the primacy of the learner's active participation in his or her own learning and development. Therefore, rather than revisit the differences between their formulations, it is more helpful to the present study to explore the ways in which Piaget's thought can extend and enrich Vygotskyan foundations.

Previously, I noted that Vygotsky's experiments demonstrated the transition of language from external to internal, and of speech from accompanying action to preceding action in the form of a plan. Here, I suggest that Piaget's descriptions of the roles of imitation and play offer the mechanisms by which those external actions are internalized. In the language of Engeström's model, Vygotsky focuses on the way that speech connects the individual to the object/ive via the community or social context; Piaget emphasizes the way actions performed (operations) upon artifacts in the environment mediate the relationship of the learner to the object/ive. While Vygotsky, unlike Piaget, recognized that even our artifacts carry cultural histories, Piaget nevertheless continues to offer a means by which interaction with those artifacts enables the internalization of new concept knowledge.

The generalized actions used to internalize new knowledge, according to Piaget, are imitation and play. In order to describe how these actions contribute to development, Piaget first outlines his concepts of *assimilation* and *accommodation*. With assimilation and accommodation, Piaget describes two *functional invariants* – functional because they describe modes of interacting with the environment, and invariant because they are characteristic of all biological systems. Assimilation occurs whenever an organism utilizes something from its environment and incorporates it into its existing structures, while accommodation refers the change that takes place in an organism in order to adapt to its environment. For example, when I see a new kind of food, I understand that it can be chewed and swallowed and digested just like the foods I am familiar with. If, however, I am given unfamiliar utensils with which to eat the food – chopsticks to a

typical American child, for instance – then I will have to accommodate my process of eating to the tools available. Thus, interaction with one's environment consists of a give-and-take between assimilating external elements into existing patterns of activity, and accommodating oneself to environmental elements that require new modes of activity.

How do we learn those new modes? How do we know that some aspects of the environment are amenable to assimilation? Piaget observed that adapting oneself to the environment (or vice versa) consists of the paired processes of imitation and play. Imitation as a learning function is straightforward. When a learner is imitating, accommodation prevails as the learner copies actions that he or she has seen someone else doing. For Piaget, the importance of imitation is as an active representation of knowledge. "Imitation is first of all a prefiguration of representation. That is to say, it constitutes…a kind of representation in physical acts but not yet in thought" (Piaget & Inhelder, 1969, p. 55). With familiarity, this external representation is later internalized via the mental image, finally becoming an abstracted thought. Or, as Piaget puts it,

> With the mental image, which follows, imitation is no longer merely deferred but internalized, and the representation that it makes possible, thus dissociated from any external action in favor of the internal sketches or outlines of actions which will henceforth support it, is now ready to become thought. The acquisition of language, rendered accessible in these contexts of imitation, finally overlays the whole process, providing a contact with other people which is more effective than imitation alone, and thus permitting the nascent representation to increase its powers with the aid of communication. (Piaget & Inhelder, 1969, p. 56)

Note here that Piaget also suggests how social interaction and the use of language supports this function – in coordination with rather than in opposition to the learning processes that take place within Vygotsky's zone of proximal development.

Not all learning results from imitation, however. (How would human invention proceed, if so?) In Piaget's theory, a balance between imitation and free play is imperative. In play, the learner uses the environment to serve his or her own purposes, as a child might pretend that a simple platform is the deck of a pirate ship, or that her bicycle is a horse. In play, the learner finds

> …an area of activity whose motivation is not adaptation to reality but, on the contrary, assimilation of reality to the self, without coercions or

> sanctions. [Play] transforms reality by assimilation to the needs of the self, whereas imitation…is accommodation to external models. (Piaget & Inhelder, 1969, p. 58)

Yet play is not entirely divorced from reality. Through play, people find new uses for familiar materials, and new materials that perform familiar tasks more easily.

Vygotsky's work echoes this appreciation for the role of play in learning, noting that children use play to accomplish activities otherwise unrealizable (e.g. driving a car, being a teacher). He further emphasizes the importance of play for development, writing "the old adage that child's play is imagination in action must be reversed: we can say that imagination in adolescents and school children is play without action" (1978, p. 93). In other words, just as Piaget noted that imitation leads to mental imagery, which in turns leads to abstract thought, Vygotsky notes that play leads to imagination, which similarly engenders operational definitions of concepts and objects.

It is important that this discussion of Piaget's functions of assimilation and accommodation, achieved through imitation and play, not be construed as supporting a theory of learning that takes knowledge to be internalizable without regard to context. In section 2.2.1, above, learning was defined as "the process of increasing or changing one's participation in an activity," after Lave and Wenger (1991). Based on his extended discussions of universal and invariant stages of cognitive development, Piaget's theory is often associated with the position criticized by Lave as the *functionalist* position, that "society is characterized as a set of macrostructures in place, a *fait accompli* to be internalized by individuals born into it" (1988, p. 7, original emphasis). Whether or not Piaget's stages of development are in fact universal and invariant, we can nevertheless appreciate his explication of the means by which new knowledge and skills come to be used.

Participating in an activity necessitates performing action of one kind or another: speech, or physical manipulation, or both. Piaget's assertion that learning proceeds through active exchange with the individual's environment is therefore quite consistent with the socially situated model of cognition and development. Indeed, he goes so far as to suggest that intelligence itself is built upon participation in activity: "This means that intelligence proceeds from action as a whole, in that it transforms objects and reality, and that knowledge, whose formation can be traced in the child, is essentially an active

and operatory assimilation" (Piaget & Inhelder, 1969, p. 28). Piaget's emphasis on operations is an emphasis on changing and manipulating the environment, an emphasis fully consistent with learning as increased participation, and with development as the changes in individuals because of their participation in activity. It is also, as will be seen in section 2.4.2, a crucial prelude to the pedagogical design theory of Seymour Papert.

2.3 Rhetorical and Literary Theory

2.3.1 The dialogic imagination

Although the tradition of psychology offers a lens onto how language develops into thought, I turn to rhetorical and literary theory to understand how, specifically, language supports the increased participation that constitutes learning. Particularly relevant, in this context, are those theorists whose work focuses on the dialogic nature of communication. Foremost among these theorists is Mikhail Bakhtin, whose work emphasizes that meaning is realized not when one voice in a discussion prevails against another, but rather when multiple voices construct truth through careful reasoning and testing of ideas against the ideas of others. Although he uses somewhat different terminology, Bakhtin anticipates the definition of learning – of meaning-making – that this dissertation takes as its foundation. "Truth is not born nor is it to be found inside the head of an individual person, it is born *between people* collectively searching for truth, in the process of their dialogic interaction" (1984, p. 110, original emphasis). In other words, meaning is made when people, speaking with one another, participate in an activity together.

To understand the role of speech in meaning-making, Bakhtin defines the *utterance*, a unit of contextualized meaning. The utterance is a single instance of speech act, concretely bounded by context, and determined by a change of speaker; it is "a link in the chain of speech communication" (Bakhtin, 1986, p. 84). The classic example he gives is the exchange, "Life is good," "Life is good" (1984, p. 183). In this instance, the first utterance "life is good" might be a question, a declaration, or an exultation. The response, although the words are identical to the original, might affirm, cast doubt on, or sarcastically deny the first. Thus to understand an utterance fully requires consideration of surrounding utterances, suggesting the beginnings of the notion of intertextuality (this

will be discussed in more detail in section 2.3.3). This context-sensitive view of the utterance reaffirms the need to look for learning in exchanges rather than in dissociated individual speech.

Bakhtin celebrates exchange and its multiplicity of voices, describing how we are each continually embedded in a *heteroglossia* of language. "…all languages of heteroglossia…are specific points of view on the world, forms for conceptualizing the world in words, specific world views, each characterized by its own objects, meanings and values" (1981, pp. 291-292). Our speech exists within a tense web of meanings as participants are constantly negotiating their own roles and purposes in shared life. As discussed above in section 2.2.3, for learners, who are increasing their participation in an activity, this role negotiation takes on a critical importance. Yet not only are participants presenting themselves to other participants as legitimate and valuable contributors to the activity, they must also literally try to "talk the talk." Depending on the other participants, the environment, the context, and the object/ive, a speaker draws on a variety of "languages," on a variety of utterances appropriate for those different spheres of interaction. Consciousness of this variety constitutes what Bakhtin refers to as a *critical interanimation of languages*, and necessitates a choice of orientation. "Consciousness finds itself inevitably facing the necessity of *having to choose a language*…consciousness must actively orient itself amidst heteroglossia" (Bakhtin, 1981, p. 295, original emphasis). While the research presented in this dissertation cannot determine whether children are yet aware that they make these choices, as will be seen in Chapter 4 they are clearly adept at switching between languages.

2.3.2 Negotiated narrative, participatory practice

An ability to switch between languages suggests that the children I observed have a well-developed capacity for adapting to their audience (although they may be generally unaware of this adaptation). Furthermore, they are proficient at being an audience – to parents, teachers, peers, and a plethora of media. Indeed, participation in conversation entails acting as both speaker and audience at the same time, and children negotiate these roles with readiness and facility. As both speaker and audience, children have several strategies available to influence conversation. They may demonstrate a willingness or

resistance to participation, switch topics or introduce new topics, or dispute adult interpretations of events. Less directly, a child's emotional demeanor during conversation and his or her ability to put experience into words are also factors affecting the course of conversation (Thompson, 2006, p. 9). It hardly needs to be added at this point that the ability to influence conversation is also, of course, the ability to influence the activity as a whole.

In an intentionally informal learning space like a museum, aquarium, or zoo, conversations proceed not just between people – children, parents, staff – but also between visitors and exhibits. In this case, the designer (the author) of an exhibit is unlikely to be present, but interaction nevertheless unfolds as a sort of conversation between designer and visitor. Literary theorist Roland Barthes' work helps to illuminate this dynamic, describing how a text is interpreted by its audience.

> Thus is revealed the total existence of writing: a text is made of multiple writings, drawn from many cultures and entering into mutual relations of dialogue, parody, contestation, but there is one place where this multiplicity is focused and that place is the reader, not, as was hitherto said, the author. (1977, p. 148)

In *The Death of the Author*, Barthes describes the independence of the audience's interpretation of the text. In *Problems of Dostoevsky's Poetics*, Bakhtin builds on his ideas about multiplicity of voices by describing the independence of characters in a novel. For both theorists, an author, storyteller, or designer does not occupy a privileged position with respect to meaning. They may reserve information about the structure, the setting, or the style, but it is the participants who determine the outcome.

Barthes values the construction of texts that are *writerly*, that is, that allow their audience to fill in meaning with elements from their own lived stories. *Readerly* texts (or exhibits, or whatever medium is relevant), those that only encourage the audience to passively follow along with the author's intentions, are not as valuable for helping the reader to understand how it is that the text fits into their own lived experience (1970, p. 4). This same idea has taken root in the museum community as a movement toward presenting not merely interactive exhibits, but exhibits in which the voice of the visitor is valued as equal to that of the exhibit designer. Museum consultant Nina Simon, for instance, describes the goals of a "participatory museum."

> The goal of participatory techniques is both to meet visitors' expectations for active engagement and to do so in a way that furthers the mission and core values of the institution. Rather than delivering the same content to everyone, a participatory institution collects and shares diverse, personalized, and changing content co-produced with visitors. It invites visitors to respond and add to cultural artifacts, scientific evidence, and historical records on display. It showcases the diverse creations and opinions of non-experts. People use the institution as meeting grounds for dialogue around the content presented. Instead of being "about" something or "for" someone, participatory institutions are created and managed "with" visitors. (2010, Preface)

Although any experience is necessarily "participatory," designers and educators who acknowledge this may be better able to structure interactions for increased (and increasing) participation – or in other words, for more effective content learning.

2.3.3 Intertextuality and shared attention

Building in part on the work of Roland Barthes, Julia Kristeva agrees that an author is not the sole arbiter of a text's meaning. She extends this idea with her explication of intertextuality. Although often used so as to be interchangeable with "allusion," for Kristeva the term *intertextuality* highlights the value of cross-interpretation, of texts that draw on a multiplicity of authorial voices, and of the way audiences experience texts in the social and cultural contexts of their own lives. Recognizing the misunderstandings in the term 'intertextuality,' Kristeva later substitutes *transposition* to suggest that meaning is "never single, complete, and identical" to itself, but rather "plural, shattered," and found in moving from one system of representation to another (1984, pp. 59-60). Moving from speech to writing, for example, requires reinterpretation because the context of the written word is necessarily different from that of the spoken word.

In other words, someone listening to a story understands the meaning of the story by drawing on his or her own prior experience of stories, as well as on a narrative understanding stemming from his or her own life. In a museum, a visitor negotiates exhibit halls and programming using understanding drawn from other experiences, other texts: these understandings include rules about when it is permissible to speak, what is allowed to be touched, where it is forbidden to go. Visitors transpose content knowledge, as well. As discussed in section 2.2.4, this transfer of knowledge is not

wholesale, but instead proceeds as a consequence of learners bringing to a new context the operations (actions, interactions) that they have used successfully in others.

These transpositions serve not only to suggest potentially fruitful operations, but also as gateways to increasing participation in the present activity. When they are shared, they become relevant both to an individual's meaning making, and also to the community – and community-generated meaning – in which the activity is occurring. Previously (section 2.2.3), I discussed the importance of presenting one's identity as a legitimated participant. Autobiographical stories contribute to that presentation of identity, but they are also a part of the plurality of representational systems that come together in ongoing activity. When the learner is able to articulate those transpositions – either by explicitly stating memories of related experiences, or by asking others to recall shared past experience – the transposed ideas become a part of the micro-culture of the present activity, and serve to cement the learner's participation.

Similarly, explicitly sharing the present experience with others highlights the learner's intentional role in the activity. By directing another person to look at what the learner is seeing, to listen to what the learner is hearing, or to collaborate with the learner to accomplishing some task, the learner transforms an individual interaction into a social interaction. Through the simple vehicle of pointing, a private moment becomes a participatory moment.

Finally, by sharing a moment with another person, the learner invites the other to transpose his or her own memories, stories, and knowledge into the present moment. With the addition of these transpositions, the meaning constructed in the interaction becomes ever more "plural" and "shattered," but also more rich, offering further avenues for deeper exploration with the content matter and within the social relationship.

2.4 Design Practices

2.4.1 Designing the artifact: mediating relationships

In section 2.3.2, I posited that even when an exhibit designer is not present, a visitor's interaction with an exhibit nevertheless proceeds as a conversation, just as the reader of a book is in conversation with the text. Accordingly, it is not only other people and their verbal communication that influence the course of activity. Occupying the

topmost point in Engeström's model (Figure 2), mediating artifacts provide influential and essential triggers for conversation, reflection, and transposition of knowledge and skills. Furthermore, the particulars of an artifact's use, disposition, and affordances shape and channel the resulting knowledge and relationships.

For example, Sherry Turkle's landmark work, *Life on Screen: Identity in the Age of the Internet* (1995), describes how the early internet mediated relationships and social experience for users of its online spaces (MUDs and MOOs). Although it was certainly possible that users could "just chat" in these spaces, the anonymity and frontier feel of the virtual world at the time encouraged participants to explore alternative identities. Acting out the ways that these personas might behave in a digitally mediated social environment led to the construction of complex narrative experiences. Turkle suggests that participating in these narratives provided an *adolescent moratorium* (after psychologist Erik Erikson), a place where users are allowed to step away from the constraints of everyday life, experiment with alternative roles and realities, and use those realities to develop new dimensions of self-mastery (1995, pp. 203-204). Contrasting the experience of MUDs and MOOs with the contemporary experience of social networking sites such as Facebook, MySpace, and LinkedIn emphasizes the opportunities and consequences of anonymity.

Since then, Turkle has widened her attention to artifacts other than computers that mediate people's relationships with knowledge, self, and others, in two recent edited collections: *Evocative Objects: Things We Think With* (2007), and *Objects in Mind: Falling for Science* (2008). In her curatorship of these essays, Turkle emphasizes the power of artifacts to evoke, inspire, and motivate, and the ways in which people build relationships with and through the artifacts in their environments. For instance, in "The Datebook," Michelle Hlubinka writes about using her personal calendar as a record of choices made:

> My datebook enabled me to weave a matrix of possibility: I would often note three concurrent events that sounded equally enticing, and at the last minute my whims would direct me to one of them or to cross them all off my list. (Turkle, 2007, p. 79)

When Hlubinka loses her paper datebook, she notes that the digital version she begins to use instead frustrates her. Now she must choose between deleting the options she chose

against, or keeping them all and being unable to differentiate between what was ultimately done and not done. She feels as though she has lost a record of self and possible self. "I like to think that anyone could open up my lost paper datebook and see what kind of person I am" (Turkle, 2007, p. 83).

Mihaly Czikszentmihalyi has also investigated in comprehensive detail the relationships that people have with objects, and the ways those objects affect our other relationships. "Innovations developed to cope with a specific problem have a way of changing the way people do things and of altering how they relate to each other; eventually they affect the way people experience their lives" (Czikszentmihalyi & Rochberg-Halton, 1981, p. 46). He concludes, based on numerous interviews with owners and the objects they value, that "the meaning of things" is "realized in the transaction between person and object" (Czikszentmihalyi & Rochberg-Halton, 1981, p. 175); these transactions may be physical manipulations but they may also be reflective or purposive. For example, a gold necklace may be treasured by a jeweler who is proud of his or her workmanship, by a recipient who cherishes a gift from a loved one, or by a pawnshop owner for its monetary value. Czikszentmihalyi and Rochberg-Halton term these three modes aesthetic quality, attention, and goal (1981). Don Norman, similarly, suggests that "emotional design" is affective because it appeals to us on visceral, reflective, and behavioral levels (2004).

In a science museum, any of these modes may be relevant. What seems to matter for increasing learning is simply that a visitor does enter into a transaction with an artifact. Whether the reaction is wonder-, memory-, or goal-driven, an inspiring artifact or exhibit increases the participation of the visitor (see section 4.2). The task of the designer is to build on visitors' reactions to these "trigger artifacts," leading visitors into particular experiences that will increase their ability to participate in the scientifically literate community.

2.4.2 Designing the experience: mediating participation

Seymour Papert is plainly concerned with objects in environments that are designed for learning. Papert's exploration of using technology in education led him to realize that, while learning might always depend in part on the mediating structures that are

available, those structures are not always readily apparent. And yet, Papert suggests, if we as teachers and designers make those mediating structures apparent, we enable learners to reflect on and consolidate their understanding (and consequently their participation) more effectively.

This philosophy of using physical constructions in the world as cognitive mediating structures comprises what Papert calls *constructionism* (1993, pp. 142-143). When a physical construction is explicitly designed to enable learners to explore a subset of all the knowledge available in the world, Papert terms the designed experience a *microworld* (1980, pp. 117&125). Learning happens when people come to understand and apply the mediating structures available in their environments, and so the provision of those same mediating structures in a simplified environment allows students to more directly target their learning.

> Children get to know what it is like to explore the properties of a chosen microworld undisturbed by extraneous questions. In doing so they learn to transfer habits of exploration from their personal lives to the formal domain of scientific theory construction. (Papert, 1980, p. 117)

As I noted in section 2.2.4, this view of learning through manipulating artifacts is continuous with Piaget's emphasis on operations.[2]

LOGO is the best-known example of how Papert has applied this philosophy. LOGO is a basic programming language that allows users to generate algorithms that direct a digital "turtle" to draw by following instructions such as lifting or lowering a "pen," walking a specified number of pixels across the screen, and changing its heading by a specified number of degrees. By experimenting within the language and seeing the immediate and direct effects of their actions, users can construct an understanding of algorithmic programming in a piecemeal fashion[3]. This "bottom-up" strategy avoids requiring learners to understand a complex and abstract topic (algorithmic programming) in its entirety before they see the tangible benefits of that understanding. In other words,

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[2] However, Papert suggests several ways in which Piaget's theory may be fruitfully revised and extended. See especially the Preface of (1980).

[3] Claude Lévi-Strauss used the term bricolage to describe this method in The Savage Mind (1962). Sherry Turkle explores in detail the relationship between bricolage and personal computing (1995).

by communicating with a mediating artifact, the learners can scaffold their own construction of new knowledge, and consequently bring themselves to increased participation in meaningful activity.

Papert emphasizes that the activity must, indeed, be meaningful in order for it to be "well-learnable." He offers three principles to concretize this need for meaning if knowledge is to be readily taken up and incorporated into a learner's activity: the knowledge must be continuous with well-established personal knowledge, it must empower the learner to perform personally relevant projects that would otherwise be impossible, and it must make sense in terms of a larger social context (1980, p. 54). In outlining these principles, Papert is essentially echoing Engeström's model of activity, which accounts for the individual (personal knowledge), the object/ive (relevant projects), and the community (social context), as well as accounting for mediating artifacts (microworlds).

It is important to note here that Papert's use of the term "mediating structures" rather than "mediating artifacts" is helpful. It may indeed be an environment rather than an artifact that provides the opportunities for manipulation and operation (and as we move into virtual spaces the distinction between environment and artifact begins to blur in any case). For example, Vivian Paley describes her preschool classroom methods, which center on crafting spaces and tools for helping children to tell their own fantasy stories, as in the case study *The Boy Who Would Be a Helicopter* (1990). For these very young children, the relevant manipulations concern their own identities and roles as well as explorations of cause and effect, and the environment of fantasy storytelling – and story-acting – provides a ready vehicle for experimentation. Paley recounts one such occasion:

> 'Scar-der-rered,' she insists and is off to the doll corner before I can ask why the lion is afraid of a red crayon.
>
> Perhaps I'll find out later when we act out her story. It is one of my favorite kinds of questions because there is no way to anticipate the answer. Sometimes I wonder if the children deliberately think up such oddities because they know it pleases me to find good questions. Even if this could be true, it would demonstrate that children feel rewarded by the genuine curiosity of others. In an environment where people listen carefully and ask relevant questions because they need more information, storytellers may indeed be inspired to put surprises into their stories.

> Inevitably, the children learn the logical implications of an unexpected outcome. It is good training for the lifelong study of cause and effect. (1990, pp. 23-24)

2.4.3 Accounting for the person

Vivian Paley's work, which follows from a Vygotskyan understanding of play (as discussed in section 2.2.4), enables children to develop operational definitions of their social and physical environments. Designers also need these definitions. Nathan Freier suggests that by explicitly enumerating the ways that an individual is contextualized, designers can better understand human-computer interactions. Freier's work stems from a concern with the ethical and moral implications of new technologies, and offers designers a framework within which to take these facets of an individual into account.

In a preliminary model, Freier suggests that individuals can be understood via six hierarchical levels. Each individual: is constrained in a physical body (embodied); exists in a particular physical environment (situated); is able to change his or her environment (dynamic); is able to choose the ways he or she changes the environment (intentional); exists in an environment that consists of other individuals (social); and has human and humane obligations to those other individuals (moral) (2009). In sum, Freier's model describes the various ways in which a person is embedded in a larger environmental context – consistent with the relationships articulated in the CHAT model – and is therefore useful for analyzing the ways in the introduction of a new artifact or technology may change environmental interactions.

Allison Druin's work offers another perspective on how to account for the person in design: she includes her target audience (children) in the design process. Although designers are increasingly incorporating end users into their workflow by employing them as testers and informants, Druin and her research partners have found children to be avid and capable design partners (Druin & Fast, 2002; Druin et al., 1998). When children take an active role in determining the direction of product design, they bring distinct insight to the development team while they themselves learn teamwork and problem-solving skills. Druin notes that, just as individual adults do, child researchers "…have special experiences and viewpoints that can support the technology design process that other partners may not be capable of contributing" (Druin, 2002, p. 12). By

considering children to be equal stakeholders in technology design, Druin acknowledges their full participation in the design process as well as in the ultimate use practices of the resulting artifacts.

2.5 Alternative Threads

Although the preceding overview, organized loosely by discipline, is adequate for exploring the breadth of conceptual work relevant to my current undertaking, it fails to capture fully the ways that some of these fundamental ideas share family resemblances outside of the disciplinary framework. The disciplinary conventions help us to understand the various pathways and nodes of Engeström's activity triangle: individual identity, mediating artifacts, the way social rules constrain object/ives. Crucially, however, activity is not merely the collection of these relationships – it is the situated happening of the system as a whole. Regarding the activity as a whole also underscores the themes of this work that are outside the domain of any one discipline. Accordingly, this chapter concludes by addressing more explicitly these themes concerning meaning making (and, consequently, learning): it is located in interaction, it is internalized through active processes, and it is contextualized by culture.

Vygotsky is rightfully known for insisting on social interaction as a necessary co-requisite for learning, and for recognizing how important language, the medium of interaction, is to the development of thought. Rather than separating thought and language into two separate and inviolable objects of study, Vygotsky conceives of their unity as a key moment in a child's development (Blunden, 1997). He suggests that, because rational speech and verbal thought are so closely intertwined, we cannot understand thought or meaning without also understanding communicative interaction.

Similarly, Turkle and Czikszentmihalyi both find the meaning of artifacts in the ways they participate in individual and social constructions of identity. Not only do artifacts motivate and inform, their identities and ours are constructed via our interactions with them. Ultimately, our thoughts, our identities, and our tools are all relevant to meaningful activity only because they are juxtaposed with other thoughts, identities, and tools. Each by itself is meaningless: *meaning is located in interaction*.

Even the term, 'interaction,' carries with it the implication of doing. Piaget, Barthes, and Papert, each in their way, call attention to the idea that the internalization of meaning is an active, not passive, process. Piaget, as described earlier, theorizes the tension between the processes of assimilation and accommodation that leads to a child's development. New knowledge and skills are not things that can be poured into a child's mind from the outside; rather, the child must actively participate in the process by finding equilibrium between imitation and free play.

Roland Barthes, in his concern with the ways that audiences construct meaning from a text, also highlights a tension between authorial intention and audience interpretation. Just as a child cannot be taught by simply accepting outside knowledge, a text does not acquire meaning from the author's intentions, personality, or other biographical attributes. Instead, any text is "eternally written here and now" as each new reader actively constructs its meaning (Barthes, 1977, p. 145).

Papert's work echoes these ideas by demonstrating how meaning can be made via a learner's interaction with carefully designed artifacts and environments. Papert suggests that if a child of one culture develops at a different rate than a child of another culture, it is due to an environmental poverty of relevant learning materials for learning that particular skill. He suggests that children learn syntonically, that is, through identifying with an artifact in the environment. A learning environment must therefore be rich in appropriate artifacts for manipulation: *meaning requires action*.

Like Papert, Jean Lave writes that what is culturally available determines the ways problems can be formulated and solved. Activity, for Lave, is dialectically constituted between an individual and his or her social, physical, and cultural environment. For many of the theorists I have written about, the critical element in understanding meaning-making is the context in which meaningful activity takes place. Mikhail Bakhtin, for example, reminds us that we are daily moving through a variety of sociocultural milieus. Bakhtin emphasizes that we need to understand these contexts to tease apart polysemic words. In Julia Kristeva's thought, that context consists of all the associations and cultural connections that a reader brings to understanding a text. The audience's construction of meaning is situated between texts, and is dependent not only

on understanding allusions and references, but also on an understanding of how a particular medium affects the interpretation of a text.

This is also Freier's proposition with respect to human interactions with technology. If we wish to understand the ways that the introduction of a technological artifact affects the people who interact with it, we need to look at that interaction from multiple contextual perspectives. Smith and Semin echo this concern with particular focus on the ways it pans out in communicative contexts:

> In summary, the general thrust of many diverse studies is to show that cognitive processes and social behavior vary with contexts. Such a finding falsifies a model that treats inner processes as stable, automatic, and functionally invariant. All of these studies show that environmental contexts – and particularly features of the communication context, namely the relationship of the individual to partners, communicators, audiences, or fellow group members – are among the most important regulators of cognition and action. (Smith & Semin 2004, p. 21)

It is hard to say any more clearly than that: *meaning depends on context*.

In the chapters that follow, I describe my own observations of children making meaning in an informal learning environment. Throughout, my aim is to be sensitive to these three themes: interaction, action, and context. Instead of listening for one person's speech, I listen for conversations. I categorize speech according to the action it accomplishes, and code with respect to the artifact-based context. Building on the conceptual framework outlined above, I listen to the kinds of things children say when they are learning; more importantly, I listen to how the children's speech mediates their own participation in scientific observation.

3. Research Methodology & Data Gathering

3.1 Introduction

My methods of inquiry follow directly from my theoretical grounding and research questions: since I am interested in the learning and storytelling that happen in the midst of everyday life, I have collected data from informal learning environments. It might be argued that research sites such as museums, zoos, and aquariums are not strictly "everyday" environments, that people make special trips to these places with a variety of motives including learning, entertainment, and strengthening social relationships. Yet those are also everyday motives. Additionally, since I am interested in how we can design to support informal learning in a variety of locations, it made sense to pursue my initial research in places where people expect the artifacts to facilitate learning. This approach is supported by recent research in museum learning that suggests that family conversations are a rich source for generating holistic sociocultural understanding of informal learning (Ash 2003; Ellenbogen, Luke, & Dierking 2004).

The methodological approach described below was inspired by the work of Jean Lave as she describes it in *Cognition in Practice* (1988). In particular, Lave writes passionately about the impossibility of accurately understanding learning and cognition if it is only studied in laboratory and classroom contexts. She takes issue with the assumption that cognitive processes can be divided from the settings and activities of which they are a part. Yet she does not reject laboratory studies or simulation experiments. In her work, Lave uses these isolation techniques to "confirm tentative descriptions of activity derived from observation" in the relevant contexts. "But for explanation," she continues, "for light on why problem solving takes a particular form, it is necessary to go back to ongoing activity in the [everyday setting]" (1988, p. 121). In other words, understanding about what is happening during everyday cognition and problem solving ought to come from everyday settings. Asking study participants to perform similar cognitive tasks in relative seclusion is valuable to confirm these ideas, or to send the researcher back for more observation. This multimodal approach allows the researcher to begin and end with knowledge that is valid outside of the laboratory, yet it

also allows for the precision and isolation of contributing factors provided by laboratory experiments.

In the case of my own research, I have chosen to privilege the data available in a designed informal learning context, with the expectation that simulation and laboratory confirmation may follow in future research. I have also augmented and clarified the observational data collected by conducting semi-structured interviews with other museum educators. Their perspectives on both the observational data and on my interpretations enrich the conclusions considerably. Additionally, my concern with artifact design within these environments allows opportunities for cross-checking of observational hypotheses. The observational data led to design implications for artifacts that facilitate learning, and then to a design proposal based on those implications. Ultimately, the test of design theory is the efficacy and user experience associated with designed outcomes.

3.2 Research Site

Observational data was collected at The Children's Museum of Science and Technology (CMOST) in Troy, New York. CMOST is a small- to mid-sized museum with approximately 12,000 square feet of exhibit space (personal communication), and serving over 60,000 visitors annually in recent years (The Children's Museum of Science and Technology, 2010). Because I am a part-time education staff member at CMOST, using CMOST as a basis for observation offered both ease of access and a familiarity with floor exhibit layout that considerably improved my ability to make sense of the audio data. Although exhibit locations are occasionally updated and modified to accommodate traveling, new, or retired exhibits, the approximate floor plan during the time span of my data collection is illustrated in Figure 3.

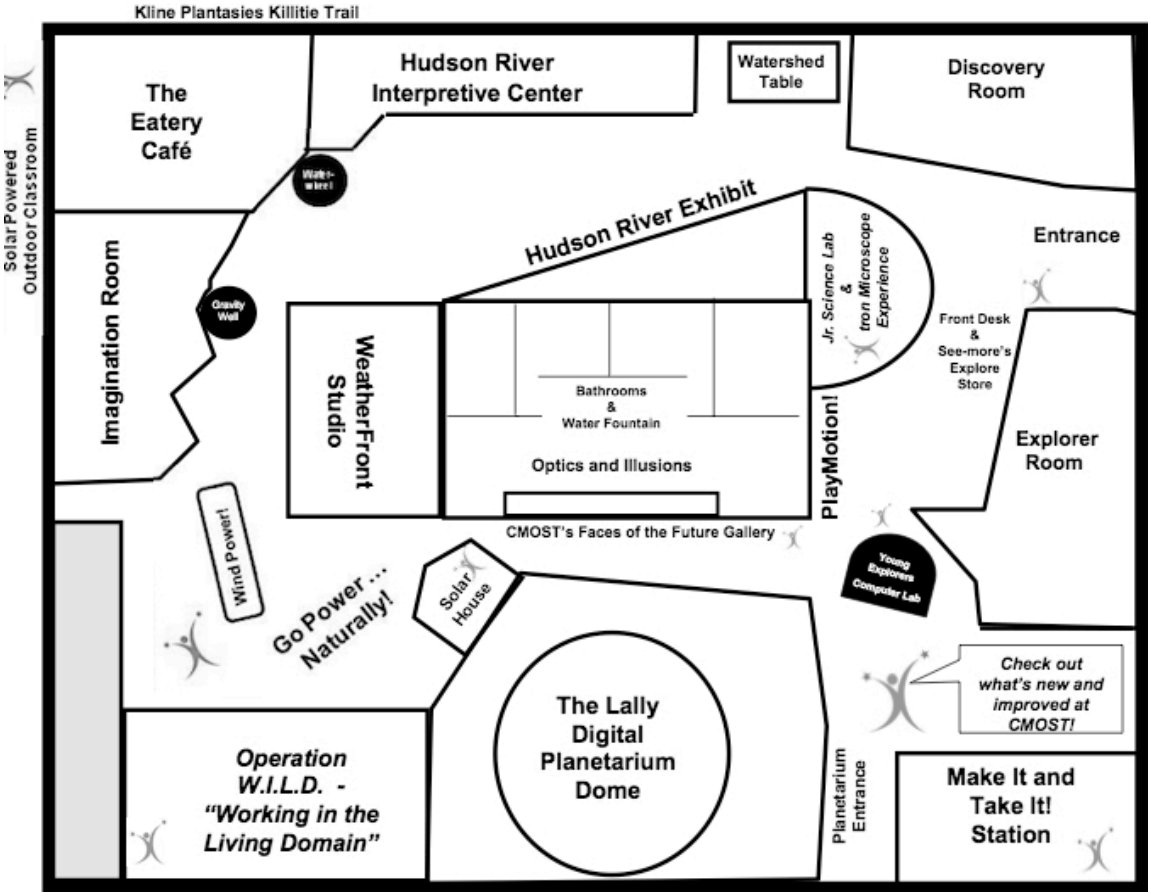

Figure 3: Exhibit layout of CMOST during data collection, courtesy of CMOST

3.3 Primary Participants

Participants were recruited from families visiting during normal museum operating hours after they were admitted at the museum's front desk. If the family included a child aged 4-12 years, the family was approached and offered a gift card in compensation for help with the research project. Potential participants were briefed on what their participation entailed, namely, wearing a digital voice recorder on an arm band for the duration of their visit or until they chose to end their participation in the project. Children and parents who agreed to participate were then led through the process of informed consent, asked to sign consent forms, and surveyed for basic demographic information including age, grade or years of formal schooling, sex, ethnicity, and whether the participating child was accompanied by any other children during this visit.

Finally, both parent and child were instructed in the use of the digital voice recorder, in the event that they wished to turn it off for privacy during any portion of their participation.

In total, 13 children were recorded during their visits to the museum. All of the children spoke English natively. Children wore the recorders between 26 minutes and 158 minutes, for an average of 67 minutes and a total of 864 minutes (or 14.4 hours) of total recorded observation time. The average age of the children recorded was 7 years, with an average of 3 years of formal schooling (1 child was home schooled, and 1 child was not yet of school age – these two are not included in the schooling average). All of the children were ethnically white. Sex was split fairly equally, with 7 girls and 6 boys recorded. Seven of the children were accompanied by other children (from 1-3 siblings) during their visits; the remainder visited with either one or two adults only. Demographic data is summarized in Table 1.

	Mean	Std. Deviation	Median	Range
Age	7	2	7	4-12
Years Schooling	3	2	3	0-8
Accompanying Children	1	1	1	0-3
Minutes Recorded	67	36	55	26-158

Table 1: Demographics of child participant population

3.4 Analysis of Museum Recordings

3.4.1 Speech coding

Recordings from the first four participants were initially reviewed to develop categories of speech utterance grounded in observation. After these first four, three more participant recordings were reviewed to ensure that no new categories of utterance emerged from additional participants. Following this initial category development, all of the recordings were imported into the multimedia data analysis program Transana (Fassnacht & Woods). The emergent speech categories were entered into Transana as

keywords for later labeling of utterances. A full list of speech categories and their definitions can be found in Appendix A.

As a validity check, these emergent speech categories were compared to the categories developed in McDonald and Pien (1982) to code mother conversational behavior as a function of interactional intent. McDonald and Pien's schema has been used, among others, by Hoff-Ginsberg (1986) to research children's language development and in modified fashion by Kerig (1993) to investigate effects of marital quality on child development. The categories used in the present analysis correlate well with McDonald and Pien's categories, with a few modifications as can be seen in Table 2. Specifically, the present analysis 1) does not distinguish between types of directives; 2) groups all positive and negative adult feedback for both verbalizations and actions into the categories of Corroborates [positive] and Corrects [negative], as well as grouping reflective questions – those that provide no new information – into the Corroborates category; 3) groups reparative questions and permission requests into a single category of Negotiates; and 4) provides a finer distinction between types of spontaneous declarations, in order to reflect the types of speech found in the science museum context. In general, these modifications follow logically from the differing research focuses: where McDonald and Pien concentrated on the functional intent of parental speech to control or converse with a child, the present research is interested in the ways conversation unfolds with respect to learning new information.

Regarding distinctions between declarative statements, I break from other informal science learning coding schema (e.g. Crowley, et al, 2001) by identifying Explains, Narrates, and Reads as categories of interest rather than grouping explanatory accounts into a single category of "explanation," which may include reference to causal relationships or explanatory analogies drawn from personal experience as well as more objective reasoning. Furthermore, the present analysis applies the same scheme to parent, child, and staff speech alike, although there are differences in the frequency with which the different populations make each type of utterance. Finally, it will be noted that I have chosen to emphasize verb forms as categories rather than the noun forms (e.g. Corrects rather than Correction) in order to underscore the concept of speech as action (see section 2.2.2.).

McDonald & Pien	Desjardins
Directives 1) Direct Commands 2) Indirect Commands	Instructs*
Questions 1) Repairs 2) Test Questions 3) Real Questions 4) Verbal Reflective Questions 5) Action Reflective Questions 6) Report Questions 7) Permission Requests/Offers of Help	 Negotiates Elicits* Questions* Corroborates Corroborates Explains Negotiates
Prompts 1) Question Prompts 2) Directive Prompts	 *Undifferentiated from preceding utterances*
Attention Devices	Points*
Feedback 1) Responses to Questions/Directives a. Positive b. Negative 2) Acknowledgements of Previous Declaratives a. Positive b. Negative 3) Feedback for Actions a. Positive b. Negative	 *Positive feedback grouped as* Corroborates *Negative feedback grouped as* Corrects
Spontaneous Declarations	Declares Exclaims Explains Narrates Reacts Reads Recites

Table 2: A comparison of the McDonald & Pien (1982) and Desjardins conversation coding schemes. Categories with an asterisk (*) share a one-to-one correspondence.

Within Transana, clips (time-stamped segments of the audio recordings) were marked and categorized according to the artifacts that focused the conversations. Conversations that did not involve reference to an exhibit or exhibit component in the museum space were not included in this analysis. These extraneous conversations consisted of things like negotiating departure time, locating non-exhibit elements of the museum such as restrooms and drinking fountains, and disciplinary actions taken by parents. Ultimately the data set included a total of 299 clips categorized into 57 topics referring to exhibits or exhibit elements. An average of 23 clips and 19 unique topics per child were recorded. Each of these clips was then transcribed and further segmented according to speaker. Within each speaker segment, utterances were categorized according to speech functions. For example, a parent might explain and then elicit without passing the speaking role to the child in between functions, yet these are two distinct utterances. A keyword reflecting the appropriate speech category was then applied to each utterance in each clip.

Finally, using Transana's native keyword visualization tool, each artifact-focused clip was graphed according to how the categories of speech utterance developed in conversation over time[4]. By equating Transana's keywords with categories of utterance, this visualization method corresponds to Cheryl Geisler's method of Activity Analysis (personal communication). In this technique, the horizontal axis represents time, and the vertical axis is labeled according to the categories of analysis. These graphs inspired a variety of analytic insights. For example, from these graphs it can be determined which types of children's utterances are effective at generating continuing conversation about an artifact, and the kinds of responses adults and siblings make to different types of utterances. Additionally, by graphing interactions with a single artifact during the time span of an entire visit, it is clear when children make repeat visits to artifacts, or when an artifact has captured attention for longer or shorter time spans.

[4] For visual clarity and for better control over axis and data labels, the graphs in the chapters that follow were re-drawn using Microsoft Excel.

3.5 Educator Interviews

In order to correlate my observations of family conversations with staff interpretation, I conducted semi-structured interviews with 3 education staff members at the same museum. Their individual experience with formal and informal education is summarized in Table 3. A semi-structured interview methodology allows the researcher to present the initial direction of conversation and topics to be discussed, but is responsive to the needs and contributions of the interviewee as well. Interviewees may offer insights that the researcher cannot anticipate, or open new avenues of conversation.

	Age	Sex	Years of Informal (Museum) Education Experience	Years of Formal (School) Teaching Experience	Subject Specialty
A	35	F	2	15+	Special Ed., Biology
B	51	F	8	2	Life Science, Animal Behavior
C	27	M	3	2 summers	Biology, Chemistry

Table 3: Demographics of educator interview participants

Sample interview questions:

- In your experience, what kinds of stories do children tell you?
- How frequent, in your estimation, are children's autobiographical stories as compared to other stories?
- Can you give an example of a child's story that you would judge to be autobiographical?
- Why do you think children tell this kind of story?
- Are there certain kinds of places, environments, objects, or events that, in your experience, lead children to tell autobiographical stories more frequently?
- How do you usually respond to children's autobiographical stories? Do you have a strategy for responding, or are you more likely to improvise?
- How would you judge if a child was being strictly factual or embellishing an autobiographical story?

The resulting interviews were transcribed and are included in this report as qualitative reflections on children's communicative methods during their visits to this museum.

4. Findings & Discussion

4.1 Small Stories in the Museum

By its very nature, everyday activity is unremarkable, a truism reflected in my observations of families visiting a museum. Here we hear a boy exclaiming over a scary-looking crab, there is a mother reminding a toddler to touch gently, and an educator asking where a girl has seen magnets before – in her ordinary, everyday life. Yet precisely because these acts are so unremarkable, because they form the substance of learning that we all do successfully, each day, looking at them through an analytical lens reveals noteworthy features. In this chapter, I address the features and themes of the observational data, contextualizing my interpretations with respect to other empirical studies and their conceptual implications. My discussion is organized by the social and material contexts of stories – that is, what triggers the stories of museum visitors, and who hears them? What patterns of action and interaction do my observations reveal? Ultimately, three ideas present themselves: stories as markers of identity, carriers of metacognitive knowledge, and indicators of the ways that affective states intersect and intervene in learning processes.

Before dissecting the data, it is helpful to distinguish more concretely between narratives, stories, and small stories (see also Bamberg & Georgakopoulou, 2008). Certainly there are various ways to define the former two terms, and in everyday language the two are used nearly interchangeably. For clarity here, however, I will distinguish narrative as a particular kind of story, following Nelson (2003a): a narrative provides a time and place, an overarching goal and a motivation to reach it, a moment of crisis, emotional response, conclusion or resolution, and evaluation. By contrast, a story is a more general form that is simply a telling. A lyric that speaks only of intense feeling at one isolated moment in time is a story, but not a narrative. "I am at the store and I am trying to decide between two flavors of ice cream," is a story, but it is not a narrative. The folk tale of Hansel and Gretel, on the other hand, is both a story and a narrative.

What, then, is a small story? It is a story that is simple, short, usually personal, and ephemeral. It can be a projection of future events, or the reflection of an idea that is preoccupying the teller in that moment. A small story is a nugget of information offered

by a participant in an interaction as part of the performance of self in that moment. Often the story has little obvious relevance for a person's long-term conception of self – if there is such a thing – but it has immediate relevance for a person's present performance of identity. Bamberg & Georgakopoulou describe them thus:

> Small stories can be about very recent ('this morning', 'last night') or still unfolding events thus immediately reworking slices of experience and arising out of a need to share what has just happened or seemingly uninteresting titbits. They can be about small incidents that may (or may not) have actually happened, mentioned to back up or elaborate on an argumentative point occurring in an ongoing conversation. Small stories can even be about – colloquially speaking – '*nothing*'; and as such indirectly reflect something about the interactional engagement between the interactants, while for outsiders, the interaction is literally '*about nothing*'. (2008, p. 5, original emphasis)

For instance, one child that I encountered at a museum outreach event (i.e. held at a location other than the museum) asked, "Are you from the museum?" When I assented, he continued, "'cause I've seen you before, I went to a birthday party there." This is not a narrative, nor is it likely that the boy will remember having met me twice as a formative event in his life. Yet in that moment, our previous encounter was important to establishing the tone for the learning that we were engaged in. It was a small story, and I will show in the sections that follow how this story and others like it are important components of learning activity. This chapter is organized by the contexts that trigger stories and other notable communication behaviors: the physical contexts of artifact encounters (section 4.2); the social contexts of interacting with staff, self, and family (section 4.3); and the interaction contexts of exhibit design (section 4.4). In each of these sections, I'll consider the conversations I recorded from the overall perspective of how time is spent in the museum and which exhibits engendered significant conversation and storytelling. I'll also take a closer look at specific interactions or episodes to understand how small stories play out in conversation, and where there might be opportunities for greater facilitation of science learning.

4.2 What Triggers a Story?

4.2.1 Affective objects

Perhaps it is not surprising, but it is the case that every story the recorded visitors told in the museum began from an experience with an artifact. I mean "artifact" loosely – some of these are living things, some of them are particular spaces through which visitors move. Of course, a museum is a museum precisely because it offers an intriguing array of artifacts, a collection of things for contemplation. Many of these things are in a museum because they are in some way novel, unusual, out-of-the-ordinary, and the museum offers visitors a chance to view or experience them with more closeness than would otherwise be available. Because they are not the objects of everyday experience, one way that they inspire visitors to look more closely is by triggering a strong affective or emotional response.

The small stories that result from these affective responses, in the observational data, are stories about *right now*. Strong affective responses seem to engender a need to comprehend, sort, and share the encounter that triggered the response. In the small stories I gathered, many artifacts inspired visitors to come back to them – in person or through language – again and again during the span of their visit. If repeated reference to an artifact is an indication of the intensity of the impression it has made on a person, most of the children I recorded seemed to be struck by at least one artifact such that the experience colored their entire visit to the museum. Figure 4 illustrates the location in time (with respect to the entire time recorded in the museum) and duration (represented by gray bands) of three children's initial and repeat visits to the objects of their interest (a screech owl, a log with a taxidermy bear head inside, and a comparison of high- and low-watt light bulbs, respectively). The first child (Figure 4a) returns again and again to a live screech owl. She alternates between exclaiming over its cuteness (in just over 10 minutes, she uses the word "cute" 20 times) and talking to it in exaggerated, high-pitched speech, as one would to a baby:

> Ohh. Hiiii. Hello, guy. What're you doin'? Hello. Hi! Helloooo. Hiii. Ohhh, it's so cute! Hi little fella, what're you doin'? What are you doin'? You're a cutie, aren't you?

She also makes 7 distinct attempts to get other members of her family to join in her appreciation of the owl, and, upon finding out that the owl is a rescued owl who is blind in one eye, shares this fact with other family members 10 times in the span of about 4 minutes.

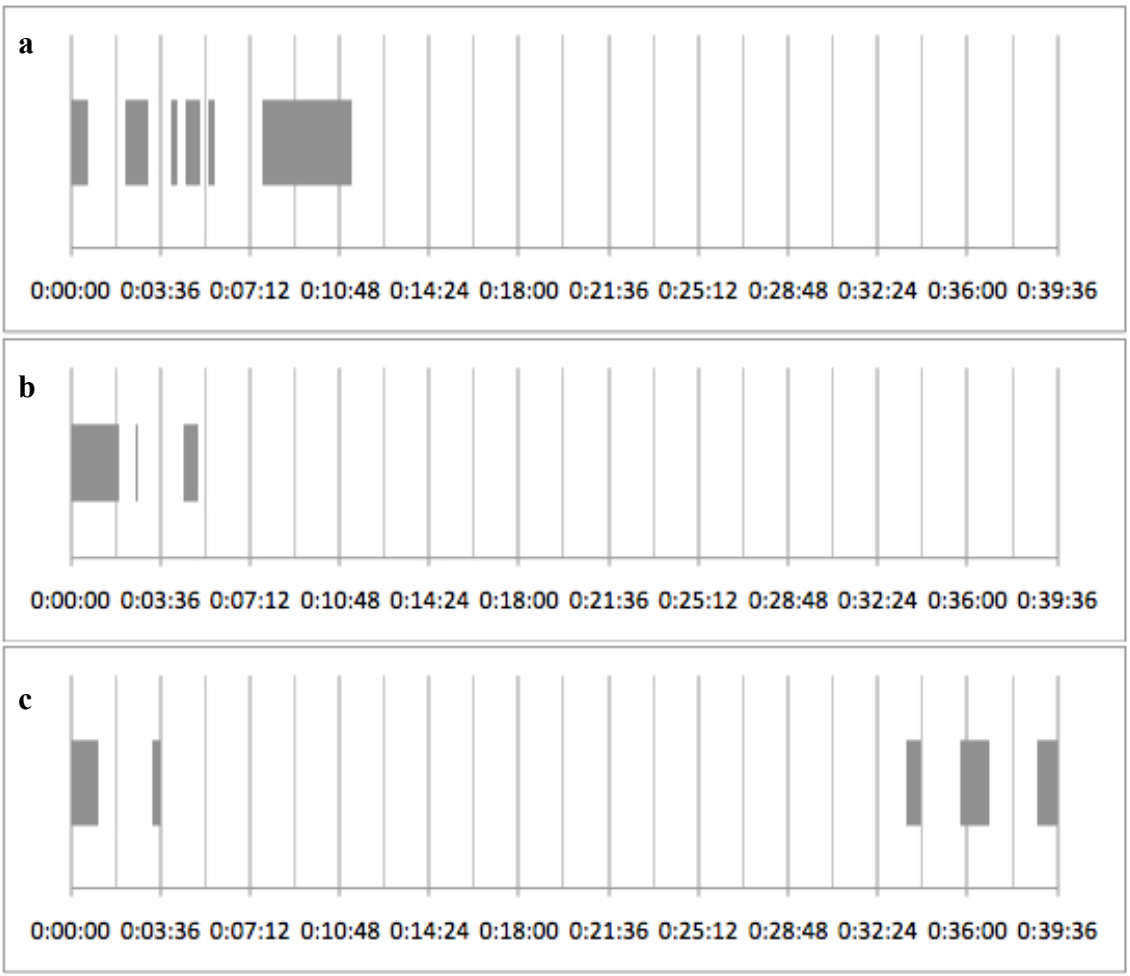

Figure 4: Topical repetition in children's conversation. Gray bands represent the duration of conversations about a particular artifact: a) owl; b) taxidermy bear head; c) comparison of high- and low-watt light bulbs. Note that time scales are zeroed at the moment a child first begins speaking about the respective artifact.

Just as dramatically, another child (Figure 4b) reacts to a taxidermy bear head, placed behind glass in the dark end of a hollow log that children can crawl into to see its gaping mouth and impressive teeth. Although she does not seem literally terrified, this girl repeatedly emphasizes a desire to put distance between herself and the bear:

> Aah! A real bear's under there. A real bear head is under there. A bear head is under there. Bye! Bye! Help, aah!

This is followed, after a few similar exchanges with a parent and sibling, by a whispered aside directly to the audio recorder[5]:

> There's a giant bear head, and I am not goin' in there, cuz there's a hole to feel his headddd. His face, his teeth, right, teeth.

Finally, when it seems as though she has moved on from the encounter with the bear, has looked at several other exhibits, and is about to begin a chemistry experiment with a staff educator on the opposite side of the museum, she brings up the bear head one more time (see Excerpt 1).

Educator:	This is the time of day where we bring out an extra demonstration, something that you won't usually experience, just by looking around the museum. It can be all sorts of different types of science, umm, related and relations, and, today I've one that goes with chemistry.	Declares
	Have you heard of chemistry before?	Questions
Child 1:	Just please don't make me... (Overlapping with end of educator's speech)	Instructs
	Yeah, just please DON'T make me look at that bear head in there.	Instructs
Educator:	Okkaay. Nope, definitely won't make you look at the bear head.	Corroborates
Child 1:	Good!	Reacts
Child 2:	I already saw it.	Narrates
Educator:	What?	Questions
Child 2:	I already saw it.	Narrates
Educator:	You already saw it?	Questions
Child 2:	Yeah.	Declares
Educator:	He's not real anymore though, so he can't hurt you.	Declares
Child 1:	Good.	Reacts

Excerpt 1: Repeated affective response to a bear's head hidden in a log

[5] This was the only occasion in any of the recordings where an aside was clearly directed to the voice recorder rather than to another visitor in the museum.

The third example of a strong affective response to an exhibit is immediately striking for the relatively long span of time that passes between revisits to the same topic. For this child, nearly half an hour passes between the first two episodes about the exhibit, and then an additional three (see Figure 4c). Each time, he does little more than exclaim, "I found a watt-o-meter!" or "High watt, low watt!" as he pushes the respective buttons to light the bulbs. His mother participates by saying "wow," disinterestedly, twice. She does offer an interesting way to investigate the exhibit, the third time he brings it to her attention, instructing, "Now, what you do is you watch how slowly it goes, and then how fast it goes if you use the other one." Yet even here she starts to physically move away from the exhibit, and from the child, before she's even finished speaking.

Although they may not sound much like "stories" at first, each of these children is constructing a small story in response to their ongoing activity. The story may begin with discovery, "I found…!" or with an exclamation of emotion, "Awwww," or "Ewwww." In each case, however, there is a clear and strong affective response to an artifact present in the museum. Perhaps the first child, a 10-year old girl visiting with two younger siblings, is composing a small story about herself as an empathetic maternal figure (she repeats "aww, it's cuuuuute" at the rabbit's cage as well). It may be that in the third example, the boy's need to return to the exhibit repeatedly stems from the minimal recognition that his mother pays to his discovery. Yet even without speculation as to the reasons for particular reactions, we can see that emotional responses to artifacts fundamentally constitute the ways that these children participate in museum activity.

4.2.2 Focus objects

Artifacts in the museum trigger emotions, and they also trigger interpersonal experience; they serve as a shared focus for the construction of social stories. While many people might have similar emotional reactions to novel, startling, or beautiful artifacts, other artifacts seem to engender collective responses that are highly differentiated. These stories begin from experiences that a group has shared previously, or develop from one group member's purposeful direction of the conversation. In the recorded data, these kinds of collective experiences tended to arise from exhibits where there was no clear

canonical way in which to interact. For example, a dugout canoe near a waterfall (Figure 5) generated a historical story about the purpose of the canoe, a photo opportunity, and a moment of imaginative play that ended with "man overboard!" Similarly, a cave-like structure labeled "beaver lodge" (Figure 6) was used by one family to explore the way sounds vary in different spaces (Excerpt 2), by another family as the inspiration for a "future story" about building a similar hiding space later at home (Excerpt 3), and by a third with little regard for its physical form, only as a space from which to peer into several animal habitats (Excerpt 4).

Figure 5: Dugout canoe at CMOST[6]

[6] All photographs are by the author, with permission from CMOST.

Figure 6: Beaver Lodge and adjoining Hudson River aquarium

Parent:	If you go in there, that'll echo. Go in there and try it.	Instructs
Child 1:	I'm scared.	Reacts
Parent:	Whoa.	Exclaims
	Yeah, it echoes in here.	Declares
	Come here.	Instructs
Child 1:	Can I see the echo?	Questions
Parent:	Come on in. Come on in, and talk in here. C'mon! Now talk in here.	Instructs
Child 2:	Hello?	Interacts
Parent:	Do you hear the difference in your voice?	Elicits
	Now go outside and say the same thing.	Instructs
Child 2:	Hello?	Interacts
Parent:	See, you hear the difference?	Elicits
Child 1:	Helllloooo.	Interacts

Excerpt 2: Beaver lodge as a space for investigating echoes

Child:	I like it inside this tree.	Declares
Parent:	This is cool, isn't it?	Reacts
	I wish Daddy could make us one of these, huh.	Narrates
Child:	Mm hmm. I wish Dad could make us a tree that had a [unclear].	Narrates
Parent:	Yeah, let's ask him to hollow out that big pine tree.	Narrates
Child:	Uh huh.	Corroborates
Parent:	And we could make a…and then we could make a hidey-hole, and peek at all the wild animals that come out at night.	Narrates

Excerpt 3: Beaver lodge as inspiration for a future project

Child 1:	Whoa, Mom, come in here. Mom. Look.	Points
	They've got a snake in this one.	Declares
Parent:	Eww.	Exclaims
	Can I stand up in here?	Questions
Child 1:	There's a snake in that. It's under that piece of bark.	Declares
Parent:	Ooh.	Exclaims
Child 2:	Eww what?	Questions
Parent:	I'm looking in here, and I find, nothing. I don't know.	Narrates
Child 1:	Ooh, oh my gosh,	Exclaims
	there's a frog,	Declares
	eww.	Exclaims
Child 2:	I think we're s'posed to find a frog in here.	Narrates
Child 1:	Oh, lookit here you can see the trout. And a catfish,	Points
	that's disgusting.	Reacts
Child 3:	Where's the frog?	Questions
Child 1:	Big catfish.	Declares
Child 2:	I wanna see that.	Narrates
Child 3:	Where's the frog?	Questions
Child 2:	Lemme see the catfish in the...	Instructs
Child 3:	Where's the frog?	Questions
	Gotta get out.	Narrates
Child 1:	Did you see how big the catfish was?	Questions
Parent 2:	Yeah, did you see the black snake over here, too?	Questions
Child 3:	Yeah, it's awesome.	Reacts

Excerpt 4: Beaver lodge as a space for investigating animals

These artifacts and spaces participate in the object-centered learning that other authors have described. The variety of ways a single exhibit space can be used suggests that we reconsider museum objects for their power to elicit "personal and idiosyncratic responses…in which autobiographical references and history are intertwined with the specific object or the class of objects represented by the artifact" (Rennie & McClafferty, 2002, p. 204). These families' conversations remind us that it is not the objects themselves that are important to museum activity, but rather the stories and experiences that are crafted around and from and through the objects (Gurian, 1999). The stories that emerge may be connections to prior experience or fodder for future interactions, and may also become an opportunity to understand more fully the kinds of operations that the artifact affords. For example, Excerpt 5 illustrates a visitor's continuing understanding of electric circuits. Although this boy begins with what appears to be some doubt in his ability to construct a circuit on his own, after a few minutes of exploring the materials he is confident enough even to correct a mistake in the second iteration of lighting a bulb. In this example, the heart of the small story is the exclamation, "I made it work!" However, there is more to the story than that. The sequence, "I don't know what that is," and then "I know what that is," although they refer to two objects, marks an important transition to greater participation (and it is worth noting that the child could not have made the bulb light without using the puzzling 'alligator clips').

Ultimately, of course, what is recognizable in each of the examples given is the interrelatedness of individuals, families, artifacts, and spaces, and the way all of these factors mediate for the others an experience of participation in a knowledge-centered activity. Artifacts alone do not constitute the experience of a museum visitor; in the next sections I will explore the data to learn how the audiences for stories also contribute to an informal learning experience.

Child 1:	I'm gonna make a circuit. Okay, circuit board, two alligator clips, I don't know what that is.	Narrates
Child 1:	Hey Bella, let's do this together.	Points
Child 2:	I wanna do my own...	Narrates
Child 1:	I need your tech help.	Narrates
Child 1:	Oh a battery, I know what that is. And a low-watt light bulb. Hey, low-watt light bulb, that's one of our things. Well we found the wind turbine, we ah, I found lightning, over in the puppet show. Let's see, low-watt light bulb.	Narrates
Child 2:	[unclear question]	Questions
Child 1:	Yeah.	Declares
Child 1:	Let's see. This can't be too hard, can it? That'll be uh, hook the red hoodad over here, umm, uhh, oh, here we go. Clip this guy here, ground a control, whatever that means.	Narrates
Child 1:	Ahww, I made, I made it work!	Narrates
	Look! Bella, look!	Points
	It actually worked! I, I didn't think I would make a lightbulb, work.	Narrates
	Look at that!	Points
	I bet you could like, shock someone to death.	Narrates
Child 1:	Hey, hey hey hey.	Exclaims
Child 2:	I wanna see, I wanna see this one.	Narrates
	Wait, lemme see that. A'right, stick that one, on there, on the battery.	Instructs
Child 1 & 2:	None of them are working / It doesn’t work.	Declares
Child 1:	Oh, this isn't on.	Declares
	Here, you gotta use that one for the battery.	Instructs
Child 2:	I wanna do this one.	Narrates
Child 1:	Haha, it works. My lightbulb.	Narrates
	That's so awesome.	Reacts

Excerpt 5: Drawing on prior knowledge when experimenting with circuits

4.3 Who Hears a Story?

4.3.1 Stories to strangers

As discussed in Section 2.2.3, personal stories contribute to the dynamic construction of social roles, and consequently to the learning environment. Central to this thesis is the role that story telling plays in the construction of the self and identity. A self, however, is only relevant in juxtaposition to other selves, in relationship to the other people who occupy a space along with the self. In the museum context, other selves present may be family members or friends, museum staff, or other visitors who are strangers. When a child visits as part of a school group, others present will also include fellow students, teachers, and possibly parent chaperones. It is to these others that stories may be told. As Leinhardt and Knutson note after listening to and cataloguing hundreds of museum conversations,

> Identity is not constructed in a vacuum. A sense of self and of activity guides what people do, what they see, and what they say in a museum. It is this very dialectic that makes the construct of identity so central to a discussion of learning in museums from a sociocultural viewpoint. (2004, p. 51)

A typical small story from my experience as a museum educator will help illustrate how these stories contribute to the dynamic performance of self. Peter[7] exemplified a child negotiating his "many selves to be displayed on different occasions." He was the oldest child, about seven or eight years old, visiting the museum with extended family; several younger siblings and cousins circled around him. Their chatter was unusual for our small museum in that it was conducted in a language other than English. Yet as I had an opportunity to interact with the family, it became clear that Peter had a better understanding of conversational English than his mother did. During the course of their visit, I conducted a short interactive conversation about a few varieties of turtles that live in and along the river that runs through our city. The children had a chance to meet turtles from the museum's living exhibit: a diamondback terrapin and an eastern box turtle. I also showed them, for comparison, the stuffed body of a snapping turtle. Although the terrapin and box turtle were alive, the large size of the snapping turtle

[7] All names used throughout this dissertation are pseudonyms.

seemed to elicit the most interest, and after a few moments, Peter volunteered, "I've seen one of this turtle [sic]." Surprised and a bit skeptical, I asked where he had seen the snapping turtle, and he responded, "In the grass." At that point, his mother stepped in and corrected him: "What you have seen, back home, is something like that turtle [pointing to the box turtle]. It put the head and the legs inside, her back, her cover is more like green than that color, you have seen that."

Peter's story is simple. He had seen a turtle before, and when pressed, he elaborated with a brief description of its environment. It was irrelevant to Peter that it was somewhat unlikely he'd seen a snapping turtle in the grass (they're primarily aquatic turtles, unlike box turtles which are terrestrial), and accuracy was left for his mother to clarify. Instead, like many young visitors to the museum, Peter seemed to want to demonstrate a prior experience with the animal, to claim a familiarity. In the course of his day at the museum, Peter was constructing a self who was comfortably bilingual, who focused the attention of his younger siblings and cousins, and who by right of prior experience was a legitimate participant in informed conversation about turtles.

This anecdote exemplifies Leinhardt and Knutson's statement, quoted earlier: "Identity is not constructed in a vacuum." Peter, and every other person who engages in conversation in a museum, is articulating a sense of self to other people nearby. Socially situated articulation is key to the role that stories play in setting the stage for learning, because stories allow not only a construction of self-in-the-moment, but also an identification of self with other selves and the sharing of valuable information about the status of the selves as participants in the learning activity.

In my professional experience as an educator, I am the audience for at least one story (and usually several) each and every time I begin a conversation with a group of museum visitors. Interviews with colleagues corroborate this experience:

> …they have to find some way to tie it into them. You know, "my grandpa one time took me fishing," and...they're sure they saw sharks in the Hudson River…because that's something we're talking about at that point. And how carried away they can get with it and how each child builds on that story, they have some experience that goes along with it, whatever it is, and the next kid in line's story may be "I went to the dentist and he had a fish tank," but they have to be able to tie something in there with that. (Interview B, personal communication, 2011)

It is therefore immediately striking that the field transcripts, drawn from typical museum visits that include a few interactions with staff educators but mostly intra-family conversation, do not include as many stories about past experience as I would have expected based on my own experience. The stories of prior experience that do appear in the transcripts are mostly told to strangers – other visitors, or more often to staff educators interacting with visitors on the museum floor. Why do children tell fewer stories about their past experiences when they are exploring with their siblings and parents than they do with museum educators? I suggest the answer is based in the performance of identity. The story in Excerpt 6, for example, has little to do with science museum content, and seems instead aimed at demonstrating the storyteller's membership in a group.

Child 1:	I need a crayon	Narrates
Child 2:	I've got the yellow one.	Declares
Child 1:	I'll get the red.	Narrates
Child 2:	This is actually [unclear]	Declares
Child 1:	I like red.	Narrates
Educator:	You like red?	Questions
Child 1:	I like all the colors beside black.	Narrates
Educator:	Me too. I like even black, it's sort of good sometimes.	Narrates
Child 1:	All Emma likes is black and purple.	Narrates
	Emma, tell her what colors you like.	Instructs
	Emma mostly likes black and purple.	Narrates
Educator:	What's that?	Questions
Child 1:	Emma really likes black and purple.	Narrates
Educator:	Black and purple, that's a good combination.	Reacts
Child 1:	I don't like pink and red.	Narrates
Educator:	No?	Questions
Child 1:	Jacob wants…Jacob wants everything to be yellow.	Narrates

Excerpt 6: Story demonstrating knowledge of siblings' preferences

As will be discussed in section 4.3.3, families do refer to shared prior experiences, but those stories are usually "remember when" stories, and are more often told by adults than by children. Autobiographical stories from children of the "I did that" sort, by

contrast, serve to present one's own identity as a legitimate participant in the activity, and the activity of exploring a museum mostly encourages that presentation that to be made to a stranger. Staff educators may be especially meaningful "targets" for museum visitors' past experiences, because an educator is a stranger who also holds the position of knowledge authority in the museum. In Excerpt 7, one of the children claims a familiarity with the topic material, but then falters a bit when she realizes she isn't sure of her vocabulary. With a bit of corroboration from the educator, she finally reasserts her claim of prior experience.

Educator:	...where we explore how things work, and what happens when we bring new chemicals or substances together, um, and sometimes you have big reactions, big changes. Um, a reaction is a change of some sort. So, some of those changes can be small, so,	Explains
	do you want to rip this paper for me?	Instructs
Child 1:	Sure.	Declares
Educator:	Is it still a paper towel?	Elicits
Child 1:	Yep.	Declares
Educator:	Can you crumple it up in a ball?	Instructs
Unknown:	(sounds of paper crumpling)	Interacts
Educator:	Is it still paper towel?	Elicits
Child 1:	Yep.	Declares
Educator:	Yep. But it's changed, right?	Elicits
	You change it a couple different ways. But even though it's still paper towel, it's taken on a new form. So it's a little bit different. When we have small changes like that, we usually call them physical changes, something that doesn't change what the item is. There's another kind of reaction in chemistry though that we call a chemical reaction.	Explains
Child 2:	Oh, yep, I remember that from last year.	Narrates
Educator:	You remember that word?	Questions
Child 2:	Mm hmm.	Declares
Educator:	From science class?	Questions
Child 2:	Oh, no, we were learning about interactions.	Narrates
Educator:	Interactions? That sounds like a different word for the same thing.	Corroborates
Child 2:	Yeah.	Declares

Excerpt 7: Prior experience with chemical reactions

Alternatively, sharing a meaningful story with a knowledge authority can serve to portray family identity as well as individual identity, as when a parent prompts a child to tell the educator about a family experience (Excerpt 8).

However, these stories need not be useful only as markers of identity. They offer a possibility for a child or other visitor to contribute to the scaffolding of his or her own learning by informing an educator about the visitor's operational knowledge of the topic. This then enables educators to co-construct effective learning discourse. In other words, visitors' autobiographical stories establish signposts in the shifting landscape of fluid social roles and facilitate the recognition of prior knowledge and experience.

Educator:	You're welcome, thank you for coming over.	Declares
Child:	Mommy, can we go to another little exhibit over here?	Questions
	It's another little...	Declares
Parent:	You shoulda said we had the turtle in our backyard that laid eggs.	Instructs
Child:	Um, we had a turtle in our backyard that um, dug a hole,	Narrates
Educator:	(ohhh)	Exclaims
Child:	and um, planted eggs, but um, then, when, they didn't hatch right away so we dug 'em up, and um, we found baby turtles still under there, like still trying to get up. So we buried 'em up, and I think they're still down there, There may have been tunneling somewhere else.	Narrates
Educator:	That's a natural thing, sometimes their eggs take a very long time to hatch, they take over a month, um, and, yeah, and the mother will just leave them because when they're born they know how to take care of themselves,	Explains
	isn't that	Elicits
Child:	(yeah)	Declares
Educator:	strange?	Elicits
	Right from the very first time they hatch out of their eggs, they know how to find their food and how to make their way in the world.	Explains
Child:	Wow.	Exclaims
Educator:	That's a pretty neat thing to see.	Reacts

Excerpt 8: Family story about a turtle nest

Stories, as we have seen, are told in recognition of a trigger object: there is a motivation to be involved, and then a desire for participation with the object and consequently with the educator or other person affiliated with the object.

> Learning in a museum is a social process that is in part a consequence of the historical experiences of individuals and in part a consequence of the interactions with artifacts and curatorial expressions as the two connect or even collide with each other. (Leinhardt & Knutson, 2004, p. 49)

The small autobiographical story is in this sense a mediator insofar as it validates the teller's participation in an activity. Once the participation is legitimated, the information contained in the story about the learner's prior experience becomes significant for supporting the construction of the learning itself. One museum educator notes that a learner's ability to relate to the experience may motivate increased attention:

> And it's just that they do like to relate the things I'm talking about to their life…and I just figure let 'em do that because they'll...pay attention a little bit more if I'm telling them something about turtles in general, and they can relate that to their pet turtle and be like, "oh, I should be feeding them crickets too" or…"they really like strawberries so I have been giving them strawberries." (Interview C, personal communication, 2011)

It is tempting at this juncture to imagine a simple learning situation of messages sent and received between educators and visitors: educator inspires desire to learn, visitor tells story to acknowledge motivation and inform the educator about his or her prior knowledge, educator imparts new information, visitor learns. It would be easy to define scaffolding as the mutual provision – that is, each actor contributes a part – of foundational knowledge that enables the visitor to internalize new knowledge. Yet as discussed in Chapter 2, learning does not consist of simply adding knowledge to a collection, as one adds books to a library. Lave and Wenger's treatise on legitimate peripheral participation makes clear that learning is not a simple transmission activity with a definite beginning and end. They write, "in our view, learning is not merely situated in practice – as if it were some independently reifiable process that just happened to be located somewhere; learning is an integral part of generative social practice in the lived-in world" (1991, p. 35). Instead of a simple model of learning that entails repeated exchanges of transmission and internalization, a model of learning as legitimate peripheral participation entails scaffolding that is co-constructed even as it is

used as a foundation for fuller participation by all actors in the immediate learning context.

Scaffolding as used here is not simply vocabulary for describing a pedagogical style. Education practitioners drawing on the work of Lev Vygotsky have, as Lave and Wenger note, often interpreted scaffolding as "explicit support for the initial performance of tasks to be later performed without assistance" (1991, p. 48). Here, I offer a rich interpretation of scaffolding as the reference frame of prior experiences, actor relationships, contextual (cultural) expectations, and dynamically constructed social roles that form the support for ongoing learning practice. Scaffolding is the situation described by Engeström's activity model (Figure 2), and learning consists of change to the relationships that comprise the model, as the actors move forward in time. To reiterate, the learning-as-being-in-the-world paradigm promulgated by Lave and Wenger implies that participants in an exchange must establish together knowledge of each other's expertise, roles, and relationships within the larger cultural context, and they must do all of that with or without the explicit understanding that they are doing so.

An awareness of the ways small stories communicate features of those relationships and roles can contribute to an educator's effectiveness at facilitating informal learning experience. In other words, educators can use autobiographical stories of prior experience as an opportunity for iterative assessment during an interaction with a visitor. A few examples from my own experience as a museum educator will illustrate the kinds of knowledge that can be assessed by listening to visitors' stories. The tide pool exhibit at CMOST consists of open salt-water rock basins that are home to several tide pool creatures, including horseshoe crabs. We discourage visitors from reaching into the pools, both for their own safety and for the sake of keeping the water relatively clean. Museum staff members, however, are trained in lifting out the horseshoe crabs in order for visitors to see more easily. On one occasion, a teacher and student from a visiting school group approached me near the tide pools and the teacher asked if I could pick one up so that they could see what the bottom looked like. As I did so, carefully preparing by cleaning my hands and removing my watch, the student looked interestedly on and remarked, when I lifted the horseshoe crab gently by the edges of its carapace, "they're hard to pick up. Because on the beach in South, um, Carolina, they let us pick them up."

The student's story spoke to an embodied experience: she had a memory of trying to pick one up, which both informed her motivation to see a crab again, and helped her to identify with my task. From just these few words, I could surmise that this student had a sense of the geographical distribution and habitat of horseshoe crabs, and had a physical knowledge of the hardness and the slipperiness of their carapaces. In the ensuing conversation, I was able to move quickly past these basics to other intriguing facts, such as the use of horseshoe crab blood for pharmaceutical testing.

Another story was related to me following a workshop about electric circuits. Several parents paused to tell me how much they enjoyed the session. One mother in particular – a member and regular workshop attendee – told me how pleased they (she, her husband, and son) were with the workshop, as just the day before the son had been playing with a toy robot dinosaur in the driveway. Noticing where the dinosaur's battery case was, the son then proceeded to take the entire toy apart to "see what it looks like on the inside," and try to figure out how it works. She followed this story with another about how she had "been telling them [son and husband] about it for at least two years," referring to a demonstration using a pickle to demonstrate conductivity (it glows yellow when inserted in a circuit that is plugged into a power outlet). This mother took time out to tell me these snippets in order to relate her son's prior interest and identification with circuitry, and also to make the point that she, too, was involved and interested in the activity.

If we assume that more time spent with an exhibit or artifact suggests more participation and deeper interaction with a topic, then an analysis of the cumulative time that visitors spent at each exhibit adds further support to these claims about small stories, educator interaction, and more meaningful learning experiences. Of the two exhibits with which each family spent the most time, at least one for each family was facilitated by interaction with a staff educator (with the exception of three families who did not interact with an educator at all during their time at the museum – these were also the three shortest visits overall). Furthermore, aside from time spent with CMOST's Young Explorers Computers, nearly all of the longer exhibit interactions are accompanied by either visitors' stories or staff explanations (and often both), as shown in example graphs of two families' visits (see Appendix B).

These kinds of stories explicitly mark past learning experiences and offer opportunities to build on those experiences, as museum educators often do intuitively. One interviewee noted that she always tries to find a way to relate a story back to the topic at hand.

> I think a lot of the time the stories that they tell you have a teaching moment in them too. Like "I have a turtle just like that in my house that we found when we went on vacation, and it was all alone and it was scared so we took it home." And then there's a teaching moment there, how it wasn't scared, that's what you thought it was, but it's probably more scared now because it's not in its home. (Interview B, personal communication, 2011)

It has been noted that some of the challenges facing informal learning institutions include getting funding agencies to recognize that learning outcomes may be difficult to assess using traditional means (e.g. tests), and in communicating how learning in one context can support learning in others (Vadeboncoeur, 2006). We need as well to consider alternative learning outcomes, such as attitudes, interpersonal skills, and identity emergence (Brody, Bangert, & Dillon, 2008). Educators can use small stories in conversation with individuals to help visitors build on or change existing attitudes and beliefs, and they can also use them in aggregate to make a case for the kinds of learning that happen in informal environments, and the ways that informal learning institutions can support other kinds of academic progress.

All three interviewees commented that, while they prefer to listen to visitors' stories as they arise in conversation, they often struggle with time constraints – particularly when the learners are visiting with a school group. The affective pathways that are engaged via encounters with trigger artifacts in the museum could support storytelling for assessment at a later time, and need not be limited a visitor's time in the museum itself. One educator, who has worked both in museums and in traditional schools, was emphatic about the use of having schoolchildren share stories about their museum experiences after a visit had concluded:

> So what they have to do, is they have to build on what they've seen, what they've done, what they've experienced, and something like the museum, going back to school after the museum trip, and writing, three, four – you know depending on their age – sentences about what they did, is a great connection, and then you build on that. "Okay, well we went to the

> museum and we talked about life cycles." So, "what do you remember, and what do you remember," and we can make a story all together using the entire class, and go over, and "okay, you forgot, you forgot a step. Who can help her remember the next step?" And they teach each other, and they're learning together… (Interview A, personal communication, 2011)

Constructivist theorists repeat this advice, noting, "it is crucial that…teachers listen to and actively seek to explore students' accounts of their responses to the museum and its exhibits" (Anderson, Lucas, & Ginns, 2003, p. 196).

4.3.2 Stories for self

Educators may not be the only useful audience for stories, nor the only assessors. "Self-assessment activities help students to gain a greater awareness of their capabilities and to establish realistic learning goals" (Brody, Bangert, & Dillon, 2008, p. 5). Having an occasion to tell a story allows learners to reflect on and consolidate their learning experience – to engage in metacognitive thinking. I define metacognition as any self-directed process used to control, direct, or plan other cognitive processes (Bhat & Kolodner, 2009), recognizing that those other cognitive processes may be interpersonal rather than individual – consistent with the definition of learning used throughout this dissertation. Metacognition aids learning by helping students determine what information is relevant to their current needs as participants (Land, 2000), what sequence of tasks they will pursue, and the goals of their participation (Bhat & Kolodner, 2009). For example, in Excerpt 5 (section 4.2.2), the boy working with circuits recognizes the components that he recognizes (batteries) and those that are unfamiliar (alligator clips). Articulating this seemed to allow him to begin from his prior knowledge, and use context to determine what the label "alligator clips" referred to. In this case, the small story the boy told himself about the material objects in front of him at the "Tinker Table" helped him to scaffold his own thinking about what he knew and didn't know. Research with high-functioning autistic children suggests that working through stories may also be useful for helping them to construct coherent (that is, causally-appropriate) explanations, particularly when adults scaffold their articulations of the stories (Levy & Fowler, 2005), and there is every reason to suppose that metacognitive stories are also useful to non-autistic learners for the construction of scientific explanations.

In the museum recordings, the most frequent kind of metacognitive scaffolding that takes place is reading from signs. Many of the signs are explicitly worded to encourage visitors to ask questions and then look at an exhibit to find the answers (Figure 7). Parents, too, often look to the signs for help explaining how an exhibit works, what it is "meant" to demonstrate, or why it is of interest; in doing so, these parents tell their own small stories about how to make use of the museum space. At the astronaut glove box exhibit (Figure 8), some parents choose to read the signs aloud themselves, modeling metacognitive thinking (Excerpt 9), while others strongly encourage their children to do the reading, instructing them directly how to engage in metacognitive behavior (Excerpt 10).

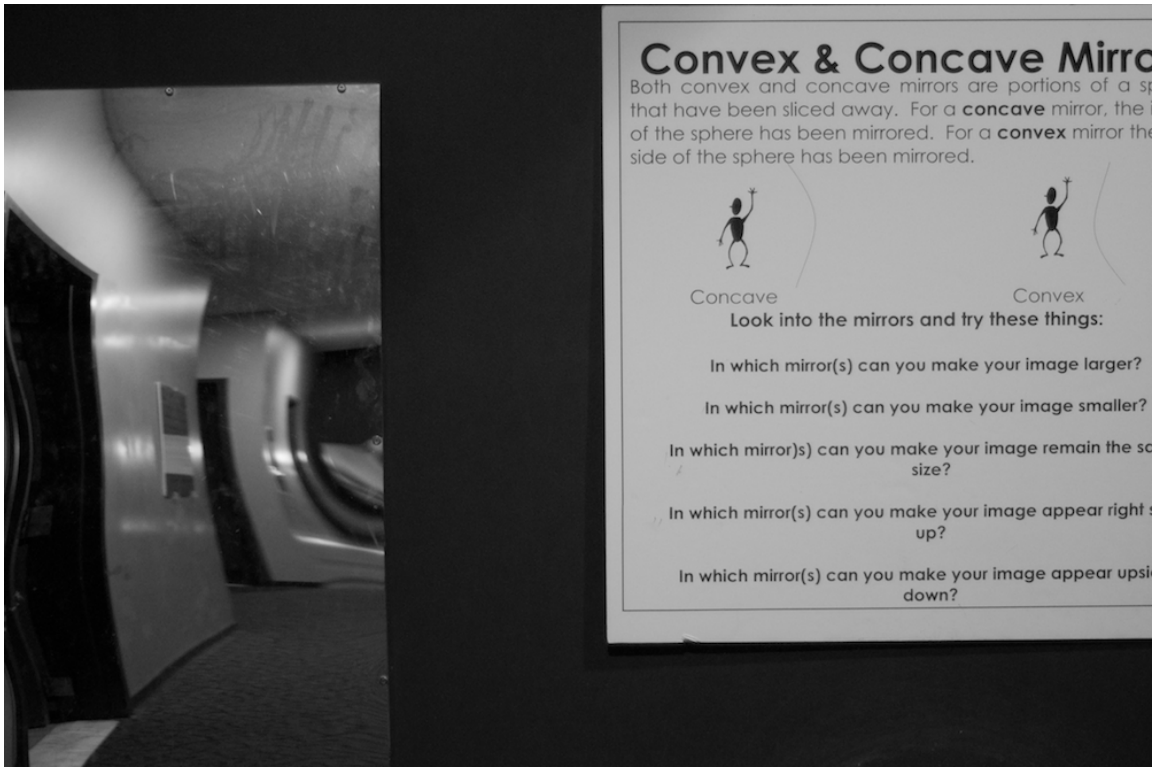

Figure 7: A sign near the mirror exhibit scaffolds learners' exploration

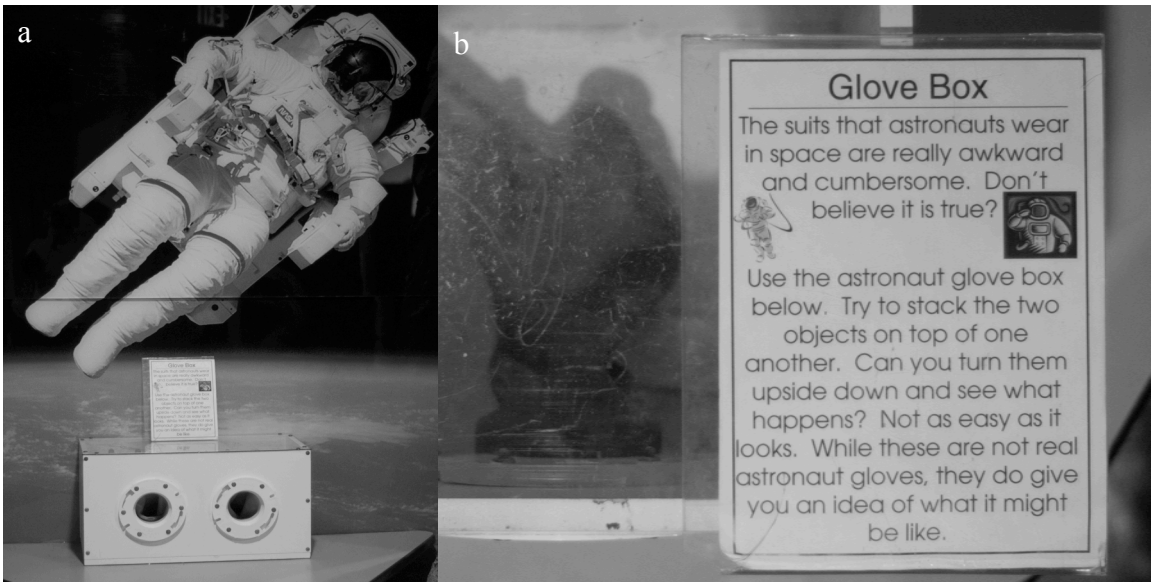

Figure 8: a) Astronaut gloves exhibit; b) Close-up of top of glove box and signage

Child:	What d'we have to do?	Questions
	[thumping sounds]	Interacts
Parent:	Mia.	Points
Child:	Heh, glove box.	Declares
	Astronauts wear in space...clumsy...[unclear]	Reads
Parent:	Use the astronaut glove box, try to stack the two objects on top of one another other. Can you turn them upside down and see what happens? Not as easy as it looks. While these are not real astronaut gloves, they do give you an idea of what it might be like.	Reads
Child:	I did it.	Narrates
Parent:	Was it hard, or easy?	Questions
Child:	Kinda easy, you just gotta find out what hand to use, cuz they can only go so far.	Narrates

Excerpt 9: Reading the sign at the astronaut glove box exhibit

Child 2:	Here, you stick your hands in.	Instructs
Child 1:	What, I have to try to, What, do you have to try to open it?	Questions
Child 2:	Look what I caught.	Points
Parent:	What's in there?	Questions
Child 1:	It's cool.	Reacts
Parent:	Oh, it's the glove that the astronaut wears so that's how you feel…	Declares
Child 2:	Oh, it is?	Questions
Parent:	...yeah, well you're going to have to do some reading here girl.	Instructs

Excerpt 10: Instructed to read the sign at the astronaut gloves exhibit

Finally, metacognitive thinking is not confined to "what to do," "how to do it," or "what it means." In section 4.2.1 I discussed the way affective responses to artifacts interacts with museum learning; metacognition can also direct the way learners respond to their own affective reactions. Feelings of familiarity and fluency or of difficulty regarding a task, a sense of confidence in one's knowledge, or the mistrust of an instructor are all examples of affective metacognition (Efklides, 2006). Learners' stories play an important role in affective metacognition by mediating the subject-object/ive experience. For instance, when students or museum visitors are negotiating a situation that they find somewhat fearful or anxiety-provoking, a story can relate that anxiety, and provide an opportunity for the educator to demonstrate his or her trustworthiness. The issue of trust is crucial. "...if students 'trust' their teacher they are more likely to turn to them for guidance in their learning efforts and be accepting of the teacher's influence attempts" (Wooten & McCroskey, 1996, p. 95). Alternatively, recalling a similar prior experience may help a learner to control their own reaction – a reaction that may be increased openness to learning or a closing off. In a science museum, the same objects that are story triggers because of their novelty or surprise effects are also, often, objects that elicit fear: reptiles, insects, electricity, chemical reactions. Frequently in these cases, a child will verbally recall an episode where they have seen the object of anxiety before, but without ill effect. A common story is something like one boy's during the second half of a show about animal life cycles, as I pulled out a large ball python: "I saw on TV, this guy had a huge boa constrictor wrapped around him." The snake he had

witnessed previously was even larger than the one in front of him, and its wearer had come to no harm.

Less common but even more relevant to negotiating fear are memories of direct contact with the fearful object. One girl, for example, told a story about a close encounter as an infant: "When I was a baby, well, really little, I had a snake on, this snake crawled up my arm, and, and, I was like, 'Daddy Daddy Daddy' ‘cause it was gonna bite me, but it didn't ‘cause, um, he got it." A more explicit and more clearly articulated negotiation with fear was related to me by one of the chaperones accompanying a school group. A middle-aged woman, perhaps 60, accompanied a group of 4th graders on a field trip. She could have been grandmother to one of the students, or maybe a teacher's aide. The program for that group included a basic introduction to food chains, and the live animal show included Madagascar hissing cockroaches, a box turtle, and again a ball python. Afterward, she was one of the last people out of the room, and she paused to thank me for showing the snake especially. She said that this had been the first good experience she'd had with a snake, and then related her other snake stories. There was one about her childhood, when her brother used to find dead snakes in the garden and put them around her neck to tease her; another episode of uncomfortable snake contact happened a few months prior when she accidentally ran over a snake with her bicycle and felt so bad about it she went back to see the damage she'd done. She took pains to repeat that this was her first positive experience, and she was clearly delighted that the python was so large, docile, and gentle. Simply telling her stories allowed this visitor to acknowledge both her fear and reflect on her ability to move beyond her fear in order to have a rewarding interaction.

As hinted previously, however, affective metacognition can have a negative effect as well. In stark contrast to the stories above, one interviewed colleague related a recent interaction with a visiting school group in which one teacher’s verbal reflection on her affective response to snakes – fear – colored the experience of the entire class. This teacher was so vocal about how snakes were “scary” and “icky” that her students’ expectations were colored with negative emotion. Thus affective metacognition is not always helpful in realizing the goals of museum staff, which is even more reason for

educators to be aware of how those affective metacognitive stories mediate visitors' experiences.

4.3.3 Stories with family

Not least, of course, are the stories that are told with and to the group that a learner is visiting with: this is usually family or friends close enough to be considered family, or a school group. In my museum recordings, all of the children visited with family, and approximately half of them visited with siblings. There is a rich history of literature describing parent-child conversations, including the ways parents and older siblings use narrative to bring their children into family culture and to help them organize and remember past events (Manier, 2004; Thompson, 2006), as well as the ways families can scaffold their children's scientific and historical understanding (Gleason & Schauble, 2000; Tenenbaum, Prior, Dowling, & Frost, 2010). There is also growing evidence that the act of remembering may itself be a social and communication-centered act (Nelson, 1989; Neisser & Hyman, 2000; Manier, 2004). "Memory is something that we as humans do, that is, it is a meaningful action we perform in the sociocultural contexts that we take part in creating, and within which we live" (Manier, 2004, p. 256). While "grand narrative" structuring is perhaps not very important in everyday remembering, the small stories that form the foundation for this thesis are central to it (Hyman, 2000). Taken together, the social nature of memory and the communication habits of families offer insight into the ways that museum experiences exist beyond the temporal bounds of a museum visit. Families may foreshadow together what will happen during a museum visit, or review a day's experiences later at home. Museum experiences may lead to plans for future action, as in one beaver lodge excerpt described in section 4.2.2, when a mother suggests to her child that they could have dad build them a similar hidey-hole (Excerpt 2). Alternatively, museum encounters may trigger reminiscence about other important events in a family's life, such as when a child's fascination with owl hoots sparks a parent's nostalgic recollection of owls heard in his or her own childhood (Figure 9), or when a woman exclaims upon seeing an iguana (Figure 10), "we saw those on our honeymoon!"

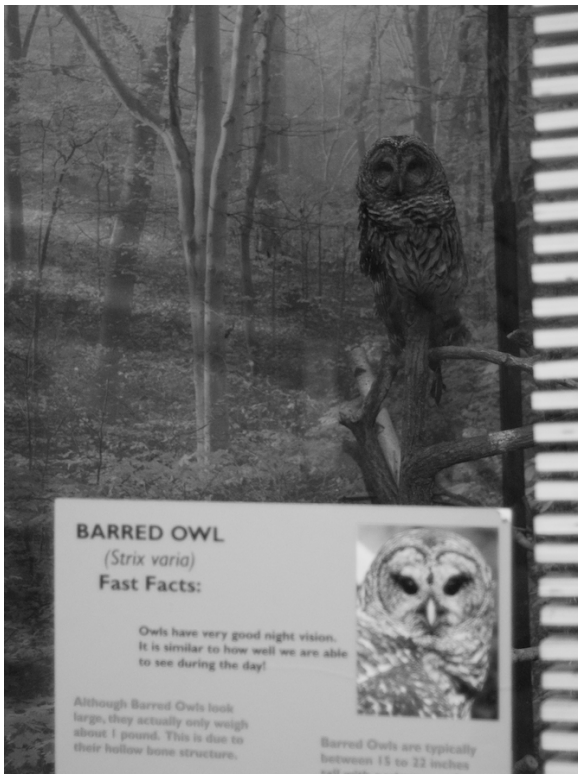

Figure 9: Barred owl Susie lives at the museum due to losing a wing in a car accident

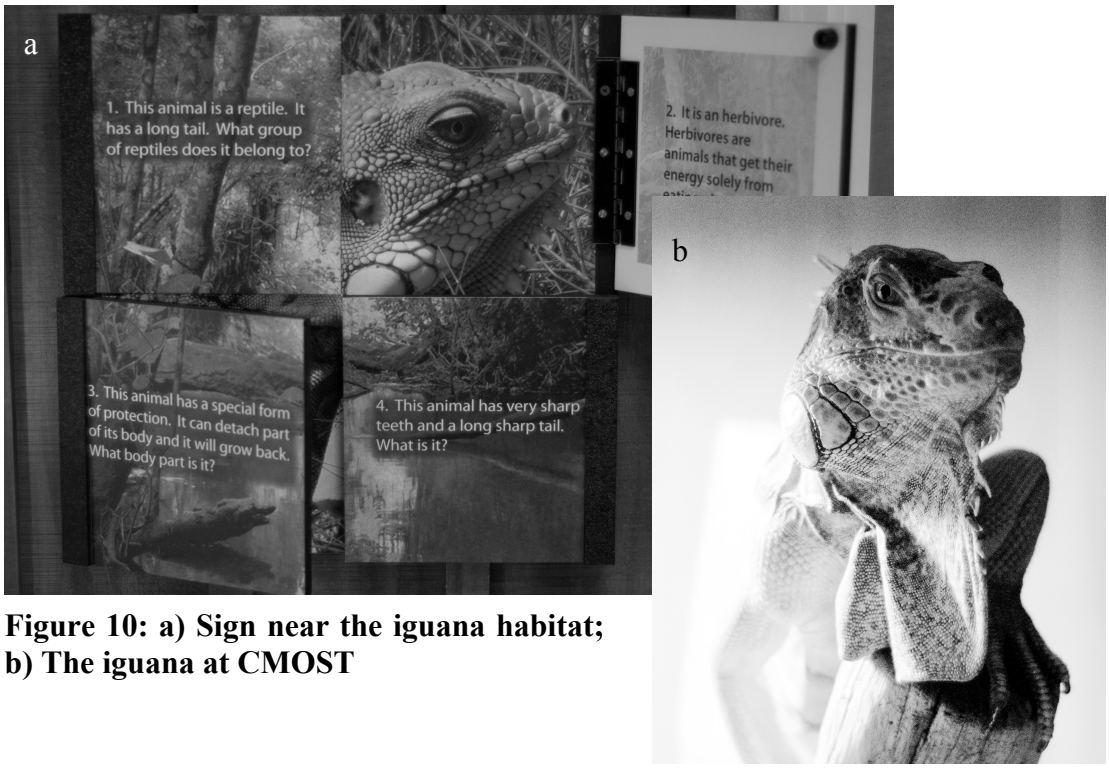

Figure 10: a) Sign near the iguana habitat; b) The iguana at CMOST

Of course, just as adult emotions can affect children's experience of the museum (see section 4.3.2), some adults may have stories that run counter to the educational goals of the museum, as in one story recounted by an educator:

> I remember a time…there was a lady who had this story about a box turtle that she had taken from the wild, and she would not let us talk to the kids. She was very intrusive into the program. And I know [a colleague] was having a very difficult time and I finally had to say to [the lady], "we'd be really happy to talk with you about that after, but not now, because the kids need to get their program." But again she kept intruding as we were telling, we were doing, I think, What's Eating What, so we were talking about how turtles belong in the wild, and what happens if you take them out, and…that whole food chain thing, and you know, she's telling us what she does with the one at home that she took from the wild. And…finally I had to say, and I just, I really felt justified in saying to the kids, "I understand that she has a turtle at home, what she did was not the right thing to do."
>
> And she was quite offended afterwards, and [the colleague]…she couldn't believe that I said that, but we're trying to teach the kids how important that is, and [the lady] was undermining what we were doing. And I'm just a stronger personality so I found a way to say that's just not okay. And I talked to her later, and I said, "you know, if it works for you, it's not my business to tell you that you're right or you're wrong." But I said, "you have to understand that the lesson that we're trying to give the kids is an entirely different lesson. So, you know, I'd be happy to talk with you about what you have and why I have a problem with it, but..." and…she listened for a few minutes, she didn't want to hear it, there was no changing her mind, which was fine, but I think I made her see that I wasn't aiming to be rude to her...Just trying to get the kids to know the lesson that they need to know. Because those are the ones you get the most, are the animals they took home with them. You know? And I hate those stories. (Interview B, personal communication, 2011)

In this case, the educator found a way to try to mitigate the effect of the adult's story, but we cannot know ultimately how successful that intervention was. Moreover, in focusing on the educational goals the educator had for the children, the contrary motivations and storytelling needs of the accompanying adult were necessarily a lower priority. Complete understanding of how these stories relate to ongoing family science learning will require fieldwork beyond the scope of the present thesis, such as home interviews and observations prior to and following a museum visit, cultural probes aimed at the

science learning conversations that happen during family interactions, and innovative experiments involving parent-child interaction.

4.4 Not-Stories

Although the heart of the present investigation is the storytelling communication of children in the museum, a comprehensive study of my museum recordings reveals two other kinds of communicative behavior that warrant attention: pointing, or communication with the goal of shared attention; and activity consisting of performance and play. Graphing the communicative acts of the recorded families reveals how prevalent pointing behavior is (Figure 11). We point in order to share an artifact of interest with family/group members. Why is the desire to share attention so strong? I suggest that learners implicitly recognize that community mediates their own participation in interesting activity. The quickest way to increasing participation is earning the acknowledgement of other participants that the artifact you have found is, indeed, interesting and worthy of further study.

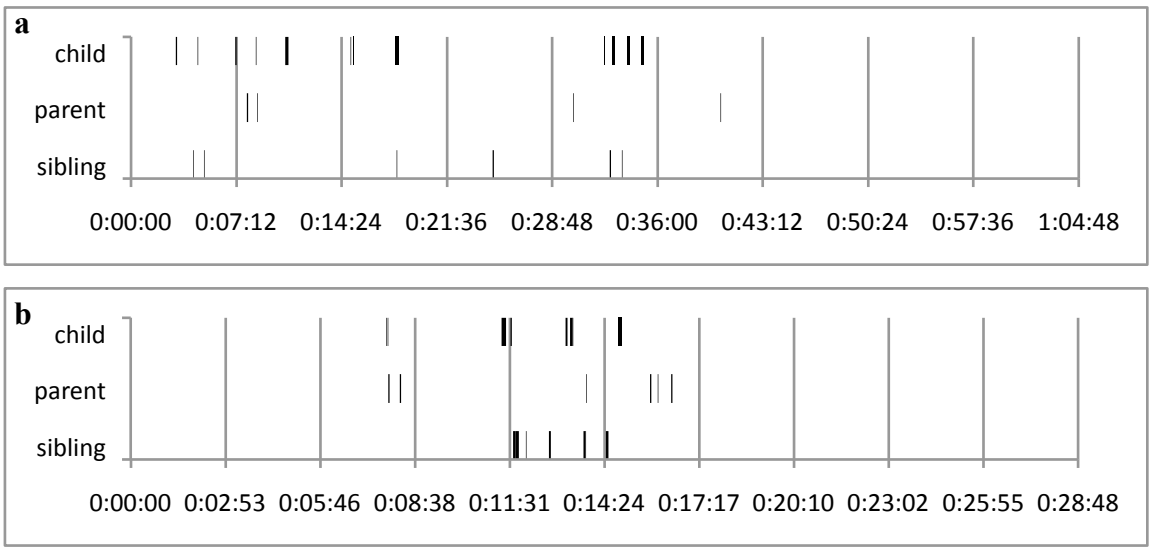

Figure 11: Examples of the distribution of family attention-directing utterances during the museum visits of two families, (a) and (b). The horizontal axis marks the time at which the utterance occurred, where 00:00:00 is the moment recording began. Wider gray bands include more than one pointing utterance. (Note that "sibling" may refer to one or more additional children visiting with the family.)

If what you are doing is interesting, others join in. That joining in may consist of looking at something, talking about it, asking questions, or telling stories. Alternatively, joining in may mean participation in other kinds of social exchanges. In the museum studied, two exhibits in particular inspired not only pointing, but also a near-immediate transition to play and performance modes. The most performance happened at the weather exhibit, which consists of a conspicuous performance space in front of a camera, with a greenscreen for a backdrop. After recording a weather broadcast, with or without the aid of the script scrolling on a monitor that faces the performer, visitors can watch themselves on a nearby television. The performances observed at the weather station were similar to those reported by other researchers:

> The visitors create elaborate and embellished actions with and around the exhibits…Such performances are produced in the moment at hand. The 'performers' not only use the exhibits but also create engaging and enjoyable experiences both for themselves and those observing them. (Meisner et. al, 2007, p. 15)

The most active play took place in front of the PlayMotion[8] exhibit. In this space, long stretches of time were recorded (see Figure 12) consisting of nothing more than laughter, grunting and other breathing indicating exertion, and the occasional brief instruction or exclamation (e.g. "get it!"). This space is a large blank wall, upon which is projected a changing scene. Visitors interact with the wall by positioning their bodies so that their shadow falls on the wall, and the scene changes to respond to their dynamic positions. For example, in one program, visitors can raise their arms so that their shadows "catch" or "bounce" projected images of the planets in our solar system – a successful catch earns a brief snippet of information about a planet. In another, standing still causes a projected tree to grow on the shadowed portion of the wall, while a third looks like rippling water where visitors can make waves by jumping and waving (or try to avoid making waves by ducking and crawling below the sensitive area).

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[8] PlayMotion is a registered trademark of the exhibit manufacturer. More information can be found at http://www.playmotion.com/.

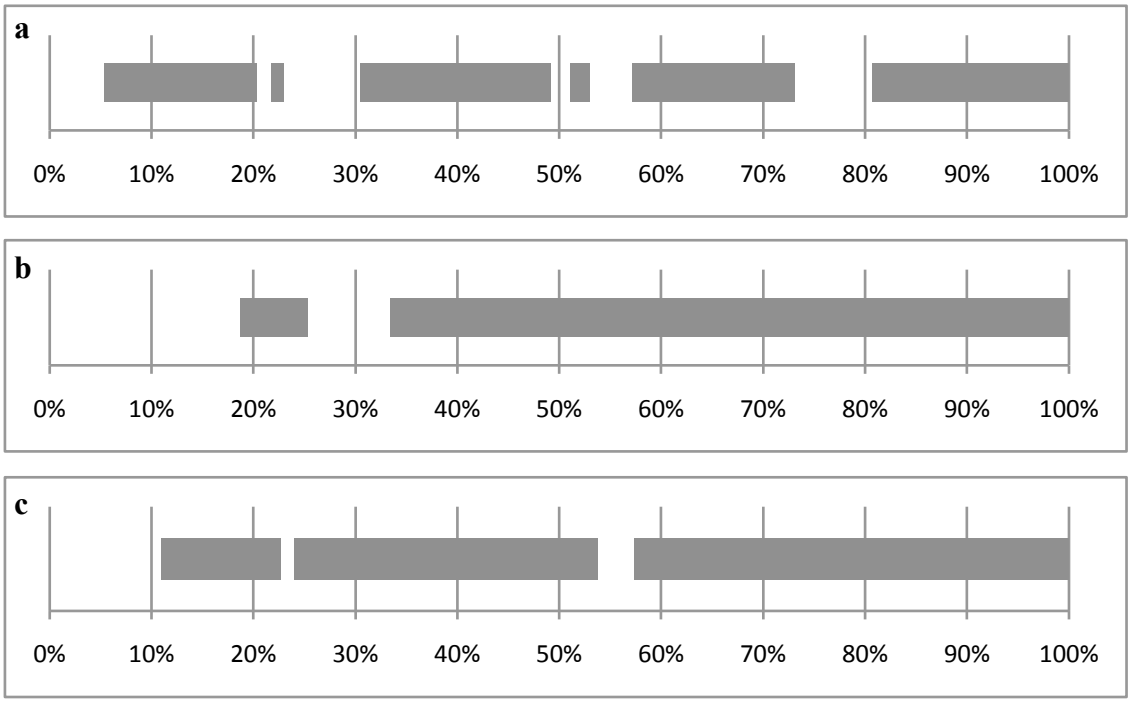

Figure 12: Play behavior at the PlayMotion exhibit. Gray bands mark time spent playing (as opposed to conversing) as a percentage of total time spent at the exhibit, for three different families (a), (b), and (c).

These two exhibits share several features that encourage and reward this kind of immediate interaction: each of these two exhibits features a large enough area for several visitors to share the performance/play space, and it is immediately clear what the participation of the visitors will accomplish. Furthermore, those accomplishments are novel and satisfying. However, both the weather station and the PlayMotion are underdetermined[9] enough so that visitors can easily stray from the canonical modes of interaction to accomplish goals of their own invention. For instance, school children often use the weather station to record dancing, singing, or screaming rather than any kind of speech about the weather. Families will often include performers who flirt with alternative interpretations of how to present the weather: they might mimic drowning in the flood that appears on screen behind them, pretend to be struck by lightning, or interpret a moving pressure system on a weather map as though it represents some apocalypse bearing down on the local region.

[9] Justine Cassell developed an interface design philosophy she calls "underdetermined design;" I use the term the same way (see Cassell, 2002).

Neither performance of this sort nor physical play comprises a story – not even a small story of the sort I have examined in the other sections of this chapter. However, just as small stories provide insight into the ways visitors' personal verbal communication supports their learning, more detailed attention to physical play may offer insight into the non-verbal communication that accompanies science learning. Performance seems to straddle the verbal and non-verbal modes, and attention to its use in informal learning contexts might provide researchers with better understanding of the variety of activities that support learning.

4.5 Summary

Whether it is a momentary performance or an hour of boisterous play, the recollection of the snake who lives in the garden wall or a plan to carry out an experiment with kitchen ingredients later, this chapter has tried to highlight the importance of the ordinary activity of visitors to a science museum. The unremarkable and ephemeral is where the bulk of our lives are lived, and consequently where most of our meaning-making takes place. If, as educators, we want people to bring more science into their lives – to find a sense of wonder in the natural world, to take civic action using evidence-based reasoning, to imagine the best future that human achievement can bring – if we want ordinary people to do all that, then we must make science a part of ordinary conversation. I have tried to show in this chapter that in order to do so, we should also do the opposite: recognize that ordinary conversation is how people participate in science, and learn to use those small stories as pathways to increased participation.

By looking closely at excerpts of ordinary conversation and by taking a broader view of overall conversation patterns, this chapter showed how listening to visitors' stories offers deeper understanding of learners' affective and metacognitive needs, and allows assessment of both prior experience and future goals. In the next chapter, I will build on those understandings to develop design implications for supporting interaction within the museum and for helping learners to communicate with others about their participation. I will offer a design proposal for a distributed museum that acknowledges visitor participation and connects that participation to effective scientific discourse. Ultimately, the data presented here and the design presented in Chapter 5 both stem from

the same question: how can museums best harness the enthusiasm and energy of playful visitors to initiate deeper understanding of science, while still respecting the various motivations, goals, and values of diverse visiting populations?

5. Design Implications & Proposal

5.1 Prior Art and Proposal Goals

Many scholars have found children and their stories to be provocative grounds for design and research. Primarily, however, other designers have focused on facilitating children's telling of either fantasy or historical stories, rather than their own lived experiences. Some designers are concerned with providing spaces for children to tell and share their play stories, as in the "StoryMat" project described by Justine Cassell (2002). StoryMat appears to a child as simply a rug that looks like a stylized map. As children play on the rug with toys, either alone or in pairs, their speech is recorded and correlated with where on the rug (at the image of a house, or a river, or a town, etc) the child is located when he or she speaks. When, later, another child plays on the rug, if the second child should move to the same location, the Story Mat is then prompted to tell the story that the first child told. Thus, one child's solitary play is enhanced by hearing the stories of a child who played there previously. The researchers' observations suggest that children who do not normally verbalize or tell explicit stories when playing alone are more likely to do so with the scaffolding of Story Mat. Other work in this area includes Montemayor's physical programming environment for kindergarteners, which provides a mechanism for children to create stories by determining the kinds of interactive effects they want to include in an acted-out story, which they then program by waving a "magic wand" (2003).

With respect to science learning in particular, historical materials may be used in conjunction with newer technologies like scanners, digital cameras, web pages, and digital archives that allow schoolchildren to reconstruct a story of a particular working scientist (Kafai & Gilliland-Swetland, 2001). The case study described profiles students who are directed to try to "get inside the mind" of a historical naturalist. The project was situated outside of the classroom with visits to archives and to the field sites that the naturalist frequented, but it was also maintained inside the classroom where the naturalist's work of sorting, tagging, and analyzing was carried out. The explicit goals of the project were to capture the situated facets of a naturalist's work as well as the social elements of imagining the naturalist's interactions with his colleagues and of

working in research teams. Unexpected but welcome, however, was the opportunity to also address the moral nature of scientific research, as students came face to face with changing historical norms about science, for example the collection of animal specimens.

However, most designs that incorporate children's stories do so with an eye toward increasing children's reading and writing skills (as in Cassell, 2004; Ryokai, Vaucelle, & Cassell, 2003). While there is no doubt that these skills are important, I have tried to build on previous work discussing the role of language in science learning (e.g. Wellington & Osborne, 2001) to show how stories may also be useful in science learning directly. In the following pages, I develop the findings discussed in the previous chapter into practical, concrete suggestions for experience and exhibit design.

Here I will take into account not only my own observations and interpretations, but also the results of design evaluation research that has examined the variables that trigger motivation and learning in informal education contexts. Those variables include social involvement, hands-on opportunities, surprise, novelty, and interest sparked by knowledge acquisition (Dohn, 2010), factors which imply that experience design should be sensitive to a diversity of learners and social situations, physical interactivity, apprehendability, and conceptual coherence (Allen, 2004). Exhibit design in particular may need to also be responsive to the ways learners approach visual material, including the amount of visual information that visitors can take in at one time (Cook, 2006) and – as we saw evidence for in Chapter 4 – the role of labels in visitors' conversations (Atkins, 2009). Finally, since visitors to science museums often come as part of an intergenerational family group, design for these environments would do well to take into account the particular needs of groups as opposed to individuals (Borun, 2008) and the ways families approach learning in museums (Ash, 2003).

In this chapter, I'll first discuss these research-driven design implications, and the ways that they intersect the cognitive tasks in which learners engage. To structure the material, I turn to a tool that has long served to provide a common language about learning goals: Bloom's Taxonomy (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956), and the more recently revised version of the Taxonomy (Anderson et. Al, 2001; Krathwohl, 2002). Then, building in particular on the theme of metacognition that has

underlined the discussion of my field observations, I propose terminology to better describe the ways exhibits and other technology design support or discourage metacognitive and reflective thinking. To conclude the chapter, I offer a word-portrait of an informal learning institution that strives to engage learners in scientifically literate activity in an ongoing fashion, beginning from the experiences (and stories of experiences) that matter to its members and visitors.

5.2 Evaluating Small Stories

5.2.1 Bloom's Taxonomy

The original Bloom's Taxonomy proposed a pyramid of types of information-based activities: knowledge, comprehension, application, analysis, synthesis, evaluation. The revised taxonomy uses two dimensions rather than one, acknowledging that there are different kinds of knowledge (factual, conceptual, procedural, and metacognitive) as well as different cognitive processes that act on knowledge (remember, understand, apply, analyze, evaluate, create).[10] One of the original authors of Bloom's Taxonomy writes, in an overview regarding the revised version, that the taxonomy was intended from its outset to serve as "more than a measurement tool" (Krathwohl, 2002, p. 212). The Taxonomy provides a common language for discussing learning goals – in the language of this thesis, methods for increasing participation in meaningful ways – both broadly and specifically for particular courses of instruction. It also highlights the variety of cognitive tasks that may be used in undertaking any particular activity in any given knowledge domain, and provides a means for evaluating "the congruence of educational objectives, activities, and assessments" (Krathwohl, 2002, p. 212). For present purposes, it is this evaluative use of the Taxonomy that will help to organize an understanding of the ways small stories contribute to participative learning.

Although a visitor to a science museum may or may not have a specific educational goal, the museum as an institution does have an object/ive (usually embodied in a

[10] Although the cognitive process dimension is roughly hierarchical, as the original Taxonomy was, the revised Taxonomy's authors also acknowledge that some tasks associated with "simpler" processes may in fact be more complex than some tasks associated with processes higher in the taxonomy (Krathwohl, 2002, p. 215).

mission statement) just as a traditional classroom teacher has for his or her students. Even in an informal learning context, therefore, it is reasonable to speak of related objectives, tasks, and assessments, although each of those may look quite different from those found in traditional schools. Here, I am concerned with small stories as activities – what object/ives do they appropriately contribute to? I have also suggested that small stories may be useful for assessment – what object/ives can be assessed through learners' storytelling? With regard to the knowledge dimension of the Taxonomy, it seems readily apparent that a small story could carry any kind of knowledge: factual, procedural, metacognitive, or conceptual. In Chapter 4, we saw the first three of these contained in Excerpt 8 (turtle egg-laying), the anecdote about horseshoe crabs related in section 4.3.1, and Excerpt 5 (electrical circuits), respectively. There are a number of instances in the field recordings where conceptual knowledge (and its limit) is spontaneously demonstrated in a small story, too, as here in Excerpt 11.

Child:	Oooooh! Wind power! Oooh!	Exclaims
	[Sound of cranking]	Interacts
Child:	Wind power!	Exclaims
	[laughter, cranking] This is wind power.	Declares
Parent:	[inaudible]...really fast to make them go?	Questions
Child:	No, you don't have to do it fast at all. [Cranking] You just have to turn 'em. It's like a hand generator.	Declares
	[Cranking] We only have the big one!	Declares
Child:	Here actually, you're really turning a real generator. [Cranking] This is the strongest generator of them all.	Explains
	Watch.	Points
	[Cranking] This actually turns 'em on.	Declares
Child:	Hey Mom, these are real generators, they turn on LEDs!	Points
Parent:	Wow, lemme see. [Cranking]	Instructs
Child:	Look I got one on. [Cranking]	Points
Parent:	This one turns on different lights. [Cranking]	Declares
Child:	They're real generators. They turn on mini LEDs.	Declares
	[Cranking] I turned on all of them for once.	Narrates
	[Cranking] This is awesome.	Reacts
	Can you turn this one?	Instructs
	(Excerpt continues on next page)	

	(Excerpt continued from previous page)	
Child:	It turns on separate lights. They're hard. Plus when you spin it, because this one is the more powerful generator. And, it's hand powered. There's a generator, there are generators in here.	Explains
Parent:	I don't think that has a generator. I think that thing answers questions.	Corrects
Child:	[Cranking] I'll get the other one! Hurry up! Get it spinning!	Instructs

Excerpt 11: Conceptual knowledge at the wind power exhibit.

With respect to the cognitive process dimension (remember, understand, apply, analyze, evaluate, create), stories are one part of a learner's toolkit to access different modes of working with knowledge. We have seen clearly that stories can help learners to recognize and recall a variety of information. A story may also help a learner to understand information, as he or she compares an artifact to one seen previously, explains why an experiment is expected to come out one way or another based on prior experience, or interprets evidence to draw conclusions about his or her observations. For example, in Excerpt 12, two siblings compare evidence from a similar experiment they'd done previously with an experiment unfolding in the museum.

Educator:	We have a chemical reaction that we'll experiment with that uses these little tablets here, and they're called Alka Seltzer.	Declares
Child 1&2:	Oh, yeah.	Declares
Educator:	Yup, you've seen those before?	Questions
Child 2:	Yup.	Declares
Child 1:	Yeah, because we did like an experiment that we put a balloon on top of a um bottle, and then we put Alka Seltzer in it, and then it, and then the bubbles would make the balloon blow up.	Narrates
Educator:	Very neat,	Reacts
	I've done that with baking soda and vinegar, but I haven't done it with Alka Seltzer before, that's a neat…	Narrates
Child 1:	And it actually does work, and it works.	Narrates
Educator:	…a neat [unclear] experiment. Very neat.	Reacts
	(Excerpt continues on next 2 pages)	

	(Excerpt continued from previous page)	
Child 2:	Yeah I've done that one with Alka Seltzer too. And it may look like this 'cause I think it's the same one. It may be.	Narrates
Educator:	Maybe, we'll see. In…those experiments worked because inside the Alka Seltzer tablets there's two opposites. There is an opposite called an acid, and there's an opposite called a base. And when those two opposites come together they always have a big reaction. So you'll always notice some big changes happening.	Explains
Child 2:	Oooh.	Exclaims
Educator:	And, let's see. So, what sorts of changes did you see with the Alka Seltzer tablets in your experiments before, since you've both experimented with it before. What sort of things happened?	Elicits
Child 2:	Umm, well, it um, all the bubbles fizzed up and it blew the cap off.	Narrates
Educator:	Alright. So you had lots of bubbles.	Corroborates
Child 2:	Yeah.	Declares
Educator:	Um, so that tells us that a chemical reaction has happened, that those two opposites have mixed together, because there's bubbles! And bubble …mean a new state of matter, it means a gas. We're starting with a hard solid here, and breaking it up, but it's still solid. And I have some liquid, some water in here too. When that water meets that solid, it dissolves it, and makes those two opposites meet, and have a big reaction, and make those bubbles, those gas molecules come out. So, what I'm going to try to do with those bubbles is make it into fuel, let those bubbles be rocket fuel. And we'll see if we can turn this little film canister into a mini-rocket, and make it jump up a little bit. All those bubbles. So I've got a tablet in there, I'll put some liquid in there, some water, and put a cap on as fast as I can, flip it, and see if it'll jump. Some of the canisters work different than others, so if it doesn't jump very high the first time we can try a second time with a different one.	Explains
	Are you ready to see?	Questions
Child 2:	Yup. [silence]	Declares
Educator:	[popping sound]	Interacts
	Oops, popped in my hand before I could even let go. It may pop again, let's see. [loud pop]	Narrates
	(Excerpt continues on next page)	

	(Excerpt continued from previous 2 pages)	
Educator:	Whoa!	Exclaims
Child 2:	That's exactly what Amanda's experiment did, only it's flipped it over and popped the cap, the cap.	Narrates
Educator:	Yup, that's exactly what this did, and it even hit the ceiling,	Declares
	did you hear it hit the ceiling?	Elicits
Child 1&2:	Yeah.	Declares
Educator:	It was a pretty powerful rocket.	Declares
	That's what I was looking for, I was hoping we would get a good one. Yeah.	Narrates
	Do you see all the bubbles?	Elicits
Child 1&2:	Yeahhh.	Declares

Excerpt 12: Comparing prior and current experience

Similarly, stories can help learners to apply procedural knowledge to execute an operation, analyze factual knowledge by organizing and attributing, and even to plan new creations (as noted, stories are not limited to past experience, they can also be projections of future undertakings).

5.2.2 Design implications

If small stories can convey the various threads of the knowledge dimension[11], then they can also be used for the kind of informal, improvisatory assessment discussed in Chapter 4. Are these stories useful to anyone other than learner and educator? Are they useful to other learners, for example? Analysis of the museum recordings suggests that a visitor's pointing is effective at getting the attention of other visitors in the same group or family, and that it often is followed by sharing information unknown to the other members. This is true both for parents sharing information with children, but also for the opposite case. Thus a museum interaction that engages even one member of the family can take advantage of family stories to reach other members as well. It may be that Mom is more likely to read a sign, but Daughter insists on asking a staff member an awkward question ("isn't that cage too small for an owl?") that reveals a surprising

[11] For additional examples of the kinds of knowledge carried by stories in the museum, please refer to the extended set of excerpts in Appendix C.

answer ("it would be if she could fly, but she's lost a wing due to a car accident, and that's the only reason she lives here anyway.") Later, Dad's willingness to perform and be silly in public engages the entire family in an observation-based game, and Grandma studies the museum map to discover that there's a quiet corner with an experiment that they wouldn't have found otherwise. The implication is that a museum's willingness to engage visitors through a variety of media can be an effective knowledge-sharing strategy within the institution's physical boundaries; as will be discussed in section 5.4, there is no reason not to extend that variety to an institutions' virtual presence as well.

Yet stories may not be able to participate in all of the processes located in the cognitive domain of the revised Taxonomy. Although my recordings are limited, I saw no evidence of evaluative stories. Small stories may initiate a planning process (part of creating), but by their ephemeral and informal nature, they are not suited to more involved processes of generating and producing creative work. While stories provided opportunities for analytical thought, moving from simple comparison to more complex differentiation only took place in the recordings with educator facilitation. Small stories, ultimately, are small. They are powerful identifiers of individuals' self-perceptions, they are valuable carriers of metacognitive knowledge, and they are crucial indicators of the ways that affective states intersect and intervene in learning processes, and it is helpful for learning facilitators and exhibit designers to recognize them as such. Small stories can inspire learners to seek more deeply and to ask more widely, but they are not the end or the sum of participation in meaningful activity. Designers may use visitors' stories to generate interest and to encourage learners to continue engaging with the material, but in between must be other opportunities for engagement with the more complex cognitive processes (analyze, evaluate, create).

At the same time, designers – in which label I include educators who are planning lessons, improvising responses on the museum floor, and assessing the efficacy of educational strategy – might effectively capitalize on what small stories can do. Pressed for time (even in the informal environment of a museum), educators often feel the need to limit learners' stories in order to move on to other interactions: questions asked and answered, explanations conferred, demonstrations executed. These are all valuable activities, and each designer must evaluate his or her own priorities. Nevertheless,

designers can find ways to make space for learners' own voices. One colleague I interviewed said she always tried to make a point, if time did not seem to permit stories right then, of inviting them at a more appropriate time:

> If I see, with that story, if I see five more kids' hands instantly come up and I know that we're gonna lose where we're going, then I stop it. But I always try to make a point, if I'm out exploring with them later, to say, "if you had something that you wanted to tell me come and tell me when we're exploring and we can talk about it then." (Interview B, personal communication, 2011).

Either in person or with the help of technology, providing an opportunity for learners to speak from their own experience opens possibilities for learners to add to that experience in meaningful ways. Stories tap into the key affective facets of participation – motivation and identification – and thereby reinforce the reasons why people engage in meaning-making activity in the first place.

In summary, I suggest three design implications stemming from this research:

- Provide opportunities for storytelling in order to take advantage of learners' affective responses to artifacts and media and to reinforce their reasons for participating.
- Offer a variety of artifacts and media to engage learners, because individuals will share their preferred modes with each other, increasing participation through social engagement.
- Build on the ability of stories to initiate and maintain engagement by embedding storytelling opportunities alternately with activities that engage more complex cognitive processes.

5.3 Exhibits That Push or Pull

5.3.1 The need for new terminology

Design to support personal small stories is hampered by a lack of language to talk about how design does or does not support these informal stories and their associated substance: identity narratives, affective responses, and metacognitive reflection. For researchers who study children's use of technology and designers who are incorporating the participation of children into their research and design practices, the situation is often

complicated by discussing technology in technologically-mediated contexts. For example, asking a child to respond to a video of a robot will likely elicit a different response than asking a child to draw a picture of a robot with which he or she would like to play. In this section, I suggest that an initial step to more fully understanding those distinctions is an unambiguous and affect-neutral terminology for describing mediating artifacts, especially those making use of contemporary technologies.[12]

Existing terminology for describing the influence of a technology or medium on its activity context is insufficient for this purpose due to one of two features: the distinctions made are affectively charged, implying that one end of the terminological spectrum is somehow "better" than the other regardless of context; or, more subtly, the terminology available does not sufficiently describe the opportunities for learner interaction with the artifact. Falling into the first category, for example, are distinctions such as *passive* versus *active* media, or technologies of *consumption* versus *construction* (e.g. Cassell, 2004). These terms imply that some mediating artifacts require the user to actually do something to accomplish some goal, while other media is simply for a learner to sit in front of. Similarly, in education circles the terms *teacher-centered* and *student-centered* are used to describe the ways in which teachers either rely primarily on lectures or actively involve their students in some other learning task. The underlying value judgment, at least in much current conversation, is that a good teacher will strive to offer activities that have students physically doing something as much as possible.

The implication that visible activity is always better is misleading and not appropriate to all contexts. A television documentary or a lecture, while not requiring an observer to physically move or create in any way, can inspire critical thought and reflection – the metacognition that is such an important part of increasing one's participation. Reflection is as essential a part of the development process as is analysis and application of information. "Like designers, students...must be able to make explicit their reasoning and tradeoffs, to justify the decisions they have made in the course of their project" (Loh et. al, 1998, p. 627). In other words, so-called "passive" media or "consumption" technologies can, in the right contexts, promote rich cognitive and meta-

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[12] The ideas presented in this section are a continuation of ideas first presented at the 2008 ACM Conference on Interaction Design and Children (see Nelson & Freier, 2008).

cognitive activity and student-constructed knowledge despite no visible physical activity. Some designers of multimedia instructional tools stress this, noting that hands-on activity and social collaboration need not be the only hallmarks of constructivist learning (Mayer & Moreno, 2002). Others offer specific strategies for designing technology to support reflection (Lin, Hmelo, Kinzer, & Secules, 1999). Alternative terms are therefore needed to describe children's technologies so that the connotations of the terms do not detract from the description of a technology's learning affordances.

Not all existing terminology suffers from affective connotations. Marshall McLuhan, for instance, introduced a distinction between *hot* and *cold* media. "A hot medium is one that extends one single sense in...the state of being well filled with data" (1964, pp. 24-25). He then notes that hot media are low in participation, while cool media are high in audience participation or completion. While this scale is appropriate for describing the information-richness of a medium, as in the first part of McLuhan's definition, it does not adequately articulate the possibilities for audience participation and creativity. In other words, a hot medium might encourage audiences to contribute to meaning-making even when they do not contribute to content. McLuhan suggests that a photograph is hot because it is well filled with visual data. Data alone, however, is not enough to construct meaning. In order for the photograph to communicate meaning, the audience must also bring its knowledge of context, its skills of visual interpretation, and its intentions.

5.3.2 Proposed terminology

Learning the skills, knowledge, and intentionality to interpret and act upon the world around us is a social process, as has been noted by both educational theorists and technology designers. As Clifford Nass and colleagues have studied, people respond to even minimal technological personification (i.e. a voice) with the same social rules as they apply to human actors (Nass, Moon, Morkes, Kim, & Fogg, 1997). In the case of technologically mediated instruction, or instruction mediated by an exhibit rather than another person, the technology takes on the role of the more capable party with respect to Vygotsky's zone of proximal development (see section 2.2.1). This transference of instructional agency from the designer(s) to the technology itself implies that we need to

understand more than just techniques for imparting information and skills to learners. We also need strategies and vocabulary for describing how a particular design is positioned with respect to the entire spectrum of developmental activities, from knowledge recall and metacognitive reflection to creative synthesis and invention. While Bloom's Taxonomy of developmental activities categorizes and outlines cognitive processes (discussed in section 5.2), even the revised and updated taxonomy does not describe how mediating artifacts stimulate or hinder those processes.

For this purpose, a semantic continuum is suggested in order to describe the ways in which designed artifacts inspire invention, reflection, or some combination of the two. Design that operates in an inventive mode tends to "pull" on the user, encouraging user-generated content. Design operating in a reflective mode, by contrast, "pushes" content toward the user, stimulating the user to generate meaning through a process of analysis and deliberation. This terminology is affect-neutral, allowing designers to use it to plan, execute, describe, and reflect on their own projects without misleading assumptions. Additionally, it is accessible to users, particularly children, and will be helpful for researchers and designers who inquire into user's relationships with various technologies.

It should be noted that these terms do not replace McLuhan's hot-cold scale. Rather, they are orthogonal to it, as shown in Figure 13 below. Use of a medium in a particular context might be hot and reflective, as with a downloaded photograph, video, or recording. That same medium takes on a different context and position on the scale when it is modified, rearranged, or otherwise incorporated into a user's own invention. The use of journals in Loh, et al. changed from inventive to reflective and back again at different times as children's ideas were incorporated into the design process (1998). A lava lamp seems to be the epitome of passive technology, affording little more than a gaze. In the context of a physics classroom, however, it could be highly reflective, inspiring discussion and cognitive growth.

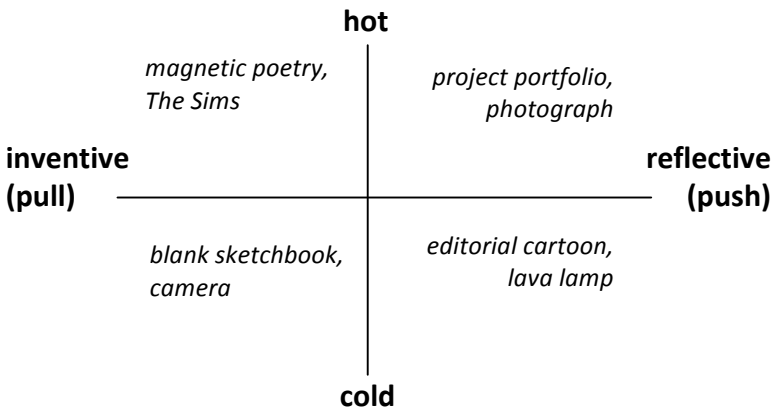

Figure 13: Examples of artifacts as organized by both McLuhan's hot/cold scale and the push/pull scale.

The stimulus for this terminology was a conversation, not about teaching children, but about learning from children. Children's understanding of abstract concepts like energy or electric current is often based on concrete images, objects, and people. Helping them to articulate these ideas, therefore, often requires offering them a variety of media with which to express themselves. The child's choice of medium, however, whether new technology or old, influences his or her response. The availability of vocabulary to describe whether the medium is more reflective or more inventive is helpful for designers as we consider how best to involve children in designing for increased participation in scientifically literate conversations.

5.4 Design Proposal

5.4.1 The cloud museum

The fieldwork reported in Chapter 4, the implications discussed in the preceding sections of this chapter, and the careful thought of numerous contemporary museum practitioners all suggest that a key component of facilitating learners' increased science participation is to reach them in their everyday, ongoing activity. A single visit to a science museum may be entertaining, informative, or even inspiring, but it has not truly succeeded unless it provides a route to continuing increased participation. To that end, many museums hope to capture repeat visitors, sell memberships, and experiment with programming formats that reward serial visits.

Contemporary technology offers a platform from which to do even more. Of course, social networking tools like Twitter and Facebook are already used to remind museum audiences of upcoming events, let them know about special deals, and communicate institutional culture. However, some museums are beginning to explore possibilities to do more to facilitate participation than simply encouraging visitors to come to the physical museum space. Storytelling Kiosks implemented by Brad Larson encourage museum visitors to reflect on their experiences as part of visits to particular exhibits (Larson, 2010). Jasper Visser of the Museum of National History of the Netherlands writes about using the Foursquare model of points and badges to reward visitors for participating in specific activities, whether in-person or digitally (2011). The North Carolina Museum of Life and Science offers a Twitter/Flickr game called "Name that Zoom," where participants try to guess the source of an image that has been magnified two hundred times by the museum's dermascope (Tench, 2011). An annual invitation from the Fairbanks Museum and Planetarium in Vermont asks readers of its "Eye on the Sky" weather and astronomy blog to contribute their observations of the transition from winter to spring, eliciting responses like, "pussy willows in the swamp," "red-winged blackbird sitting on a fence post this morning," and "the dirt over our septic tank is exposed" (Breen, 2011). These simple observations, provided along with the locations of the observations, serve as the beginnings of a community-generated phenology database useful to climate and environment scientists. Building on an existing virtual community, other museums are exploring ways to both contribute to and benefit from Wikipedia: by contributing well-researched articles about material in their physical exhibit halls (Bernstein, 2010); or by including Wikipedia citation codes in their digital collection database for easy addition of collection information to wiki pages (Chan, 2011). Gurian suggests that to become truly "essential" institutions, museums should provide extended access to information alongside the physical objects of interest:

> I am proposing coupling the power of the object's physical presence with the speed of the Internet and am suggesting that the result would encourage the visitor to find out more than just the information the museum has about a subject of interest. I am eager that the proprietary information held within individual museums be combined with related information from other sources for the public to use. It is the availability of linked (and often unexpected) information connected to the physical

> objects and made readily available on the spot through an electronic search engine that would make the museum fully interesting to the visitor. (2006, p. 12)

Museums are also are experimenting with ways to reward increasing participation, including tiered memberships, crowd curatorship, and special "invite only" events. All of these practices provide alternative routes of entry for engagement with a museum, and also offer pathways for continued dialogue between a museum and its audience (which may even include people who never set foot in the exhibit halls).

Together, thoughtful and well-planned use of these strategies could comprise an evolving informal science learning institution that is responsive to audience needs and also guides visitors to successful scientific civil discourse. I propose the metaphor *cloud museum* as an appropriate way to describe a museum-based community comprised of both physical and virtual participation. Clouds are part of weather everywhere affecting all people, and observing their presence and formation is an activity that requires only a quick tilt of the head – but can be enjoyed for the entirety of a lazy afternoon as well. Furthermore, "cloud computing" has come to describe the act of accessing information from a distributed network of servers and storage units, with shared resources, software, and data provided to end users on-demand rather than stored on local, personal devices. Some example services or interaction mechanisms that a cloud museum for science might apply are listed in Table 4 (for parents) and Table 5 (for children). Of course, there's no reason why the strategies in each table couldn't be modified for use by other museum visitor segments – or by other kinds of museums – depending on the needs and audience of any particular museum. The parent list presented here, for instance, targets parents *as parents* rather than as a primary audience, but a museum could also institute variations of the strategies in the "for children" table and extend invitations to participate to adults. Similarly, these suggestions are based on a science-museum model, but they could easily be adapted by art museums, history museums, and other informal education communities. Finally, no single cloud museum needs to apply all of these. The idea of being a "cloud museum" is that visitors engage with museum content and the museum community even when they are not physically at the building that houses museum exhibits and artifacts. (In fact, perhaps a museum doesn't need to have a physical

building at all, although the strength of the affective responses visitors have to physical artifacts suggests that a non-virtual home is an advantage.)

a	Leave a comment on a message forum at the museum website (or Facebook page) about "how my family brought science home with us from the museum." The first comment from each family earns an e-mailed coupon for a reduced admission fee.
b	Review an exhibit-related book and post it to the museum website, get a coupon for use at the museum's gift shop.
c	Bring a child to five workshops at the museum during the course of a year, and have your membership extended by a month for free.
d	Bring a first-time visitor to the museum, get 10% off your membership renewal.
e	Take your family out to hike the trail at the museum and post a photo of something you saw to the museum's website to enter it into a museum-sponsored contest. Winner earns a science activity kit for doing experiments at home.
f	Tweet a question about a local natural phenomenon, get a reply from a museum staffer that has an answer or directs readers to a reliable source.

Table 4: Opportunities for parent participation at a cloud museum

Children can earn badges by participating in cloud museum activities. Badges could be displayed on an anonymous but customizable profile in a special section of the museum website. Badge-earning is a reward in itself, but could lead to layered rewards like additional customization options, special privileges while at the museum, or an invitation to an "insiders' club" party at the museum.	
a	Volunteer to give a new (peer) visitor a tour of the museum to earn a "tour guide" badge for your service. Give three tours, and earn the right to wear an "official museum tour guide" vest when you come to the museum.
b	Tell a story (reviewed by a moderator) about an experience you had at the museum on the gallery page matching that artifact on the museum website. Each story earns points toward a "storyteller's" badge.
c	Play a content-related game; earn "knowledge leader" or "skill champ" badges.
d	Post a data log of something you observe around your house, school, or neighborhood. For example, how many birds visited your feeder during April, or on what day did you first observe a seed sprouting in the garden? Earn a "data head" badge for meeting a certain number of data points. Earn a "publishing" badge by turning your observations into a science fair project.
e	Watch an animal-monitoring video (eagle chicks, bears fishing, etc) at least 5 times in 5 weeks to earn an "animal watcher" badge.
f	Draw a picture of something you saw at the museum and post it to the website's (moderated) gallery to earn a "science illustrator" badge.

Table 5: Opportunities for child participation at a cloud museum

5.4.2 Design personas and scenarios

The development of fictional design personas is a reliable strategy used by interaction designers to ensure that the designer has an audience other than him- or herself in mind (Grudin & Pruitt, 2002; Pruitt & Adlin, 2006). Those personas can then be used to imagine scenarios of actual interactions with the design (Benyon, Turner, & Turner, 2005). Scenario-building can be used to assess, at early stages of a design project, whether or not the proposed interactions will be appropriate to the intended audience. Scenarios serve the further purpose of communicating to design stakeholders how potential target users might approach an end product. In the following pages, I'll use the design strategy of fictional personas to describe, via an imagined design scenario, how community participants might interact with a cloud museum, and the commensurate rewards – including learning – that they might gain from their interactions.

Scenario 1:

Josiah Peterson is 9 years old. He first visited the museum with his fourth grade class. Josiah enjoyed the educator-led program about animal adaptations, but the fish in the aquariums that represented different local habitats especially fascinated him. His grandparents took him fishing once a few years ago, and he was interested at the museum to see what catfish and trout looked like when they were swimming around underwater. The day after the museum trip, Josiah's teacher asked the class to log on to the museum's website from the school computer lab. The teacher instructed the students to create anonymous profiles on the site (or to log in if they already had a profile). The teacher said they could go back later during free-choice time, if they wanted to add colors and other designs to their basic profiles. Right now, the teacher wanted them to write a short message about something they'd seen at the museum, next to its picture in the website gallery. Josiah clicked through a few pictures of a water wheel, the planetarium, and a solar panel, and then paused to look over at his friend Toby's screen and laugh at how Toby was reenacting the performance he'd given yesterday at the puppet theater. Toby decided to write his memo at the photo of the puppets, and Josiah looked through a few more photos of lightning, constellations, and an iguana before he clicked onto a photo of the brook trout he'd seen at the museum. There were a couple of

comments from other people already written beneath the photo. One read, "I got to help feed the trout when I was at the museum! It was so cool to see them swim right for the little bits after I put them in." The other comment said, "I think it could be neat to have gills and swim under the water, but they look gross to me." Josiah clicked into the text box that was there, and started to write, "These fish are kinda like the ones I coght [sic] with my grandpa once when we went fishing Id like to go fishing again someday." Before he clicked "submit," the teacher came by and helped Josiah to correct his spelling and punctuation errors. Then he clicked the button, and was surprised to see a window pop-up with a message in it. "You've earned a point towards your first badge! Make two more comments on other pictures in our gallery, and you'll earn a New Explorer badge to decorate your profile with!" The New Explorer badge was a cartoon picture of a little goat climbing a mountain, and Josiah thought it would be pretty easy to do two more comments – he was already planning to go back and write about how funny Toby's show was at the puppet theater picture. Just then the teacher called for the class to return to the regular classroom for the next activity. By the time free-choice time rolled around that afternoon, Josiah had forgotten all about the website; he was too busy building a bridge out of Legos with Toby and their other friend Mitchell. He didn't remember until it was time to go home, when the teacher handed out some free passes that the museum had given the children so that they could visit again sometime with their parents.

When Josiah got home, he left the free museum pass with his backpack on the dining room table, and went into his older brother's room to play video games with his 15 year old brother Paul. Paul and Josiah played their current favorite first-person shooter game until they heard their mom, Aline, come in the front door a little after five o'clock. She called for Paul to help her with dinner in the kitchen, and when she saw Josiah in the doorway behind him, she asked him to clear and set the table. Moving his backpack, Josiah saw the free pass from the museum and ran to give it to Aline. "Hey, Mom, we got these free tickets from the museum yesterday!" Taking the free pass from her son, Aline tried to remember what museum Josiah had gone to yesterday. "Where is this, what museum?" "The *science* museum, Mom! They had fish and lizards and snakes and computers and a waterwheel…we should go sometime!" "Okay, maybe," Aline responded tiredly, and stuck the pass in her pocket. Later that evening when she

was getting ready to crawl into bed, Aline found the pass again and looked at it more closely. "I guess he had a good time," she thought, "maybe I can get my parents to take him some weekend."

Scenario 2:

Grace Truex, now 7, has been going to the museum with her family for as long as she can remember. She and little brother Brody, who is 5, are homeschooled by their parents. They usually study math and language arts in the morning with their mother, but she heads off to her job at the nearby greenhouse and plant nursery after lunch. Their dad, Sam, gets home from his part-time job just before she leaves, and they spend afternoons doing whatever he's in the mood for that day. Sam Truex loves taking his kids to the museum. He's always enjoyed being outside and observing the natural world, but he doesn't always feel like he knows how to explain things to his kids. He appreciates being able to ask questions of the educators at the museum, and he encourages his kids to spend time exploring the exhibits there. Because admission is included in the membership fee, the family has been members at the museum for the last couple of years. They're considering signing Grace up for one of the summer camps this year, since they know she loves spending time with other kids her own age and not just with Brody.

One of the things Grace always does when she visits the museum is to show Brody her favorite exhibits. Her current favorites are a baby ball python and the new color-mixing station they have, where she can play with different colors of light to see how they mix together. Today when the family arrives at the museum, after Sam is done checking the family in at the front desk, Grace races off to check on the python. A museum volunteer is nearby, cleaning some of the other animal's homes, and she greets Grace with a smile – they recognize each other from other visits. "How long is he now?" Grace asks, "He looks bigger. 'Cuz last time I was here, he could fit under that log, but now he's pushing out!" "I think he is bigger," responds the volunteer, "hang on a minute and I'll take him out so we can look." When she sees the python up close, Grace is sure he has grown, but the wriggling snake won't stretch out for a proper measurement. She expresses her frustration to the volunteer, who responds, "you know,

if you want to see how fast baby animals grow, there's a new camera up on a nesting pair of red-tailed hawks that live just across the river from here. I think they put it up on the museum website, if you want to check it out." Not needing much encouragement, Grace hurries over to the museum kiosk that displays the interactive website. She quickly finds the link to the webcam – it's one of the news items on the front page – and spends a few moments gazing at the bluish-white eggs peeping out from beneath one of the adult hawks. She calls to her brother to come see, and her father peers over their shoulders. "Oh neat, Gracie. Why don't you add that link to your own museum profile, so you can find it again easily?" Grace immediately finds the login page and enters her information, and the purple and green page that appears reflects her lively personality. She's already earned a couple of badges from the museum: she has a storyteller's badge and an illustrator's badge, and she's pretty sure that she's getting close to earning the "spot the invasive species" skill badge. When she adds the link to the hawk nest webcam to the page, she sees a pop-up message that tells her she can get an animal watcher's badge if she checks in at least four more times over the next five weeks. She points this out to her dad, who makes a mental note to help her remember to do that, although Grace isn't the kind of kid who needs a lot of reminders. Grace then rushes off to visit her other favorite spots in the museum, leaving Sam to log out of her profile for her (though he knows the page will time-out automatically in just a few minutes if there is no activity).

While his kids are busy at a nearby exhibit, Sam browses the books in the museum's gift shop. He's looking for a book that will help them learn about animal tracks, figuring that the spring's melting snow will leave a lot of mud under the trees at the park near their home, and that there might be some prints to examine. With the help of some tags on the shelves that read "Member Favorite" and offer a one-line synopsis, he finds something that looks about right. There are a couple of thick field guides, but one book is laid out so that Grace, at least, could easily match a picture and a name without help. As he's paying, the cashier reminds him that if he reviews the book for the website, he'll earn a coupon for his next purchase. After checking to see that Grace and Brody are still happily busy with a magnifying table, Sam heads back to the kiosk, where he quickly adds the book to his own profile page so that he remembers to review it later.

Finishing up, Sam finds Brody tugging on his sleeve, asking for pennies for the gravity well. As they're walking over, Sam asks Brody if he remembers why it's called the gravity well. "Ummmm, cuz…cuz gravity pulls things down?" Brody guesses. "Right, but why don't the pennies fall straight into the hole?" Sam asks. "I don't know," Brody admits. Grace, catching up with her family, chimes in "because they're moving sideways so fast!" and gets a nod of approval from her father. Her enthusiasm catches the attention of another girl visiting with her mother. "What's moving so fast?" she asks Grace. "The pennies in the gravity well, watch!" is the response from Grace, but it's Brody who gets to demonstrate first the way the pennies roll around on their edges as they spiral down into the well. The three children are occupied for several minutes with a whole roll of pennies, while their parents chat about how their kids love this place. When it's time for the Truex family to head home, Grace protests that she hasn't had time to visit everything yet, but she stops when Sam reminds her that they can come back next week for the kitchen chemistry workshop. In the meantime, she can keep working on her virtual badges and check out the new book Sam bought. "And check on the hawk babies!" Grace reminds her father. "And definitely check on the hawks," he agrees.

5.4.3 Design outcomes and evaluation

A cloud museum is not, strictly speaking, a design for an interactive exhibit, or website, or other media, although it includes all of these things. Rather, it is a museum design and innovation philosophy building on the conceptual framework outlined in Chapter 2, the results articulated in Chapter 4, and the design implications noted in section 5.2.2: that effective learning is equivalent to increased meaningful participation in ongoing activity; that personal storytelling is a powerful tool for leveraging identity, affect, and metacognition in the service of increased participation; and that ensuring that participation is meaningful requires facilitating a learner's transition from personal storytelling to more complex cognitive processes. These outcomes are embedded in the web of relationships described by Engeström's triangle model of activity (Figure 2), dynamic relationships that change through time and place. A cloud museum strives to recognize and account for those interrelationships between individuals, artifacts,

communities, and object/ives. By emphasizing physical place, a cloud museum acknowledges the primacy of physical artifacts in inspiring strong affect and identification. By providing pathways for virtual participation, a cloud museum responds to the ways contemporary learners build and maintain relationships with each other and with information.

A cloud museum is both a goal and a means toward that goal. The goal is a network of learners at different stages, communicating with each other about and around artifacts of interest, through and with a variety of media both physical and virtual. The network need not exist all at once – indeed, it would probably be counterproductive to institute too many kinds of connectivity at one time. Like the community in which it is embedded, the cloud museum can grow, change, pare back, and grow again in response to its constituents' needs. Its measure of success is its measure of participation: at some times that may mean a lot of people participating shallowly, at others it may mean a few people deeply committed to using the spaces that the cloud museum provides. This is not to say that the design cannot fail. The design fails if it is unused. It fails if it does not connect participants to *meaningful* activity, or if participants do not trust that participation will be personally valuable. These criteria apply not just to a museum's intended audience, it should be noted. They apply also to internal participants, to staff and volunteers whose assigned tasks are the maintenance and development of cloud museum activities. These participants, too, must believe in the value of their contributions.

Because of its distributed design, however, a cloud museum may be more successful with some aspects than with others. Some parts of the cloud might be "sticky," with many regular visitors or users. Other parts might be fleeting, with very little activity most of the time but occasional "cloudbursts" of greater participation. For instance, the museums Twitter feed might reflect only an occasional staff post about something of interest, until a remarkable local weather event inspires parents to seek explanations, or until several community members report in the span of a few days that they've seen a bald eagle soaring in the area. These trends are reflected in physical museum visitation as well: Saturday mornings might be always steadily busy, but Mondays are only busy during school holidays, or when the museum has a special event going on. The

distributed nature of a cloud museum makes it more robust, and it also makes measuring its effectiveness more difficult. To gauge the success of the cloud museum, one might have to return to our starting place, and listen to the visitors. If they're captivated by the cloud museum, they will point it out to their friends and family, they will return again and again, and they will tell each other stories about their experiences there.

6. Conclusion

6.1 Contributions to Knowledge

This dissertation examined the ways children use language to construct scientific knowledge in informal science learning environments, with particular attention to small stories. By facilitating and building upon language interactions that are already in use by learners in these contexts, and by adding to our understanding of the relationships, operations, and contexts where effective learning takes place, this research contributes to ongoing efforts to improve experience design and science education. Without doubt, public understanding of science needs improvement: scientifically literate citizens can make decisions based on evidence rather than instinct, using critical analytical thought to supplement reasoning based on social and moral values. Many public voices are pushing for stronger science education in schools, and while improved schooling is certainly a valuable goal, most science is learned outside of school. Public science understanding could therefore benefit greatly from increased investment in alternative and informal venues for increased participation in science by the general public. Leading education researchers have suggested that it is time to consider the question of effective informal science learning more holistically, building on our understanding of isolated factors to develop an overall portrait of informal learning experiences.

In the preceding chapters, I developed a theoretical orientation and empirical methodology to respond to these current research needs. By approaching the study of science museum learning from an activity-theoretical perspective, this work accounts for the interrelated activity of individual subjects (including their affective needs and goals), material contexts, and social contexts. Activity unfolds dynamically in the communicative relationships between an individual and his or her environment; development is the result of participating in human activities, while learning is defined as the process of increasing or changing one's participation in an activity. Theoretical contributions from literary and design studies augment our understanding of what participation entails, of what learners are doing when they build meaning from the texts, artifacts, and environments that they operate within (and contribute to).

A learner's operations and contributions to his or her environment comprise a dialectical relationship, one that necessarily extends through time. Although this was not a longitudinal study per se, recognizing subject's relationships with their own memories implicitly accounts for the dynamic construction of knowledge and skill. A full understanding of small stories, however, admits that stories are not only about past events and experiences, but are also ways of working through present experience and of planning for future activity. Indeed, developing the skill to "talk the talk" is a key operation in increasing participation in any knowledge domain. The empirical observations I conducted were attentive to the processes of learning by considering verbal interaction to constitute primary activity: the way learners' conversations represent past, present, and future actions; and the social and material contexts of those conversations.

These actions and contexts were teased apart via qualitative coding of conversations, parallel input from a variety of stakeholders, and visual analysis of learners' activity patterns to begin to answer the questions posed in the first chapter of this dissertation. I asked how children use narrative language and experiences in informal science learning environments. How do stories contribute to science learning, and are stories a good way to communicate prior knowledge? Do learning facilitators use children's stories to support learning? My observations suggest three answers. First, stories are an opportunity for learners to communicate their self-perceptions of the legitimacy of their own participation in an activity – stories mark identity. Museum educators tend to recognize that this is important for visitors, strive to acknowledge visitors' identity-related stories, and struggle to make place for them when there are time constraints. Second, stories contain metacognitive knowledge, and their telling can provide an important moment of reflection about prior and new knowledge, a resting place where development comes to momentary equilibrium. My observations suggest that parents and educators capitalize on this use of stories to encourage their children to reflect on things they've seen in the museum and compare them to prior experience or to make future plans. Finally, stories can indicate to other participants the ways that affective states are influencing learning processes. Telling stories that indicate their own emotional responses to a situation seems to be helpful to the learners themselves as they

make sense of those reactions. However, other visitors' affective states can also negatively impact a learning opportunity; educators who recognize this quickly may have opportunities to mitigate a domino effect.

Recognizing that participatory outcomes are the motivation for improving learning processes, I also asked how exhibit and artifact design could support increased participation. What is the narrative role of artifacts in informal science learning environments, and what design implications stem from children's uses of narrative? Is design that supports narrative interaction in conflict with design for other kinds of learning interactions? Artifacts are central to the experiences of museum visitors. Indeed, a museum without artifacts would be difficult to recognize as a museum. Not all artifacts are equally likely to generate stories, however, as some exhibits and artifacts encourage performance or play instead. Nevertheless, all responses to artifacts fundamentally constitute the ways that visitors structure their participation in museum activity. Artifacts prompt strong affective reactions, and they also elicit interpersonal experience, serving as focal points for two or more visitors to construct stories together. These stories are one way for learners to access different kinds of knowledge, and to apply, analyze, or make plans based on that knowledge. They can be used for informal, improvisatory assessment, and they can be an appropriate means to share knowledge with other learners.

Stories engage the key affective pathways of motivation and identification, underscoring the reasons why people participate in an activity in the first place. An analysis of the kinds of thinking engaged during storytelling suggests that in all cases the key is to use that initial reaction as a jumping-off point for persuading learners to participate in more complex kinds of thinking. This research suggested three consequent design implications, detailed in Chapter 5: provide opportunities for storytelling, relate storytelling opportunities to a diverse collection of artifacts and media, and embed storytelling opportunities in larger activities that engage more complex cognitive processes.

The results and implications of my observations suggest that in order to increase public science appreciation and participation, it is important to engage them during their ordinary, everyday activity. Contemporary communication technologies offer a variety

of exciting ways to do this. Doubtless as technology continues to evolve, so will the creative and thoughtful ways that education practitioners use it to reach wider and more committed audiences. I have suggested that well considered outreach strategies using these technologies could comprise a dynamic and responsive informal education institution: a cloud museum. A cloud museum is not an exhibit, physical or virtual, and it is not a communication medium. Rather, it takes advantage of social connections and stimulating artifacts to produce an innovative and responsive arena in which authentic participation can take place.

6.2 Limitations and Future Research

In a report chronicling the changing role of the museum educator, Lisa C. Roberts observes that the task of informal education is no longer about interpreting exhibits for visitors; it is instead about negotiating between interpretations. Recognizing that visitors arrive with their own values, knowledge, and motives, museum educators are now in a position where, instead of solely communicating an institutional interpretation of exhibits, they instead mediate the intersections between museum narratives and visitor narratives (1997). Although this is perhaps less true for science museum staff than it is for educators in art and history museums, it is still true that educators today are more in the business of responding to visitors' preconceptions and prior experiences than ever before. I believe that understanding how visitors' stories contribute to their learning in museums is an important part of this undertaking.

With the research presented here I have tried to add to this understanding, but inevitably the results raise more questions than I began with. For example, the stories I recorded in the museum are only a glimpse of the kinds of small stories that learners exchange daily with their families, classmates, teachers, and others in their webs of social relationships. How do stories participate in reinforcing or countering prevailing power structures, especially between siblings? What kinds of stories do visitor groups tell each other about their museum experiences after they have left the museum? For how long does a museum experience stay an active topic of conversation after visitors have left the museum, if at all? Are stories implicated in long-term memories of museums? Do previous visits inspire repeat visits for particular reasons, e.g. to revisit a

particular exhibit, or is it the overall "feeling" of a museum visit that encourages repeat visits? How do visitors repurpose museum artifacts or interpret them in non-canonical ways, and what is the role of the museum educator when a story indicates that a visitor is approaching an exhibit with an alternative framework for interpretation? My research also only begins to touch on the non-verbal communication practices of museum visitors. What kinds of signals do visiting groups give each other about how interested they are in an exhibit, how long they'd like to spend with one exhibit or artifact before moving on, or if they find an exhibit or artifact distasteful to the point of avoidance?

The research presented here is not only limited in scope, it is also limited in scale. Although the data I gathered is rich in meaning, it included only a small sample of the museum's visitors. The sample may not statistically reflect the museum's visitor demographic in terms of membership, ethnicity, age, socioeconomic status, religious affiliation, or any other factor. Furthermore, only one museum was observed. Although my familiarity with this museum enabled me to better understand the exhibit contexts of the audio recordings, that same familiarity may also have led me to overlook aspects of the recordings that a more distanced observer would note. Similarly, limited resources meant that I was the sole coder of the recorded conversations. To crosscheck consistency and validity, research associates should also code future recordings. Finally, observing additional museum spaces or non-museum (aquarium, zoo, park…) institutions would almost certainly result in additional insights leading to more appropriate and effective design.

Despite these shortcomings, the research presented here sheds light on interactions that are, too often, overlooked. Many voices are increasingly urging educators, policy-makers, and interested learners to pay attention to the places outside of the classroom where authentic participation takes place. This research has created new knowledge about how even ephemeral conversations, casual encounters with artifacts, and ordinary small stories contribute to increasing that participation in meaningful ways. The findings presented here have theoretical significance for the ways researchers approach museum fieldwork. They also have practical significance for educators' interaction strategies, designers' efforts to integrate a variety of media into science-focused environments, and learners' own means of accessing interesting activity. Further

research based upon these findings will generate increased awareness and better understanding of the many interrelated factors that contribute to effective science learning in classrooms, museums, and daily life.

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APPENDIX A – Definitions of Coding Categories

The following is a list of speech categories observed in the conversations of the recorded children, parents, siblings, and staff.

Corrects The speaker negates or corrects a statement made by another speaker.

Corroborates The speaker verifies, corroborates, or otherwise agrees with a statement made by another speaker without adding any new information.

Declares The speaker spontaneously states facts or observations (even if incorrect); distinct from personal knowledge. Also indicates the answer to a question.

Elicits The speaker asks a question in an attempt to test, or elicit knowledge from another person; the knowledge is already known to the speaker.

Exclaims A general exclamation; statements of wonder, awe, fear, or other emotions, distinct from calls for attention or statements of content knowledge.

Explains A declarative statement made to impart new, objective content knowledge. Note that answers to questions are usually categorized as "declares" unless they include significant new information about how, why, where, or when something occurs (and is related to science content knowledge).

Instructs Task instruction; a directive statement.

Interacts Interaction speech with an animal, computer, etc.; the speech is directed to the artifact. Also includes sounds that indicate the effects of an interaction (e.g. a popping noise during an experiment).

Narrates A small story (includes personal knowledge as opposed to objective content knowledge, but may serve to illuminate or explain by way of analogy.) May also include projected future actions or intentions.

Negotiates Conversation not relevant to topical knowledge (whose turn, how to, esp. between children)

Performs Imitative or scripted speech, such as making an animal noise or filling an imagined role (e.g. weather

Plays Sounds associated with physical play, such as audible breathing, grunting, laughter, etc.

Points The speaker seeks shared attention, as in "look over there!" or "come here." Note that on some occasions “come here” is an instruction rather than attention-seeking, depending on context.

Questions A question seeking new information; the speaker does not already know the answer.

Reacts Personal reaction of the speaker to an artifact, for example, "that's weird," "I don't like it," etc. Distinct from statements of factual knowledge, or from exclamations without any explicit statement of affect.

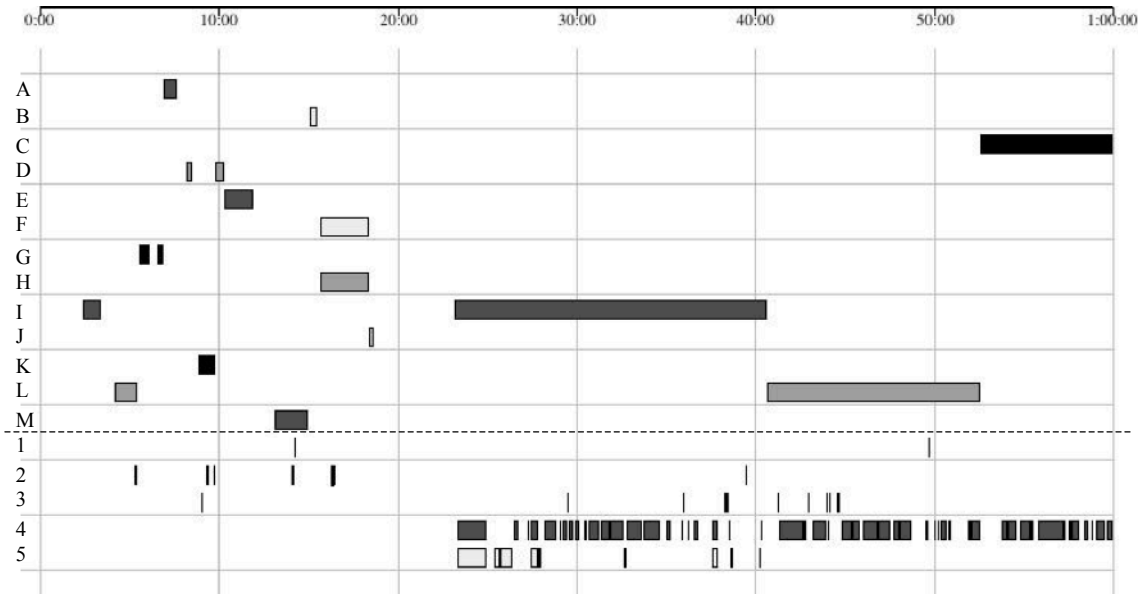
Reads The speaker reads museum signage.

Recites Singing or reciting from memory, including repeating instructions.

APPENDIX B – Graphs of Exhibit Visit Duration

Two examples of graphs resulting from plotting exhibit visit duration versus time. Selected speech utterance categories are plotted on the same axis to aid analysis.

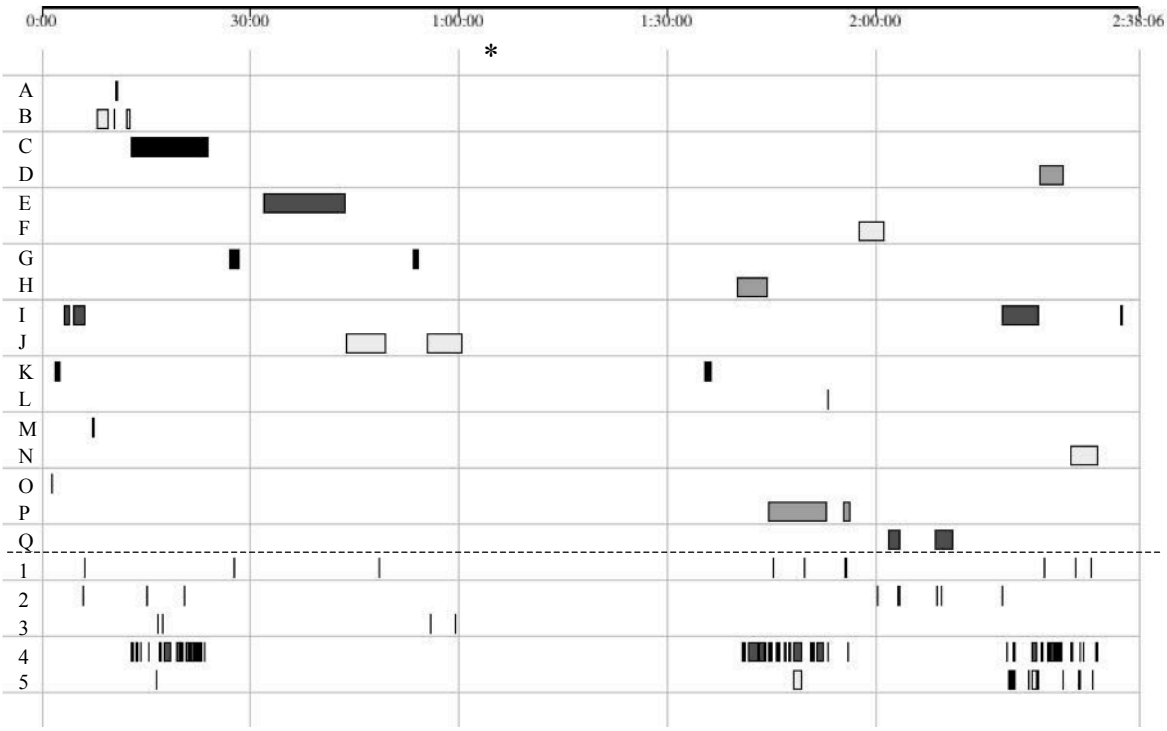
Example 1:



VISITED EXHIBITS
A: Beaver Lodge
B: Butterfly House & Specimens
C: Madagascar Hissing Cockroaches
D: Frogs or Toads
E: Gravity Well
F: Lizards
G: Owls
H: Scorpions
I: Snakes
J: Tarantulas
K: Tide Pools
L: Turtles
M: Wind Turbines

SELECTED SPEECH CATEGORIES
1: Child Narrates
2: Parent Narrates
3: Sibling Narrates
4: Staff Explains
5: Staff Narrates

Example 2:



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*The large blank segment beginning at 1:00:00 is due to the family's visit to the planetarium theater.

SELECTED SPEECH CATEGORIES
1: Child Narrates
2: Parent Narrates
3: Sibling Narrates
4: Staff Explains
5: Staff Narrates

APPENDIX C – Additional Excerpts from Museum Recordings

For additional illustration, included here are five excerpts each from recorded interactions with three of the exhibits/artifacts (a corn snake, an iguana, a hallway with unusual mirrors) that were visited by the most families. This extended set of excerpts was intentionally chosen from the large original dataset to include examples of multiple families' interactions with the same exhibits in order to show the wide range of responses that visitors had to exhibits, and also the similarities apparent even between unrelated visitor groups on different days.

Excerpts are divided by utterance, with the rightmost column showing the keyword (speech category) applied to each utterance. When recorded speech was unclear due to crosstalk or other background noise, a best guess at the speech category was made. These guesses are indicated with a question mark next to the keyword.

Corn Snake:

Child 1:	Ohhhh, Mom, look at this. Mom, c'mere, look at this snake.	Points
Child 2:	Aughh.	Exclaims
	Is it...dead or alive?	Questions
Child 1:	It's alive!	Declares
Parent 1:	Oh, it's alive.	Corroborates
Child 1:	Why would they put water in there?	Questions
Parent 1:	That's a big one.	Declares
Child 2:	Whoa.	Exclaims
Parent 1:	It's a corn snake.	Declares
Child 1:	Aren't they the poisonous kind or whatever?	Questions
Parent 2:	Predator and prey relationship.	Reads
Child 1:	He's just sittin' there.	Declares
Parent 2:	He's a corn snake.	Declares
Child 1:	He must be bored.	Narrates
Parent 2:	That's a big corn snake.	Declares

Excerpt 13: Corn snake conversation A

Parent:	Look, peanut butter.	Points
Child:	What kind of snake?	Questions
Parent:	I don't know, it's a...lemme see. Oh, it's a corn snake.	Declares
Child:	Corn snake, grrrr. I'm gonna eat it.	Narrates
Parent:	You are, I don't know muffin.	Corrects
	I think he's got something in there somewhere. I think he's got, I don't know, a small...maybe he doesn't have any food right now. Doesn't look like it.	Narrates
	Do you know what predator and prey are? A predator is an animal that preys and feeds on another animal. What kind of snake is this? A corn snake.	Reads
Child:	Wow, corn, I like corn snakes.	Reacts

Excerpt 14: Corn snake conversation B

Child 1:	Mom I found the snake!	Points
Parent:	You did?	Questions
Child 1:	You wanna come see, it's in there!	Points
Child 2:	A real one?	Questions
Child 1:	A real one, it's alive.	Declares
	Who wants to see-	Points
	but it's hiding, so you gotta be careful.	Declares
	Look. Right in there.	Points

Excerpt 15: Corn snake conversation C

Child:	Look!	Points
Parent:	I know,	Corroborates
	isn't that cool!	Reacts
Child:	Look, it's something...	Points
Parent:	It's a ...it's a ...look...	Points
Child:	Boa constrictor?	Questions
Parent:	What kind of snake is this? This snake is a corn snake, she gets her name from her patterning which resembles corn.	Reads
Child:	Corn.	Declares
Parent:	Corn snake.	Corroborates
	Is that a corn snake?	Questions
Unknown:	[whispered] It's a boa constrictor!	Declares

Excerpt 16: Corn snake conversation D

Parent:	Lookit.	Points
Child:	Ma, c'mere!	Points
Parent:	Go play the scavenger hunt.	Instructs
	And if you play scavenger hunt they'll give you, uhm...	Narrates
Child:	There's a real snake!	Declares
Parent:	Oh my gosh! It's...	Exclaims
	predator and prey. Do you know what predator and prey are? A predator's an animal that preys or feeds on other animals? What kind of snake is this? This snake is a corn snake. She gets her name from her patterning that looks like corn.	Reads
	You gotta be kiddin' me, I don't call that corn.	Reacts
	This snake,	Reads
	wow!	Exclaims
	can live to be 20 or 25 years old. A constrictor is any kind of snake that kills its snake by squeezing it	Reads
	That's how they kill their prey.	Declares
	This one eats...corn...it does not eat corn, they eat lizards and rodents but they wouldn't eat us.	Reads
	Holy camoley,	Exclaims
	that is long.	Declares
	It must be it drinks water, see,	Declares
	just like we do. We have to have water.	Explains

Excerpt 17: Corn snake conversation E

Iguana:

Child 1:	Mom!	Points
Child 2:	Jaden! I think I found the iguana! I think I found the iguana!	Points
Parent:	Oh, he's sleeping.	Declares
	Don't knock on the aquarium.	Instructs
Child 1:	This is, so huge.	Declares
	C'mon.	Points
Child 2:	Don't tap on his window.	Instructs
Child 2:	It is open. His eyes are open!	Declares
Child 2:	Ok, yeah, think that's [unclear]	Narrates ?

Excerpt 18: Iguana conversation A

Child 1:	Hey, ummm, what are we doing?	Questions
Educator:	We're just, we were just putting some plates together for our animals, we're talking about what it is that they eat. Right now, we have our salads done, but I will let you guys help me with something else in just a minute, okay?	Declares
	Now, do you remember who that's for?	Questions
Child 3:	Uh huh.	Declares
Educator:	Who? That biiig lizard,	Declares
	put it right down there for a second, okay?	Instructs
Parent:	Hold on, stay right here.	Instructs
Educator:	Now, one of you guys who just came in, whenever we feed the iguana, she has to get a shower first.	Declares
	So would you like to be in charge of the iguana's shower?	Questions
Child 1:	Yay! [laughter]	Exclaims
Educator:	Alright. Can you bring that plate over for me?	Instructs
Child 1:	Is he gonna like, jump at me, or?	Questions
Educator:	Nope, not at all.	Declares
Child 2:	No, he's a slow moving creature.	Explains
Educator:	I'm gonna put this one out, and you,	Declares
	you can set yours right in there, how's that? And now you, can just spray her down with that.	Instructs
	And she loves it, just keep on squirtin', she loves it. She's like "ahh, it's my shower!"	Narrates
	Look at, doesn't she look like she's smilin' at you? [laughter]	Points
	She says, I love my shower. She'll sneeze. Oh lookit, she lifts her arms so you can get there. She lifts her arm up. She's like, "get me under here!"	Narrates
Parent:	How many times do you have to spray her down?	Questions
Educator:	We do her at least once a day, usually two or three times a day.	Declares
	She's from a pretty moist environment, and if we keep her cage moist, then we, we get mildew and what have you in there. So this gives her the moisture she needs.	Explains
	I also have her a nice strong lightbulb I'm gonna put in there for her, her big lightbulb burnt out yesterday so I had to put a little one in.	Narrates

Excerpt 19: Iguana conversation B

Child 1:	...huge lizard...	Declares ?
Child 2:	Oh my god.	Exclaims
Parent 1:	Over here, right here.	Points
	This animal is a reptile. It has a long tail.	Reads
Child 2:	Ohhhh. It's cute.	Reacts
Child 2:	The iguana looked at me.	Declares
Educator:	Oh, she is the friendliest...	Narrates
Parent 1:	It's an herbivore,	Declares
	what's a herbivore Colby? Colby?	Elicits
Child 1:	An animal that eats plants.	Declares
Parent 2:	Yup!	Corroborates
Parent 1:	What's an herbivore?	Elicits
Child 1:	An animal that eats plants.	Declares

Excerpt 20: Iguana conversation C

Parent:	Oh, look! Look at the iguana!	Points
	What's he tryin' to do?	Questions
Parent:	Lookit him.	Points
Child:	He is dead.	Declares
Parent:	No, he's not, look at his eyes, they're moving.	Corrects
Child:	The baby doesn't like, the...baby, my baby doesn't like iguanas.	Narrates
Parent:	Your baby doesn't like iguanas?	Questions
Child:	She goes aaaaaaaaaah!	Narrates
Parent:	Well, they have big claws,	Declares
	you see these claws? Look. See the claws?	Points
Child:	Yeah, the baby's scared of the claws.	Narrates

Excerpt 21: Iguana conversation D

Child:	Oh, I found the iguana.	Declares
	Look at that thing,	Points
	it's huge. It's tail is like, twice its length.	Declares
	Looks just like our art teacher's thing.	Narrates

Excerpt 22: Iguana conversation E

Mirrors:

Child:	Mom, look at…	Points
Parent:	Hey, you look short! And I look short too.	Declares
Child:	[laughter]	Plays
	I look tall.	Declares
	Mom, lookit, I look tall.	Points
Parent:	Here, lemme see, do we get taller if we back up?	Questions
	Nope.	Declares
	We look silly.	Reacts
	Look, I'm upside down!	Points
Parent & Child:	[laughter]	Plays
Child:	I'll back up more.	Declares
	[laughter]	Plays
Parent:	We're some kind of munchkins. You could be on the Wizard of Oz.	Narrates
Child:	[laughter, unclear]	Plays
Parent:	You are funny.	Reacts
	And look, you're green, you're wearing a green shirt, you could be a munchkin.	Narrates
Child:	Mom, lookit, I have one...Look at how big my feet are! Now look how big I am.	Points
	It's so really funny.	Reacts
Parent:	I like this mirror better.	Narrates
Parent:	Oh look, here's another one right here.	Points
Child:	[laughter, etc]	Plays
Parent:	Turn around,	Instructs
	look, look at this.	Points
Child:	Mom, look at me!	Points
Parent:	Look at this.	Points
Child:	[laughter, etc]	Plays
	I'm tubby!	Reacts
	No, mama, look at this one! Mama, see?	Points
Parent:	I don't even want, I wouldn't want that mirror in my house, I'd be sad if I had to look at that all the time.	Narrates
Child:	Look how big I am, look how big I am!	Points

Excerpt 23: Mirror conversation A

Parent:	Liz, umm, Lizzie go in the middle, honey, go by the bath- in the middle by the bathroom doors and look up.	Instructs
	Luke, show Lizzie that thing.	Instructs
Child 1:	What's different,	Questions
	I don't see anything!	Declares
Child 2:	No, go look, remember that, no Lizzie. See? Lizzie, just stay there looking.	Instructs
Parent:	See us Liz?	Questions
Child:	Yeah,	Declares
	can you see me?	Questions
Parent & Child 2:	No.	Declares
Child 1:	Hold on, Luke, go, go.	Instructs
Child 2:	No, the other one Liz. The other one.	Instructs
Child 1:	What?	Questions
Parent:	See here.	Points
Child 2:	See the flat one?	Points
	Yeah, now I can see you.	Declares
Child 1:	Hi L-	Interacts
Parent:	Wiggle your nose.	Instructs
Child 2:	Hiii.	Interacts
Child 1:	Hiii.	Interacts
Parent:	Is it bouncin' off of that one?	Questions
	Ooh. Did you look at this one?	Points

Excerpt 24: Mirror conversation B

Parent:	Convex and concave mirrors.	Reads
	Look into 'em and see what the difference is.	Instructs
Child:	I'm short!	Declares
Parent:	I'm holding it for you while you get down and look at it.	Declares
	What does it do?	Questions
Child:	Makes everything huge.	Declares
Adult:	Try these things. In which mirrors can you make your image larger and in which can you make your image small?	Reads
Child:	Look how long my tongue is.	Points
Adult:	Oh there's more down at the other end. This one's convex, the one at the other end is concave.	Declares
Child:	Whoa. That's cool.	Reacts
Adult:	See 'em down there... [unclear]	Points
Child:	Mommy look at my head!	Points
Child:	Augh, you get...the pressure...	Performs
Child:	Mommy look at my head in this mirror.	Points
Adult:	I see your head. I knew you, I knew you had a big head...	Narrates

Excerpt 25: Mirror conversation C

Parent:	Oh look here, there's a mirror box.	Points
Child:	What's a mirror box, what does it do? Do you stick your hands on it or something?	Questions
Parent:	It says, oh look, it says,	Declares
	have someone go down the bathroom hallway,	Reads
	I think you look through here and you can probably see them or something.	Declares
Child:	Look through it, see.	Instructs
Child:	Here, stay right there.	Instructs
	I'm gonna see if I can see with that.	Narrates
	Can you see Ashley?	Questions
Parent:	No, I don't know I don't get it.	Narrates
Child:	I don't get that.	Narrates

Excerpt 26: Mirror conversation D

Child 1:	What's this?	Questions
Child 2:	[intake of breath] a mirror!	Declares
Child 1:	[intake] That's what we can put on our list.	Narrates
Parent:	It's a mirror box.	Declares
	What different kinds of faces can you make in the mirror?	Reads
Child 2:	Mirror, mirror, mirror, mirror, mirror, mirror, mirror, mirror, mirror- here we go.	Recites
Child 2:	Ok, now we can go to Operation Wild.	Narrates
Child 1:	Yeah. Ohh, this is a mirr...eh.	Declares
	Mommy,	Points
	my legs! They're huuuge. Gee, my boots, they're huge!	Declares
Child 2:	Geez,	Exclaims
	we [singing random syllables]	Recites
Child 2:	Heh. I'm squat.	Declares
	Now let's go.	Instructs
Child 1:	Scorpion.	Declares
Parent:	Oh, did you find the mirror?	Questions
Child 1&2:	Yeah.	Declares
Parent:	Oh, you did, ok.	Corroborates

Excerpt 27: Mirror conversation E