Architecting Learning Continuities for Families Across Informal Science Experiences

Suzanne Marie Perin

A dissertation

submitted in partial fulfillment of the

requirements for the degree of

Doctor of Philosophy

University of Washington

2015

Reading Committee:

Philip Bell, Chair

Megan Bang

Kristine Morrissey

Program Authorized to Offer Degree:

College of Education

University of Washington

Abstract

Architecting Learning Continuities for Families Across Informal Science Experiences

Suzanne Marie Perin

Chair of the Supervisory Committee:
Professor Philip Bell
College of Education

By first recognizing the valuable social and scientific practices taking place within families as they learn science together across multiple, everyday settings, this dissertation addresses questions of how to design and scaffold activities that build and expand on those practices to foster a deep understanding of science, and how the aesthetic experience of learning science builds connections across educational settings. Families were invited to visit a natural history museum, an aquarium, and a place or activity of the family's choice that they associated with science learning. Some families were asked to use a set of activities during their study visits based on the practices of science (National Research Council, 2012), which were delivered via smartphone app or on paper cards. I use design-based research, video data analysis and interaction analysis to examine how families build connections between informal science

learning settings. Chapter 2 outlines the research-based design process of creating activities for families that fostered connections across multiple learning settings, regardless of the topical content of those settings. Implications of this study point to means for linking everyday family social practices such as questioning, observing, and disagreeing to the practices of science through activities that are not site-specific. The next paper delves into aesthetic experience of science learning, and I use video interaction analysis and linguistic analysis to show how notions of beauty and pleasure (and their opposites) are perfused throughout learning activity. Designing for aesthetic experience overtly – building on the sensations of enjoyment and pleasure in the learning experience – can motivate those who might feel alienated by the common conception of science as merely a dispassionate assembly of facts, discrete procedures or inaccessible theory. The third paper, a case study of a family who learns about salmon in each of the sites they visit, highlights the contributions of multiple sites of learning in an ecological view of learning. Finally, the dissertations' conclusion highlights the broad implications for conceiving of the many varied learning settings in a community as an educational infrastructure, and reflections on using aesthetic experience for broadening participation the sciences through the design of informal environments.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

I would like to thank my committee members for their support, Philip Bell, Kris Morrissey, Megan Bang, Simon Werrett and Julie Stein. As my Chair, Phil has been supportive of my interest in the museum setting, while encouraging my interest in the many other diverse settings that people learn across their lives. He values the learning that happens within families, and has supported me through the growth of my own family, which I deeply appreciate. Kris Morrissey has been my champion since my Museology studies. Megan has never ceased to inspire through her passionate views about the role of culture and family in learning. Simon's science and technology tutoring sessions were invaluable to my growth as an academic. I appreciate Julie's support of these ideas, and for her encouragement in using the Burke Museum of Natural History and Culture as a study site.

The family participants in this research were a pleasure to spend time with, and I sincerely thank them for allowing me to join them in their family learning activities.

I wish to thank the Burke Museum and the Seattle Aquarium for allowing my research to take place over several months, as well as the other study sites: the Woodland Park Zoo, MOHAI, the Imagine Children's Museum, and the Pacific Science Center.

My sincerest appreciation goes to the Everyday Science and Technology Group (members past and present), the LIFE Center, and the Institute for Science and Math Education. For assistance with data collection and transcription, Elaine Klein, Veronica Cassone McGowan, and Briana Donovan. A special thank you to Giovanna Scalone for her guidance and excitement in conducting the linguistic analysis. And the Ugly Mug Club will always be a fond memory!

My mother and father provided my brothers and I with many aesthetic experiences of learning science as I grew up, and I would not be studying both learning and science without their influence.

Most of all, I want to thank my husband and daughters, Noah, Sophia and Rebekah, who have had to share me for many years with this project. My very deepest gratitude.

DEDICATION

For Sophia, my daughter

CHAPTER 1: Introduction

Families are the earliest social sources of knowledge about science and mathematics as a way of knowing about the world. In everyday settings, families may not always recognize what they are doing as "scientific," or that they're learning to think in scientific ways, or that they're making and communicating judgments about scientific reasoning as way of knowing about the natural world. Beyond providing resources and opportunities for learning, families are a primary source of cultural and cognitive socialization into the practices, patterns, and values of their communities throughout the life-course. Images of science – what counts as science, who can do it, and where and when science happens – influences their own recognition of family members' capacity as science learners and identity as science thinkers. Whether intentionally or not, families shape children's science-related identities as they support or dissuade children's interests and participation in related activities.

Science, technology, engineering or mathematics (STEM) learning may or may not be explicit objectives of a family activity, but rather, in everyday settings the "content, ways of thinking, and practices are woven into the common problems or activities" (Bell, Lewenstein, Shouse, & Feder, 2009, p. 93). In much educational literature, the family operates in the everyday sphere, where "everyday" is meant both as a range of settings and as a kind of knowledge. Judged by 'a job adequately addressed' (Goldman & Booker, 2009), everyday knowledge has been investigated in education literature as street vendors' mental strategies in arithmetic, proportions and geometry (Carraher & Schliemann, 2002); high school basketball players' strategies for calculating free throw percentages (Nasir & Hand, 2008); or the language used to describe a curve ball from high school baseball players (Brown & Kloser, 2009). As

venues for learning, "everyday" settings are the variety of places, activities and routines that people engage in their daily activity, and where they may often learn and use science, technology, engineering and mathematics. These include out-of-school places such as the home, playgrounds, and venues designed with science education as a primary goal, such as museums and zoos.

These informal environments designed intentionally for science learning and communicating scientific knowledge have their own characteristics and missions. With low or inconsequential assessments of learning these can be venues for safe, open-ended exploration of science (Bell et al., 2009) and family groups are a primary audience. Sometimes referred to as free-choice environments to highlight the volitional nature of learning experiences that is typical (Falk, 2001), designed informal learning settings are frequently structured to build on the participants' competencies, motivations, and culture, and enable the choice of what to do or how deeply to become engaged. The experiences in many of these designed settings are intended to be exceptional, enjoyable, to involve "doing" or interacting with the material culture of science and to experience scientific phenomena. In these moments of "great experiences," (Lemke, 2001) meaning-making is more than just a mental state of reasoning and cognition or the transmission of content, but engagement with science is an aesthetic aspect of total human activity that is bodily and rich in affect, meant to lead to a "heightened vitality" (Dewey, 1934; Wong & Pugh, 2001) and contribute to the development of identity (Bell et al., 2009; Lemke, 2001).

Such great experiences with science are a goal of informal science institutions, with the hope that they inspire and sustain interest and learning in science. But these experiences are designed in a stand-alone fashion, with the onus on the participants to make their own

meaningful connections and coordinate learning across encounters over the life time (Banks et al., 2007; Bell et al., 2009; Lemke, 2000). Such connections must be made within a single setting or across the multiple venues of school, work, leisure and everyday life to develop the multifaceted understanding that is knowledge. There is growing evidence that families and individual children do indeed generate their own learning and sense-making connections across the settings of their everyday lives (Barron, 2006; Bell et al., 2009; Bell, Tzou, Bricker, & Baines, 2012; Zimmerman & McClain, 2013; Zimmerman, Reeve, & Bell, 2009), but informal learning venues are not designed with intention to coordinate across settings in ways that could foster a deeper understanding of science, promote long-term intellectual development, and cultivate identification with the scientific enterprise (Lee, 2008; Lemke, 2001; Penuel, 2014). How can scaffolding everyday science learning experiences by supporting and extending the existing social practices within families lead to more sustained investigations and a deeper understanding of science? This is the broad question that I address through my dissertation research study.

Overview of the Study

While working as an museum exhibit evaluator and exhibit developer at two science canters, I became interested in how people drew on past experience and integrated it into their use of a museum exhibit. How small groups of people used an exhibit or what they talked about in these moments wasn't always expected, and was often creative and delightful (and occasionally destructive). But I was an observer of singular moments, and I didn't know where background knowledge came from or how a particular delightful moment I was witnessing would carry forward: Meaning-making couldn't happen in just one moment, in one momentary experience. Along these lines, this study was inspired by several conversations with parents of

my daughters' playmates: I noticed that these parents made use of many resources in the community for leisure and education, but I also noticed they weren't regularly making connections across places that could be potent learning moments – for example, in noticing the relationship between an arcteryx wing exhibit at the aeronautics museum and the live birds at the zoo. I wanted to know how these seemingly singular moments in time were continuous for families across the many places and times of their lives, and how I could design to cultivate these connections.

Embedded in these moments were what I recognized as aesthetic experience – experience filled with sensory and tactile perception, filled with emotion, and that convey values about what is beautiful and acceptable as scientific knowledge. These experiences are tied to socialization and enculturation in a way that shapes identification with science on a life-long time scale, yet could be captured in conversation. The framework of aesthetic experience could provide language that could express the awe and wonder that scientists and educators hope they can convey to lay audiences, and that keeps them personally inspired to discover and research and teach.

Focused Research Questions

These influences lead to the three focused research questions that are addressed in each of the papers that make up this dissertation:

Research Question 1: How to design a scaffolded experience based on scientific practices to support knowledge synthesis across a range of informal learning environments?

Research Question 2: How does an aesthetic experience of science phenomena in informal learning environments relate to science-linked identity and interest?

Research Question 3: How do families create continuity across experiences through the connections they make across their everyday learning experiences?

Structure of the Dissertation

The dissertation is structured as three stand-alone papers that are connected through a common data set and complementary themes. In this introduction, I outline the methods and study design of the overall research study, but each paper includes theoretical frameworks, literature reviews, detailed methods of analysis, and the findings and conclusions as they relate to the particular research question addressed in the paper.

The first paper, "Architecting Continuity of Great Experiences: Designing for Family Learning Across Settings," outlines the research-based design process of creating connections across multiple learning settings. Implications of this study point to means for linking everyday family social practices such as questioning, observing, and disagreeing to the practices of science through activities that are not site-specific. The second paper delves into aesthetic experience of science learning: "The Beauty of Learning Together: Families Aesthetic Experience in the Practices of Science." I use video interaction analysis and linguistic analysis to show how notions of beauty and pleasure (and their opposites) motivate and shape learning activity. The third paper, "Learning through Continuity of Experience: A Case Study of a Family Learning about Salmon," highlights the contributions of multiple sites of learning in an ecological view of learning.

Finally, the dissertations' conclusion highlights the broad implications for conceiving of the many varied learning settings in a community as an infrastructure, reflections on broadening participation in designed informal environments, and future work that could extend this research.

Methods and Study Design

Methods

Design-based research. Design-based research entails both engineering particular forms of learning and simultaneously studying the design and context of the learning through successive rounds of implementation, analysis and redesign (Bell, 2004; Brown, 1992). These systematic treatments offer the opportunity to apply and refine theory while yielding practical lessons that can be directly applied to educational practice (Edelson, 2002). This project is modeled after critical design ethnography (Barab, Thomas, Dodge, Squire, & Newell, 2004), in which several phases of research are integrated into the design refinement of a learning intervention. Because my research is grounded in the everyday activities of family life, borrowing from ethnographic and qualitative approaches makes sense as ethnography is the study of people in their everyday settings, with particular attention to how they make meaning in and of their lives. This meaning is inferred by the researcher through people's talk, behavior, and material tool use (Anderson-Levitt, 2006), which reveal patterns of participation that provide insight into the values explicit and implicit within the participants' cultural group.

Video research. This study used video for in-depth analyses of families' interactions in informal settings, in order to understand the learning in these settings as it occurs naturally in the various contexts, and then to use this understanding to work towards supporting the learning in these family leisure settings. Video offers a means of close documentation and observation (Derry et al., 2010), and allowed me as the researcher to interact more closely with the study participants while still capturing their interactions for analysis using the multiple analytical methods in the collection of papers that make up this dissertation – discourse analysis, interaction analysis, and corpus linguistic analyses. Such analysis is afforded through the

interactional phenomena of eye gaze, gesture, posture, content of talk, intonation, facial expressions, joint attention, and use of physical artifacts that are captured using video methods (Barron, 2003; Derry et al., 2010). Data collection methods are described in more detail in the following sections.

Settings

Sometimes referred to as "free-choice" environments (Falk, 2001) to emphasize the volitional nature of the experience, designed learning settings such as museums, aquariums and science centers are structured to build on the participants' competence, motivations, and culture, and enable their choice of what to do and how deeply to become engaged. They are venues for safe, open-ended exploration of science with low or inconsequential assessments (Bell et al., 2009). However, empirical evidence suggests that informal learning environments are not homogenous, and that these public settings can not be generalized across one another (Fleer & Hedegaard, 2010), or even to the home and public settings (Bell, Bricker, Reeve, Zimmerman, & Tzou, 2013; Zimmerman & McClain, 2013). I wished to capture family interactions in different settings, and so chose places that would provide a variety of kinds of interactions – with objects, live animals, fossils, interactive and static displays.

Three sites were the focus the research study: A museum, an aquarium, and a setting of the family's own choice. The museum and aquarium settings are designed to communicate scientific content and send broad cultural messages about science to visitors. Families are able to follow their own interests in the museum sites to a point; the educational intent of the museum can put the free-choice nature of the place into tension with the families' own agenda. Research shows that the reasons families attend museums directly influence what is learned and remembered from museum visit, with motivations ranging from entertainment to convenience to

family tradition, to expand learning about hobbies and personal interests, and to cultivate learning for children or others in their group (Falk & Storksdieck, 2009; Ellenbogen, 2002; Falk, 2009; McManus, 1994). Participants drive the learning, freely choose which exhibits to interact with and often have little to no direct facilitation from the organization, so parents often expect to comment on or interpret information from exhibits and programs for their children (Bell et al., 2009). Because of this independence, learning outcomes may not always align with the pedagogical intentions of the educators or designers, yet is reflective of the tension between the delivered content and the families' own interests and motivations as they adapt their experience to suit their own desires. The choice of location was intended to capture the families' conception of science in their own everyday lives.

Museum settings. The two designed sites for data collection include the Burke Museum of Natural History on the University of Washington campus and the Seattle Aquarium on the downtown Seattle waterfront. These two locations were selected because they are both collections-based in a traditional sense (Alexander, 1996), have science education as a primary component of their mission, specifically design for aesthetic aspects of the experience in exhibition and programs, and families are primary target audiences. As collection-based sites, the visitor experience is designed with a grounding in the objects of scientific interest – either artifacts or animal collections. Active research investigations are a formal part of the Burke Museum's and Aquarium's missions, with scientists conducting resarch and publishing in journals. Science education is a primary mission in each place, and exhibitions are planned with intentional attention to the design and aesthetic aspects of presentation.

Family's choice of activity. The third site or activity was chosen by the participant families. The families choosing their own setting had several intentions: there are many diverse

resources in the Seattle and Puget Sound region that families might participate; so that the family might demonstrate their conceptions of science and how they associate their everyday activities with science (Bell et al., 2013; Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001); and science activity and talk happens in a variety of places and ways, not just those intentionally designed for learning or for science education in a Western tradition (Bang & Medin, 2010; Bell et al., 2009). The participants selected other sites to visit, where they liked to do science together, which included: nature walk in local urban forests (3 families), the Pacific Science Center (2 families), the Museum of History and Industry, picking berries and making jam at home, the Zoo, a Children's Museum, and a BMX bike park. The various sites that the participant families chose is shown in Table 1-1.

Participants

The participating families came from across the Puget Sound region, including Bremerton, Kent, Everett, Shoreline and Seattle. Families were able to participate if they had at least one child in third through fifth grade, and all siblings and extended family members were welcome to accompany them. All the families had been to at least one of the museum sites, although for many of them, the visits had been many years prior. The families were primarily of middle- or working-class backgrounds – for example, the parents worked as elementary teachers, an ELL teacher, an informal environmental educator, nursing home wait staff, home improvement store cashier, a military contractor, and county fiscal analyst; two families homeschooled their children and this was the mothers' occupation. Characteristics of the families are shown on the following page in Table 1-2.

Table 1-1: Settings and time intervals between study visits

Family Name	Site/Activity of choice	Recruited from	Order of visits & Time interval	Interval between visits
Lark	Urban forest walk	Aquarium	Burke Museum Forest walk Aquarium	July - August 1 week 2 weeks
Crabwise	MOHAI (Museum of History and Industry)	Aquarium	Burke Museum MOHAI Aquarium	August 2 weeks 1 week
Hawkins	Home (berry picking and jam making)	Aquarium	Burke Museum Home Aquarium	August - September 3 weeks 1 week
Evans	Zoo	Aquarium	Burke Museum Zoo Aquarium	August - September 2 weeks 4 weeks
Knots	BMX bike park	Burke Museum	Aquarium Burke Museum BMX bike park	September - October 3 weeks 2 weeks
Gordon	Pacific Science Center	Elementary School	Burke Museum Aquarium Pacific Science Center	September - November 6 weeks 2 weeks
Messi	Carkeek Park salmon run	Elementary School	Burke Museum Carkeek Park Aquarium	October - December 5 weeks 4 weeks
Kim	Children's Museum	Elementary School	Burke Museum Children's Museum Aquarium	October - January 7 weeks 4 weeks
Walker	Urban forest walk	Elementary School	Burke Forest walk Aquarium	October - January 3 weeks 10 weeks
Tang	Pacific Science Center	Aquarium	Burke Pacific Science Center Aquarium	October - December 10 weeks 2 weeks

Table 1-2: Participant family names and ages

Family Name (Pseudonym)	Core participants & child age (2-3 visits)	Additional participants (1 visit only)	Ethnic heritage or additional languages (as noted by family)
Lark	Holly (mother) Isaac (father) Levi (10) Grace (8) Jared (7)		European
Crabwise	Kiana (mother) Christopher (father) Chris (11) Tommy (6)		European, Native American
Hawkins	Anita (mother) Jennifer (11) Melissa (6)	Oliver (father)	European
Evans	Donna (mother) Sofia (9)		European
Knots	Elizabeth (mother) Shawn (9) Brady (7)		European
Gordon	Lily (mother) Ruby (9)		European
Messi	Robert (father) Victoria (mother) Tina (9) Lionel (7) Bukie (3)		Japanese (mother native speaker, children and father bilingual)
Kim	Anna (mother) Lok (9, turned 10) Lucy (12) Hana (13, turned 14)	Michael (father) Sarah Pak (8, family friend) Su-ji (Anna's mother)	Korean (Grandmother and mother native speakers, children understand but reply in English)
Walker	Gloria (mother) Hope (10, turned 11)		European
Tang	Kate (mother) Tai (8)	Nathan (father) Mei (4)	Chinese (Hong Kong)

Recruitment. Participants were recruited from multiple sites with an intention to capture people who were both familiar with the museum sites already, and those who may not have been to them before. The families were recruited from the two museum locations in the study, two elementary schools, a university-based college preparedness program for underserved youth, and a university Indigenous scholars organization's list-serv.

The Seattle Aquarium, the Burke Museum and one elementary school included a brief notice in their electronic newsletter, and these were the most effective means of recruitment. I

went in person to another school and distributed flyers to three 5th grade classes. Each recruitment effort was staggered so that the visits could be distributed - at most two visits could be scheduled on one day. Weekends, especially after school started, were the available days. Recruiting and the first visits started in July, with recruiting ending in October and the family visits concluding in January.

Each child received one $10 gift card at the last visit for the gift shop, and each family received one $50 visa gift card for participation. All transportation or parking costs were reimbursed, and all admission fees were covered for the participants.

Overview of the Design Process

I created an intervention tool as a set of activities, similar to scavenger hunts or "passport" stamp books or Junior Ranger activity books, in order to provide families with activities that would extend their learning and help them explore and learn about a place independently of docents, trained facilitators, park rangers or other interpretive staff.

The scaffolding tool was designed:

- As a means of providing parents and caregivers with scaffolds to help them facilitate science learning for their children – especially for those facilitators who may not feel confident themselves or have a great deal of experience or pleasure with science;
- To enable social interactivity between group members;
- To enhance a deeper scientific understanding or significance of the actual physical object, artifact, place or animal that is the primary focus of the activity;
- To take advantage of behaviors already widely used in museums, aquaria and other social settings, namely the use of mobile devices to take photographs and videos and share them with others within their social networks;

- To foster STEM learning connections and synthesis across places and activities.

To scaffold the families' activity across settings, I drew on the science practices concepts outlined in the NRC's *Framework for K-12 Science Education* (2012), to provide the foundation of continuity across the diverse scientific content in each of the three settings and to facilitate learning connections from one visit to the next. Asking questions (Practice 1), planning and carrying out investigations (Practice 3), interpreting data (Practice 4), constructing explanations (Practice 6), and obtaining, evaluating and communicating information (Practice 8) formed a structure of activity that carried engagement across the three intervention settings.

The activities were created in two formats: a mobile phone app and a set of paper cards. Both were meant to support families seamlessly across multiple contexts. Families could check off a box to mark "did it!" and write and draw on the cards, and the app would allow them to photograph, video, tag and annotate photos, as the families' pursued their interests and related one experience to another. This categorization process within a family of deciding what to photograph, how to annotate it, and what to share with others – as they move from one research encounter to the next will provide insight into the aesthetic experiences of the families.

Data

Data sources for this design work came from observations, video- and audio- recordings of the participants, informal conversations with me about the activities during the course of the visits with parents and the children, as well as semi-structured interviews with me at the conclusion of each of the visits. Video recordings were made of the duration of each family's visits to each of the three sites, and consist of approximately 60 hours of video. At least one child, and the parent who attended all the visits were microphoned, with the logic that she/he was likely to interact with all the children. In families where members outnumbered the camera

microphones, supplemental microphones were used to capture audio.

Data Collection

The sequence of visits were to start at the place the family was not recruited from, if they were recruited from either the Museum or the Aquarium, then the choice of activity, and finally the other museum. This sequence was structured to maximize the potential for connections to be evident to the researchers, that the unfamiliar place could evoke the more familiar, and to bring the unfamiliar place into the last visits. This sequence generally held, although there was some variation due to families' schedules.

The visits were held on weekdays or weekends, whichever was more convenient for the families. Some visits were during the summer and often during the week; when school started the visits were on the weekends or school holidays. The length of time between visits ranged from 2 weeks to 2 months; the study design called for at least two weeks between visits to allow for time to pass, yet memory of the visit would not grow too distant, and to maintain the family's developing relationship with the researcher.

As the researcher, I accompanied and video-recorded all the visits except one, which was captured by a fellow graduate student because it was concurrent with another visit. A single camera was used to record most families, except for two larger families during their Aquarium visit which tended to be crowded, and so two cameras recorded that visit (with assistance from a fellow graduate student). With one camera, up to three microphones were used: two microphones recorded the audio with the video camera, and an additional single microphone recorded a third family member's audio.

Researcher Positioning

As a participant-observer in the Learning Sciences, my positioning with the families was

both that of outsider, watching, yet a friendly person to talk with during the visits. I carried the camera and interacted with the families and observed the family's interactions with each other. This changed depending on the visit: adults talked with me more often on the initial visit, and the children gradually talked more and more, calling for my attention or asking questions. In crowded places, such as summer days at the Aquarium, I could stand away from the family in the crowd and be less noticable to them. At the Burke Museum, although quiet and not crowded, the large open spaces allowed me to move close to or away from the family members to allow them their own conversations, or for me to engage with them if they solicited my attention. At the various other sites that the families chose, the families often acted as host to me - showing me around or talking about what they "usually did."

In engaging with the family, I talked with the children or adults, acted as another adult chaperone or companion for the children when the parents were interacting with another child, and the children called my attention to things they wanted to show me, asked questions, and were interested in the camera. However, I often stood back to observe the family interaction unfolding, when in other circumstances, I would have talked with the children more often or asked the children questions. For instance, I might have been able to answer questions the family member had at the touch pools, but instead they asked the volunteer staff or did not find an answer, which meant that the family was not positioning me as a tour guide or expert in any of the settings. However, if any of them did ask me a question specifically, I answered if I could, or along the way I pointed out interesting things - I tried to act as a mix of participant and observer.

Carrying the camera proved both a barrier and an ice-breaker to conversing with the children, as they were usually interested in what I could see and hear. To increase their comfort, I made it a point to offer the children a chance to look at the camera screen and to listen through

the headphones, and the children in every family spent at least a few minutes doing so. The camera also allowed me to keep some distance in interactions, so that I was able to capture the families on their own. I did not often wear the camera's headphones over my ears - I wore them around my neck so I could check the audio, but I also didn't want to imply to the families that I was unavailable for casual interactions.

References

Banks, J. A., Au, K., Ball, A., Bell, P., Gordon, E., Gutierrez, K., … Zhou, M. (2007). *Learning In and Out of School in Diverse Environments: Life-long, life-wide, life-deep*. Seattle.

Barab, S. A., Thomas, M. K., Dodge, T., Squire, K., & Newell, M. (2004). Critical design ethnography: Designing for change. *Anthropology & Education Quarterly*, *35*(2), 254–268. doi:10.1525/aeq.2004.35.2.254

Barron, B. (2003). When smart groups fail. *Journal of the Learning Sciences*, *12*(3), 307–359. doi:10.1207/S15327809JLS1203

Barron, B. (2006). Interest and self-sustained learning as catalysts of development: A learning ecology perspective. *Human Development*, *49*(4), 193–224. doi:10.1159/000094368

Bell, P. (2004). On the theoretical breadth of design-based research in education. *Educational Psychologist*, *39*(4), 243–253. doi:10.1207/s15326985ep3904

Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (Eds.). (2009). *Learning Science in Informal Environments: People, Places and Pursuits*. Washington D.C.: National Academies Press. doi:10.17226/12190

Bell, P., Tzou, C., Bricker, L., & Baines, A. D. (2012). Learning in diversities of structures of social practice: Accounting for how, why and where people learn science. *Human Development*, *55*, 269–284. doi:10.1159/000345315

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of the Learning Sciences*, *2*(2), 141–178. doi:10.1207/s15327809jls0202_2

Brown, B. A., & Kloser, M. (2009). Conceptual continuity and the science of baseball: Using informal science literacy to promote students' science learning. *Cultural Studies of Science Education*, *4*(4), 875–897. doi:10.1007/s11422-009-9198-1

Carraher, D. W., & Schliemann, A. D. (2002). Is everyday mathematics truly relevant to mathematics education ? *Journal for Research in Mathematics Education*, *11*, 131–153.

Derry, S., Pea, R., Barron, B., Engle, R., Erickson, F., Goldman, R., … Sherin, B. (2010). Conducting Video Research in the Learning Sciences: Guidance on Selection, Analysis, Technology, and Ethics. *Journal of the Learning Sciences*, *19*(1), 3–53. doi:10.1080/10508400903452884

Dewey, J. (1934). *Art as experience*. New York, New York: Penguin Group.

Edelson, D. C. (2002). Design Research: What We Learn When We Engage in Design Research. *Journal of the Learning Sciences*, *11*(1), 105–121.

Falk, J. H. (Ed.). (2001). Free-choice science education: How we learn science outside of school. New York: Teachers College Press.

Goldman, S., & Booker, A. (2009). Making math a definition of the situation: Families as sites for mathematical practices. *Anthropology & Education Quarterly*, *40*(4), 369–387. doi:10.1111/j.1548-1492.2009.01057.x.369

Lee, C. D. (2008). The Centrality of Culture to the Scientific Study of Learning and Development: How an Ecological Framework in Education Research Facilitates Civic Responsibility. *Educational Researcher*, *37*(5), 267–279. doi:10.3102/0013189X08322683

Lemke, J. L. (2000). Across the scales of time: Artifacts, activities, and meanings in ecosocial systems. *Mind, Culture, and Activity*, *7*(4), 273–290. doi:10.1207/S15327884MCA0704

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching*, *38*(3), 296–316. doi:10.1002/1098-2736(200103)38:3<296::AID-TEA1007>3.3.CO;2-I

Nasir, N. S., & Hand, V. (2008). From the court to the classroom: Opportunities for engagement, learning, and identity in basketball and classroom mathematics. *Journal of the Learning Sciences*, *17*(2), 143–179. doi:10.1080/10508400801986108

Penuel, W. R. (2014). Studying science and engineering learning in practice. *Cultural Studies of Science Education*, (August). doi:10.1007/s11422-014-9632-x

Wong, D., & Pugh, K. (2001). Learning science: A Deweyan perspective. *Journal of Research in Science Teaching*, *38*(3), 317–336. doi:10.1002/1098-2736(200103)38:3<317::AID-TEA1008>3.0.CO;2-9

Zimmerman, H. T., & McClain, L. R. (2013). Intergenerational learning at a nature center: Families using prior experiences and participation frameworks to understand raptors. *Environmental Education Research*, 1–25. doi:10.1080/13504622.2013.775219

Zimmerman, H. T., Reeve, S., & Bell, P. (2009). Family sense-making practices in science center conversations. *Science Education*, *94*(3), 478–505. doi:10.1002/sce.20374

CHAPTER 2: Architecting Continuity of Great Experiences: Designing for Family Learning Across Settings

Providing access to great experiences with science are a goal of informal science institutions, with the aspiration that moments of engagement will inspire, delight, surprise, and provoke interest and learning in science. But each kind of designed place or program – such as a natural history museum, after-school program, school field trip, or community lecture – is designed to stand-alone, so that the onus is on the participants to make their own meaningful connections and coordinate learning across places and over time (Banks et al., 2007; Bell, Lewenstein, Shouse, & Feder, 2009; Bell, Tzou, Bricker, & Baines, 2012; Lee, 2008; Lemke, 2000). Such coordination is sometimes challenging within a single setting, much less across designed learning venues, school, and everyday life. Warning against merely a series of exciting and fun experiences, Lemke reminds us that education is more than individual moments:

> …Having an exciting experience with science is valid and valuable in itself, but education must always be more than one great experience after another. Each small drama of experience must somehow play a part in still larger dramas on longer time scales. How do we promote and support longer-term intellectual and personal development in a curriculum of great experiences? (Lemke, 2001).

Families are a primary audience and user of designed settings such as museums, as well as many other, non-designed places that they consider important for learning, all of which can provide significant moments of "great experiences." There is growing evidence that families and individual children do indeed generate their own learning and sense-making connections across the settings of their everyday lives (Barron, 2006; Bell et al., 2009, 2012; Bricker & Bell, 2014; Zimmerman, Reeve, & Bell, 2009), but family oriented informal education settings are not

typically designed with the intention to elicit and connect experiences in ways that would foster a deep understanding of science, promote long-term intellectual development, and cultivate identification with the scientific enterprise (Lee, 2008; Lemke, 2001; Penuel, n.d.). By considering the range of places that families use for leisure and self-directed pursuits as an infrastructure for learning, cultivating continuity across these places becomes a great opportunity for extending and expanding science learning.

What are ways to create continuity of experience across settings for learners in informal, self-directed settings? I take up the challenge that "a central issue is how to integrate experiences across settings to develop synergies in learning…how to maximize the ecological connections among learning experiences toward outcomes and competencies of interest or consequence" (Bell, Bricker, Lee, Reeve, & Zimmerman, 2006). To cultivate that continuity, I propose that that by drawing on social practice theory and ecological views of learning, activities based on the practices of science (Bell et al., 2009; National Research Council, 2012) will support learning across family oriented informal learning settings. I investigate the questions: How can social practices be leveraged into epistemic practices in informal educational settings? How does family participation in the "practices of science" as the foundation of the activities support or hinder knowledge synthesis and application across a range of informal learning environments? In this dissertation chapter, I describe a design effort to create a tool to support family science learning that would work across multiple sites, regardless of the topic. The process of design and refinement took the form of design based research (Sandoval & Bell, 2004), and the findings lead to a series of design principles with implications for both researchers and practitioners. This paper is structured in relation to a design conjecture map (Sandoval, 2013) that details my design conjectures, the embodiment, mediating processes and outcomes of the scaffolding tool. First, I

describe the rationale for the original design conjectures, and the findings section highlight four themes that influenced the refinement of the family activities from observations and interviews with the study participants, and the outcomes that were actually documented. These findings I then use to reflect upon the original conjectures, how they evolved when put into practice, and the implications for future studies and the design family oriented learning experiences.

Theoretical Framework

Sociocultural perspectives on learning emphasize cognitive development through participation in the practices of a specific culture, which both shapes and is shaped by that participation. Aspects of sociocultural theory that are particularly relevant in the family, everyday, and designed informal learning contexts under study here are: 1) activity is situated in context, where activity is both local and where broader social forces are taken up and played out; 2) tools and material objects mediate activity and learning; 3) coordinated learning happens over a variety of timescales from seconds to years; 4) learning takes place within social interaction; 5) a more knowledgeable person often guides a novice, and 6) learning is volitional and personally relevant in family life (Nasir & Hand, 2006; Vygotsky, 1978; Ash, 2003; Lemke, 2000). Under this broad sociocultural perspective, social practice theory and the Cultural Learning Pathways framework (Bell, Bricker, Tzou, Baines, 2012) influenced my perspective on the design of the family activities used in the study and the analysis of their use and learning outcomes. The CLP takes an ecological perspective to account for the learning that happens across settings and on multiple timescales. As a theory of learning based on the context of social practices, it requires an examination of the connected chains of personally consequential activity and sense-making as they relate to material and cognitive resources. The social positions that people occupy and confront as they move in different contexts drive their participation, shaping and constraining

interests, values, expectations, and opportunity to participate. By considering the extended learning that occurs through multimodal, discursive actions that make up a constellation of events – many of those "great experiences" – we can *account for*, and as I attempt in this study, to *design for*, encouraging continuity in sense-making and learning over place and time.

Creating the Learning Activities through Design Based Research

Creation of the activities for families entailed attention to both pedagogical strategies and the design of user experience, which were refined through design-based research. Design-based research entails both testing and generating educational theory, while engineering particular forms of learning through successive rounds of implementation, analysis and redesign (Bell, 2004; Brown, 1992). Such a systematic treatment offers the opportunity to apply and refine theory while yielding practical lessons that can be directly applied to educational practice (Edelson, 2002). Design research is oriented to "finding *functions*, to understanding how desired (and undesired) effects arise through interactions in a designed environment" (Sandoval, 2013, p. 13). In this study, families used the materials and provided feedback and suggestions for activity design over the course of their participation.

A particular approach to DBR emphasizes ethnographic methods as well as the goal of the researcher to create change within an existing system, which was the model for my study design. In *critical design ethnography* (Barab, Thomas, Dodge, Squire, & Newell, 2004) the researcher becomes a change agent who is collaboratively developing structures intended to critique and support the transformation of the communities being studied. The first phase of the process is consistent with my phase one, where initial work involves ethnographic methods to understand the contexts of the planned intervention. This includes characterizing current patterns of social action and structure in the sites, understanding the meaning of the activities for

community members, and working with a few individuals to develop "thick description" case studies (Geertz, 1973; Yin, 2003).

Next, emergent from the perceived needs in phase one, the second stage of critical design ethnography is to develop a series of social commitments that have local and global significance. These took the form of pedagogical design conjectures that I describe in the next section, which were established through the first phase of family visits, through educational literature, and my own experience in museum education. I considered these as conjectures open for refinement as they were incorporated into these particular contexts with these participants. Designing the user experience, the interface and text of the physical tool, is the subject of much formative evaluation in museum environments and is significant for how it influences use and therefore the learning outcomes associated with the exhibit, tool, or program. In the iterative cycle of design-based research, the user experience is subject to refinement as much as the pedagogy, as it has a direct influence on how people engage with and learn from the object or activity.

The third and final phases of design ethnography are to: (3) reify these understandings and commitments into a design that is refined with study participants, that is never quite complete; and (4) scaling up and reinterpretation across contexts, requiring flexible design and continual adaptation (Barab et al., 2004). In my study, the third phase is the design of the activities themselves, and an analysis of how the study participants engaged in them makes up the findings section of this paper. Then, in my discussion and conclusions, I consider the refinement of the design conjectures, and propose the next iteration for scaling up and adaptation to a wider audience.

Pedagogical Conjectures

To guide the creation of the tool the families would use during their study visits, I established a set of pedagogical commitments from observations of the first three participant families, educational literature, and experience in museum education and exhibit design. A design conjecture map (Sandoval, 2013) in Appendix A shows the five initial focal conjectures, the embodiment, mediating processes and desired outcomes, that guided the development of the activities for the families. Such a map aims to make design research commitments explicit, in order to focus attention on the elements and predicted functions that require the most attention during implementation and refinement. Considered a working document, a conjecture map makes explicit the relationship between design elements and research goals, so that theory can be built and refined concurrently with implementation.

Conjecture 1: Social practices situated in families' everyday learning can be extended to epistemic practices of science. Starting from the position that the science-related social practices that are already a regular part of family life reinforces that such practices and learning is not "broken" or inadequate. Instead, I take it as both a design strategy and an equity strategy to leverage families' cultural and scientific repertoires of knowledge to support their engagement in epistemic practices related to understanding phenomena of the natural world. Observation, explanation and inquiry skills are identified as common practices in everyday family learning, and multiple studies note both strengths and needs to build more complex reasoning from these everyday starting points. Here I describe these three practices in more detail.

Observation. Descriptions and observation are commonly mentioned activities in studies of everyday science. Descriptions are an easy entry point for the most novice of learners and a

prelude to collaborative inquiry and explanation. Stated aloud, description comes to be part of a shared epistemic resource that allows a whole group to negotiate meaning for what they each see and notice (Zimmerman et al., 2009). However, beyond description, Eberbach & Crowley (2009) argue that systematic observation is a complex method that is often treated over-simplistically so that children are asked to observe, compare and describe phenomena without disciplinary context and without gaining deeper scientific understanding. Expert observation is a complex practice that is theory-laden (Brewer & Lambert, 2001; Goodwin, 1994), requiring habits of attention, disciplinary knowledge and context for noticing pertinent and salient data. I saw the design opportunity here to prompt people to share multiple observations, to articulate ideas that were perhaps incompatible, and to coordinate those multiple observations or competing explanations, giving voice to family members' who might otherwise quietly accept a given explanation without contention.

Inquiry. Collectively termed inquiry practices, questioning, making predictions, generating data, and describing evidence are areas of scientific practice that parents and children do well together, at least given specific design supports from a facilitator, program, or exhibit signage (Gleason & Schauble, 2000; Ash, 2003; Fortus, 2009; Allen & Gutwill, 2009). However, these studies also show that the areas parents are not as strong in supporting their children include self-directed inquiry and pursuit of personal curiosity questions; asking children questions that are not known-answers and which can be investigated in the moment; evaluating the quality of data for analysis and helping the child in interpretation; and in making their inferences and assumptions clear by stating them aloud. The design opportunity here is to help parents make their thinking more explicit by encouraging them to explicitly share what they

notice and find important when looking at an object together or when providing an explanation, and why they consider that element important.

Explanation and argumentation. Explanatory conversations between parents and children contribute meaningful pieces of information to children as they encounter various phenomena. In giving explanations, parents direct children's attention to more mature interpretations of their activity, socialize their children into the knowledge considered appropriate by gender and culture (Bang & Medin, 2010; Bricker, 2008; Crowley, Callanan, Tenenbaum, & Allen, 2001; Fender & Crowley, 2007), and bring in scientific content into explanations of events in moments not specifically related to science (Callanan, Shrager, & Moore, 1995; M. H. Goodwin, 2007). The answer to the question "why" drives an explanation (example questions are 'Why is the sky blue?' or, 'Why did the dinosaurs die out?'), and the answering explanation provides facts that are not in doubt – there is no need to establish validity with evidence (Osborne & Patterson, 2011). In contrast, an argument contains a claim and data. The questions that must be resolved through argument are about whether the proposed explanation accounts for all the known facts, and whether that explanation does it better than all the other possible explanations.

The concern from the literature is that however compelling and adequate these explanations are in these everyday contexts, especially if they come in the form of brief "explanatoids," such explanations may reinforce that science is a static body of facts and do not lead to the important epistemic form of argumentation or investigation (Allen & Gutwill, 2009). This may be a result of the social facilitation in the learning environment: from the parents who have only a general sense of scientific knowledge themselves, or from the particular scaffolds in demonstration-style museum exhibits that do not support deeper investigation; that novices are

reluctant to challenge those in the group with more expertise; or because of the everyday nature of the setting, argumentation has the colloquial connotation of disagreement and negative emotions (Allen & Gutwill, 2009; Sandoval & Reiser, 2004). The design strategy is to encourage family members to point out something that they may not also agree with, and to provide something that they notice or remember as evidence that might contribute to challenging a given explanation.

Conjecture 2: Sense-making connections across settings. People naturally and frequently make connections between places, events and experiences, which contribute to their learning across settings and over time. Ecological views of learning consider the ways that broad and varied contexts and supports are brought into alignment and coordination in ways that support science learning (Barron, 2004; Bell et al., 2009). Over a longer timescale, connections develop and sustain interests that people pursue as they search out other social and physical resources that support their interest, and shape identity and learning pathways (Barron, 2006; Bricker & Bell, 2014; Hidi & Renninger, 2006; Ito et al., 2013). In a shorter timeframe, such connections can be noted in conversation and action. In studies of families on nature walks, explicit connections in the families' science conversation came in the form of shared prior experience that served as an epistemic resource in the form of evidence (McClain & Zimmerman, 2014; Zimmerman & McClain, 2013). The sources of these experiences included routine activities and everyday experiences (such as hobbies or vacations), designed learning settings (such as other museums or zoos), programs for science learning (after-school and camps), media, school, references within the visit, and analogies to common items in everyday life. The desired outcome of this element is to encourage the coordination of knowledge between places, not just as a statement of fact or memory from a prior experience in the present moment,

but to extend that invocation through detailed explanation or analogies, in order to create continuity through learning experiences.

Conjecture 3: Practices of science present a unifying form of activity across diverse settings. Participation in the "practices of science" can build a deeper understanding of science, and the nature of science, regardless of the content or place that families regularly use for science learning. If the processes of science are conceived as a collection of practices (National Research Council, 2012; Rouse, 1994), science *in* practice foregrounds how science is developed through people's contributions through everyday social practices (Penuel, 2014). Directly experiencing the practices for themselves is how students will comprehend the practices, and develop an appreciation for the nature of scientific knowledge itself (National Research Council, 2012). This stands in contrast to a conception of science *as* practice, which foregrounds the mature disciplinary practices of professional science. While acknowledging that "Science" is not a single community of practice (Knorr Cetina, 1999), but has distinct disciplines that differ in the questions they pose, tools for investigation, and epistemic norms (Penuel, n.d.), the "practices of science" are presented in the *Framework for K-12 Education* as a foundational way of thinking across disciplines and is fundamental to successful understanding of science.

Developing activities based on the practices of science was intended to serve two educational design outcomes. First, as a design consideration, it eliminates the need for location-specific content which is common in family-activities, which would free the families to engage in the activities in whatever setting they choose, even when scaling beyond the three sites included in this study. The second design objective is to engage families in behaviors and cultivate habits of mind that would help them understand how scientific knowledge develops, approximate the range of approaches that are used to investigate, model and explain the world

and nature, all while accommodating and encouraging cultural dimensions and values that diverse audiences navigate in institutional educational settings.

Conjecture 4: Adults learn concurrently while guiding their children. Family studies are often studies of adults teaching children, without attention to what and how adults are learning. The conjecture here is that that adults will learn alongside their children and will find the experiences more enjoyable than if their role is only that of teacher. Many parents come to museums often in "teaching mode" (McManus, 1994), to lead and instruct their children, yet it is an objective of this project to create an opportunity for those parents to engage in practices that are organized for "adult guides to help expand their abilities to prepare learners" (Penuel, n.d., p. 25) in different settings.

Parents, caregivers, educators and facilitators play critical roles in supporting children's learning (Bell et al., 2009) yet that perspective positions the child as learner and adult as the knowledgeable other – which may not always be the case. A child may be the most expert in a family around a specific topic (Ash, 2003; Palmquist & Crowley, 2007; Zimmerman, Reeve, & Bell, 2008), or no one may hold knowledge or expertise about a given topic. Adults' own science learning tends to be directed toward specific circumstances or towards domains of interest in relation to the problems of everyday life (Bell et al., 2009) and designed informal learning settings are often regarded as geared towards children and not for adult learning (Dudzinska-Przesmitzki & Grenier, 2008). This means that adults may feel inadequate if they do not know something or are not comfortable in the space (Dawson, 2014).

The key design strategies here are that activities that support family learning should be pleasurable and engaging for the adults too –for example, in creating "juicy questions" that the whole family developed a question to which no one knew the answer, and attempt to answer it,

adults had to participate as much as the children (Allen & Gutwill, 2009). Also, parents can navigate unknown content with their children if they are recognized as being expert in knowing their children (Zimmerman, Perin, & Bell, 2010). Finally, parents learning alongside their children can model how to engage with new material and practices, leading their children in subtle ways, using their own experience and understanding (Siegel, Esterly, Callanan, Wright, & Navarro, 2007).

Conjecture 5: Repeated engagement leads to deeper learning. Repeating an activity in different places, and at different times, was intended to help the participants recognize that the same sense-making practices – questioning, explanation, making and sharing observations, for example – are the same foundational practices of science, regardless of the content or location, although they can take different forms based on the context and cultural history of participants. Writing down, drawing or taking a photograph were the design elements meant to prompt the reflective work between places and over time.

Creating the User Experience

In this section, I describe the design of the physical tools – the text, layout, and technologies that were handed to the families. The constraints and affordances of the physical tool used to mediate their experience had to be considered when designing the activities. The tool had to work flexibly regardless of location; be accessible to a range of reading levels; and be an object that could be shared, viewed and used jointly. The tool itself is a "boundary object" (Star & Griesemer, 1989) that serves to enhance the permeability of the borders of place so that interactions are as smooth as possible across; through routinization of practices and actions; and reflection to notice differences, in order to learn something new about their own and others' practice (Akkerman & Bakker, 2011).

The tool. Two formats were chosen to serve as the mediating object, a smartphone app and paper cards. The same activities would be in each format, but the families would use just one (either the app or the paper cards) throughout their participation in the study. Visitors using smartphones in the museum settings is controversial because of the concern that they distract from museum visitors being fully engaged with the objects, inhibit memories of the object, and for a perceived difficulty in transitioning attention between mobile and real-world context (Cahill et al., 2011; Hsi, 2003; Julie Stein, personal communication). Worksheets and paper-based activities are perceived to be less distracting and more appropriate in the museum setting (Cahill et al., 2011). The paper card format was meant to address this concern.

A smartphone app, in the tradition of "nomadic inquiry," (Hsi, 2004) was chosen for its ubiquity in daily life and for as a tool that would allow the families to use it to create their own artifacts (such as photos), make personal annotations and associations to science and the practices, and to include a social media component for sharing across the study participants. Mobile technology can have a place in facilitating interactions with museum exhibits and with science in everyday places and activities – especially via social practices already being used on Smartphones and tablets, such as photographs, video, and sharing these within social media networks. In a front-end evaluation survey conducted in March 2010, the Children's Museum of Houston found that more than 76% of their visitors owned a Smartphone, and 75% of visitors interviewed (n=113) would like to use Smartphone technology in the museum to help their children's learning experience (Children's Museum of Houston, 2010).

An off-the-shelf mobile app called EthosApp that collects ethnographic data by study participants themselves was selected for use in the study. This product was selected because it was simple for participants to learn, photographs and videos could be tied to the text of the

activities (called "tasks" by EthosApp), annotated by the user, and an associated website allowed the participants' photos to be shared with each other.

Selection of practices. Particular disciplinary practices from the Framework for K-12 Science Education (National Research Council, 2012) were identified as being most accessible within the designed settings of the two museums, and most likely to be easy for the families to use in other settings as well. Practices targeted the 3rd-5th grade level so that both adults and children would find them accessible (which influenced the recruitment criteria, that at least one child in the family be in or just completed 3-5th grades). The practices selected were: Practice 2 Using Models (since many objects on display in museums are models or replicas of natural systems or phenomena); Practice 4 Analyzing and Interpreting Data; Practice 6, Constructing explanations; Practice 7, Engaging in Argument from evidence; and Practice 8, Obtaining, evaluating and communicating information. Within each of these practices, more specific areas were identified as being adaptable to the informal learning settings and are noted in Table 2-1. Using and recognizing mathematics is one of the activities I included; however, I didn't feel that the informal settings supported the practice as it is outlined in the NGSS (Practice 5) and it is not included in the table.

Table 2-1: Identified NGSS Practices of Science supported in the family activities

Practice 2 **Developing and Using Models**	**Practice 4** **Analyzing and Interpreting Data**	**Practice 6** **Constructing Explanations and Designing Solutions**	**Practice 7** **Engaging in Argument from Evidence**	**Practice 8** **Obtaining, Evaluating and Communicating Information**
Progressing from K-2, build and revise simple models	**Introduce quantitative approaches to collecting data**	**Use evidence in constructing explanations that specify**	**Critique the scientific explanations or solutions**	**Evaluate the merit and accuracy of ideas and**

and use models to represent events and design solutions.	**and conducting multiple trials of qualitative observations.**	**variables that describe and predict phenomena.**	**proposed by peers by citing relevant evidence about the natural and designed world(s).**	**methods.**
• Identify limitations of models. • Develop and/or use models to describe or predict phenomena.	• Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation. • Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.	• Construct an explanation of observed relationships (e.g., the distribution of plants in the back yard). • Use evidence (e.g.,measure-ments, observations, patterns) to construct or support an explanation or design a solution to a problem. • Identify the evidence that supports particular points in an explanation.	• Compare and refine arguments based on an evaluation of the evidence presented. • Distinguish among facts, reasoned judgment based on research findings, and speculation in an explanation. • Respectfully provide and receive critiques from peers about a proposed procedure, explanation, or model by citing relevant evidence and posing specific questions. • Construct and/or support an argument with evidence, data, and/or a model.	• Compare and/or combine across complex texts and/or other reliable media to support the engagement in other scientific and/or engineering practices. • Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem. • Communicate scientific and/or technical information orally and/or in written formats.

Nature and structure of activities. One of my pedagogical commitments was that the activities should not be a prescriptive set of activities to be followed, but should align with the self-directed nature of the informal learning contexts. The activities were to be flexible for either looking at in advance or reviewing together at the conclusion of the day, in order to prompt a behavior or trigger a memory of an action or conversation during the visit. They were meant to generate recognition that something the family had already done could count as a scientific practice. Images of the activities are included in Appendix B: Images of the Cards and Appendix C: Ethos App screenshot.

Scavenger hunts are a common strategy in museums, online games, nature centers, among many others, showing a list of items to check off when they have been seen and a small reward is received when all the items are completed. Their objective is to entertain, structure activity and encourage noticing. However, such a strategy often backfires when the users do not engage or observe, in the interest of a quick completion – checking boxes off the list becomes the focal activity, rather than engagement with the objects or place. Avoiding this lack of deep engagement with the objects at hand, yet keeping the pleasure of checking the box became a user design element – multiple check boxes indicated the activity could be repeated.

The text of each task encouraged taking an action, talking about something, or a reflection. This approach was influenced by the Visual Learning Strategies method used in art appreciation for encouraging contributions of ideas, questioning, and for respecting others' ideas when they are presented – listening to others is a key technique (Housen & Yenawine, 2001). Three simple, open-ended questions are the hallmarks of the VTS method: What's going on in this picture? What do you see that makes you say that? What more can we find? These questions can work across disciplines (Yenawine, 2013) to surface shared evidence, encourage careful

looking, to both talk about their ideas and to listen to others, and discuss multiple possible interpretations (Housen, 2002). These questions guided the creation of the phrasing in the activity.

Finally, limiting the number of activities was meant to encourage repetition and uptake of specific sense-making practices. The conjecture was that doing the same activity (such as making a measurement or making a decision about a specimen to collect) would generate noticeable similarities and differences across settings for the families. Approximately 8-10 individual tasks was the target, so that families would have a range to choose from yet were few enough to engage in repeatedly in different contexts.

Study Design and Methods

This set of activities was created to be used in family-oriented informal learning settings. Ten families visited three sites as a part of the study: the Burke Museum of Natural History and Culture, the Seattle Aquarium, and a place or activity of their own choosing in which they do science, as they define it, together. The families were recruited from the two museum locations through electronic newsletters to members and non-members alike, two elementary schools, and a university-based college preparedness program for underserved youth. Families with at least one child in 3rd through 5th grade were eligible, and the families could consist of any combination of siblings and adult caregivers. The three visits with each individual family were scheduled approximately 2- 4 weeks apart, depending on the families schedules, and all the study visits occurred in summer, autumn and early winter (July through January).

The first three families to schedule their study visits were not asked to use the family activities; this was intentional in order to provide a sense of how families were making sense across the three sites before any intervention was implemented. Then six families either used the

paper-based or the smartphone app format of the activities. One remaining family had been asked to use the App, but experienced technical difficulties on the part of the app provider at the commencement of the first two site visits, so we decided they would not use it.

Settings

Every family visited the Burke Museum of Natural History and Culture, a place or activity of their own choice where the family engaged in science together, and the Seattle Aquarium. These two museums were selected to be consistent across all the families because they are both collections-based in a traditional-museum sense (Alexander, 1996), have science education as a primary aspect of their mission, design for aesthetic aspects of the experience in exhibition, and families are primary audience. The two museums settings are collections-based, so that the visitor experience is designed with a grounding in the objects of scientific and cultural value – either artifacts or animal collections. Active scientific research is conducted, with researchers on staff, and are a formal part of the Burke Museum's and Aquarium's missions. The participants selected other sites to visit, where they liked to do science together, and included: nature walk in local urban forests (3 families), the Pacific Science Center (2 families), the local history museum, picking blackberries and making jam at home, the Zoo, a Children's Museum, and riding bicycles at a BMX bike park.

Participants

The families came from across the Puget Sound region, including Bremerton, Kent, Everett, Shoreline and Seattle. All the families had been to at least one of the museum sites, although for many of them, the visits had been many years prior. The families were primarily of middle- or working-class backgrounds – for example, the parents worked as elementary teachers, an ELL teacher, an informal environmental educator, nursing home wait staff, home

improvement store cashier, a military contractor, and county fiscal analyst; two families homeschooled their children and this was the mothers' occupation.

Data & Analysis

Data sources for this design work came from observations, video- and audio- recordings of the participants, informal conversations with me about the activities during the course of the visits with parents and the children, as well as semi-structured interviews with me at the conclusion of each of the visits. As the researcher, I accompanied and video-recorded all the visits except one, which was captured by a fellow graduate student because it was concurrent with another visit. Video recordings were made of the duration of each family's visits to each of the three sites, and consist of approximately 60 hours of video. At least one child, and the mothers were microphoned, with the logic that she was likely to interact with all her children. In families where members outnumbered the camera microphones, supplemental microphones were used to capture audio.

Analysis occurred both concurrently during data collection and after completion. Data consists of fieldnotes, participant-observations, video- and audio- recordings and transcripts, video content logs, interviews with the participants, and participant artifacts, including photographs and drawings, notes and descriptions that participants wrote on the activity cards or included in their EthosApp postings. Employing an inductive analytical approach (LeCompte & Schensul, 2013; Miles, Huberman, & Saldaña, 2014), my analysis was conducted through multiple iterations of thematic development and analysis. In the first phase of the study, that of the families visiting the three research sites without any designed intervention, an iterative review of field notes and observations, creation and review of video content logs and interview transcripts were generally inductive, directed by the content of the data. Descriptive memos were

created about each of the families to identify their social practices, how families made connections across places and related their learning activities to science. These memos, in conjunction with the literature reviewed above and the conjecture map, served to inform the design of the activities.

To analyze how the families used the activities, which the findings here include, I again created content logs, descriptive memos, and coded fieldnotes and video. The findings include both snapshots that capture moments that relate – confirming or disconfirming – to my design conjectures, as well as longer analytical narratives that reflect how a theme is reflected in families' activity over time and is triangulated through the video, participant artifacts, interviews, and participant-observation.

Findings

In these findings, I look deeply at how the families used the activities to support or scaffold their interactions during their study visit in relation to their own familiar social practices, ultimately in an evaluation of the practices as an anchoring feature to create continuity in support of learning across settings. From the themes developed by creating and analyzing video, video content logs, memos, and fieldnotes, I have narrowed the number of themes presented here to highlight three key family practices – taken from the conjecture map, these are the "embodiments" and "mediating processes" that emerged as people used the activities. I trace these three practices to the learning outcomes. For each of these three forms of engagement and sense-making, I present multiple examples from across the dataset to consider the affordances and constraints of the scaffolding activities, and I include one longer analytical narrative from a single family taken across settings.

These three themes include an examination of: first, the families' use of the physical format (either the paper cards or smartphone) including the physical supports for representations through photographs and the use of their smartphones; second, the positioning of families as "real" scientists and their conception of what counted as science activity; and, finally how parents showed their own curiosity and responded to the practices of science as the anchor the activities. I then consider how these findings refine my original design conjectures and their implications in the conclusion.

Key Practice 1: Taking Photographs and Information Searching Using Smartphones

Two of the conjecture map's 'mediating processes' were intended to be complementary - participant-created artifacts were intended to evoke prior knowledge, and I focus here on the creation of one particular mediating artifact: photographs through the families' use of the smartphone. Because of the concerns about the smartphones being a distraction from the learning experience, I wished to look at how the families used the paper cards provided versus participant's phones, but the use of the phones was so ubiquitous that all of the families used their smartphones at least once during every visit (30 visits), regardless of whether they were using their phones for the research study. Answering a call, texting a person not present, checking email or text were activities of the parent; taking photos or looking up information were activities that were directly related to the family's joint learning or leisure activity during their visits.

There were several behaviors common to the families, regardless of their grouping in the study:

- All the families (10) took at least one photograph during the course of the study, regardless of the condition (smartphone app, paper cards, or no scaffolding activity).

- Using their smartphone to look up information to answer self-generated questions not answered by the museum signage or staff were joint activities between parent and child, and two families did this during multiple visits.
- Taking photographs was a frequent activity, and not just for the families using the EthosApp version of the activities. Sometimes the photos were posed or in response to a designed "photo op"– such as at the Aquarium's model of octopus tentacles to drape around the children's shoulders, but often children took photos of objects or animals that they found interesting. Of these, the animals were often "cute," such as the sea otters and river otters at the Aquarium, a small deer at the Zoo; or "gross" such as preserved frogs in jars at the Burke Museum. For the Evans family, taking photos was a common practice and something Sofia did with her grandfather; mother Donna often provided suggestions about lighting or the angle of the shot.
- Some photographs were taken to show someone who was not present, making a connection from an object or activity in the present moment to someone else. For example, Chris Crabwise took a photo at the history museum because "Grandpa would like this" and he texted the photo to his grandfather during the visit.
- The families using the App took additional photographs they did not post to the App to share with the research team.

The division of labor associated with this mode of engagement was different in the two groups: parents asked their children to do the App version of the activities, handing them the phone, and the children integrated the activities with the photographs they took during the course of each visit. If the parent was holding the phone, the child asked the parent for the phone when they wanted to take a picture of something. The paper cards the parents generally held onto, and they

coordinated the activities at the conclusion of the visit. However, this was a tradeoff: the families completed a greater diversity of the activities repeatedly using the paper cards, but the families using the App did fewer of the activities. Table 2-2 shows the number of activities completed and repeated.

Table 2-2: Number of activities families completed

Activity Format	Family Name	Number of Activity Tasks used	Number of Activities tasks repeated*	Total number of activities done during visit
Paper cards	Kim	10	8	20
	Gordon	9	4	12
	Knots	8	5	12
Mobile App	Walker	5	1	10
	Messi	2	1	3
	Evans	1	1	1
*Activities could be marked completed up to 4 times on the paper cards, and an unlimited number on the app.				

By generating artifacts through using the activities, families would be prompted to invoke prior knowledge and experience (a existing family social practice) in such a way that the connections across places and over time would be more explicit through spoken conversation, making drawings, or through taking or viewing photographs that were part of the activities. This strategy worked as hoped in just one instance: Hope Walker took a photo of scrimshaw at the Burke Museum, on their first study visit (Figure 2-1). Then, on their second outing with me six weeks later, an urban forest walk, Hope noticed worm tunnels on a stick she found, and took a

photo (Figure 2-2), recording that it was something that made her remember the earlier visit. Hope took the first photo because it was "just pretty" – she took the photo without telling her mother why she took it, but that was the reason Gloria gave in their conversation and Hope agreed. Then, on the forest walk, the stick made them recall the scrimshaw as well as another long stick that Hope collected on a beach vacation, "that looked like it had been carved." They weren't going to keep it because it was on the beach, "but then it was just really cool" so they did take it home. Gloria explained to me that they didn't know what made the tunnels, but that someone told them it was "some kind of bug."

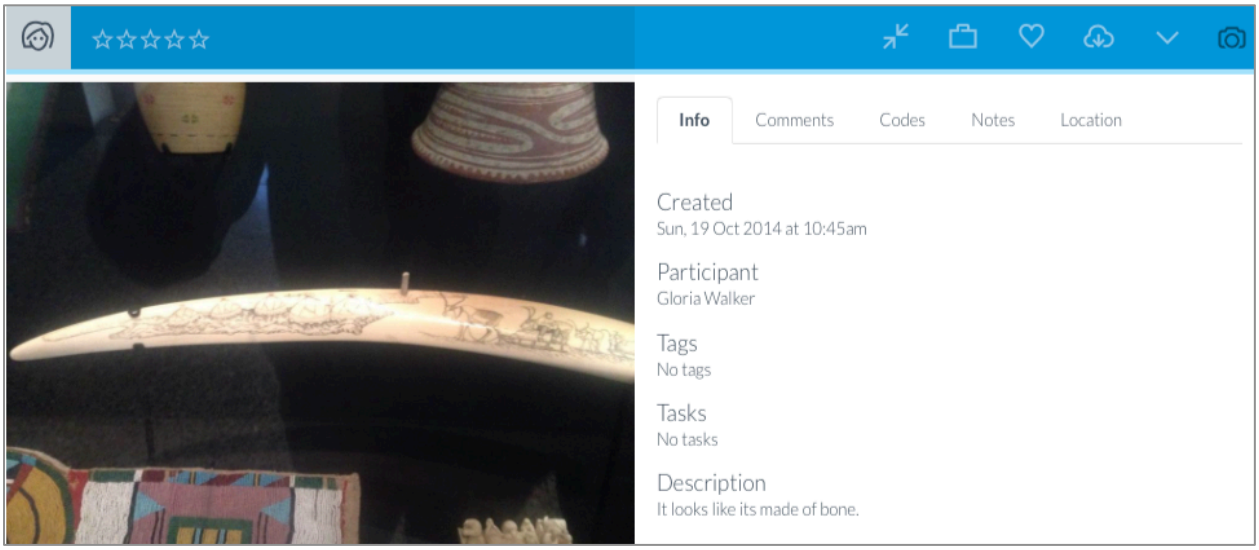


Figure 2-1: Hope Walker's photograph of scrimshaw at the Burke Museum

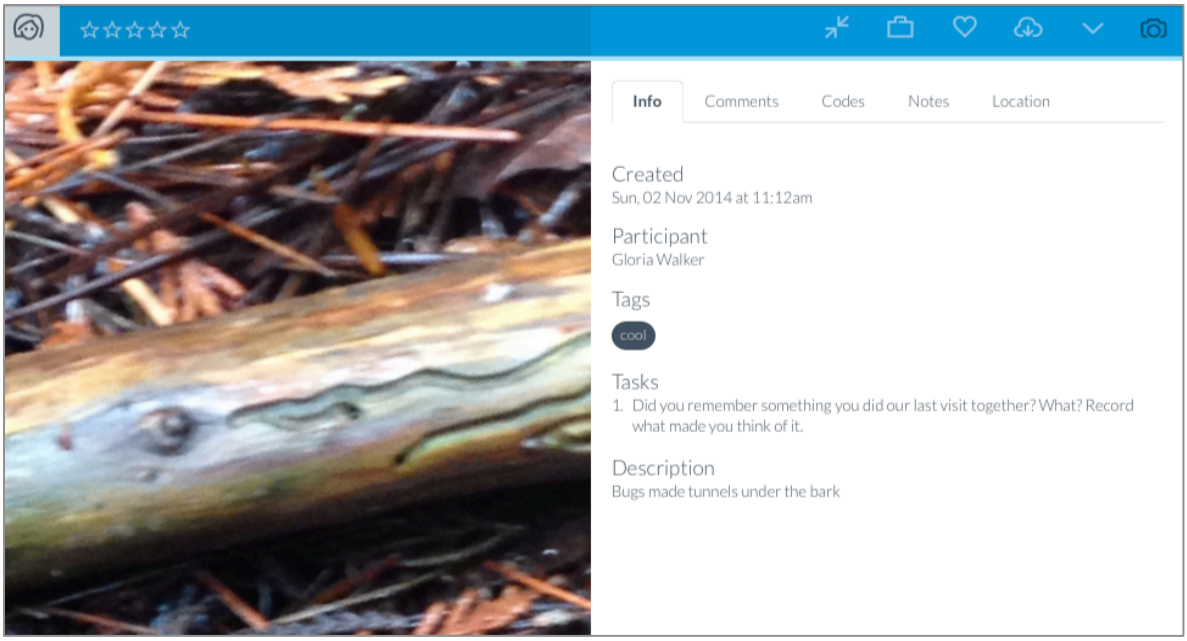


Figure 2-2: Hope Walker's photograph of worm tunnels on a stick, recalling the scrimshaw and another stick she collected

Here, they are making sense of their current experience in relation to a prior experience through a focus on similar objects of interest: the qualities of each of the three objects that tie them together; their debate about whether they should take something from the beach, the beauty of the stick at the beach led them to ultimately decide to keep it; talking about what makes the carving on the stick; and recalling the scrimshaw carving at the Museum. Making the connection across place and over time was supported by taking the photographs while sharing these experiences, and the conversation around the sticks is very much like the scaffolding activity that prompts families to decide between objects to "collect."

Taking photographs was a compelling practice for the families, whether through a smartphone or with a digital camera, and a next step in this design project would be to improve how families review and reflect on the photographs they collect. For those families who used EthosApp to do the activities, an associated website shared the participants' photos, but none of

the families visited the website. One family said they weren't interested in the others', since it was just taking the photos that was interesting to them; another family said they were interested in seeing the other participants photos, but that this view needed to be accessible through the smartphone (which was a limitation of the EthosApp). Other studies have used digital photographs to support reflective practices (Cahill et al., 2011; Land, Smith, & Zimmerman, 2013; Reeve & Bell, 2009), but these have been in structured school field trip or after-school programs, not in the strictly volitional, free-choice environment I considered consistent with the kind of learning practices in families' leisure time. A perennial issue in informal learning settings finding is the right balance of structure and allowing people to follow their own interests. One of the advantages of a the scavenger hunts, Junior Ranger workbooks, and other kinds of structuring activities in designed education settings is the reward for completion- stickers, stamps, a "Junior Ranger" badge or some other token. Balancing the spirit of the free-choice nature of the activities and the settings with motivational rewards would be something to consider in future iterations. Digital badging could be a way to meet this need, which would both provide a progressive award system, encourage participants to return to review their photos as a reference album, and encourage a digital community that could share across settings.

Key Practice 2: Positioning Families as "Real" Scientists and Doing Science

Two activities in the designed set asked families to notice themselves or others doing science. The first iteration of the activities used the word "real" in the texts of the two cards (Figure 2-3), and one family received this version of the cards. The word "real" was removed for the other families, because both my colleagues who reviewed the text and I believed it positioned the youth and families as "not" scientists – a positioning that was not the intention. However, the text of second activity – "Notice when you do science like a real scientist," "real" was kept in the

text to see when the families made the allusion to themselves as scientists.

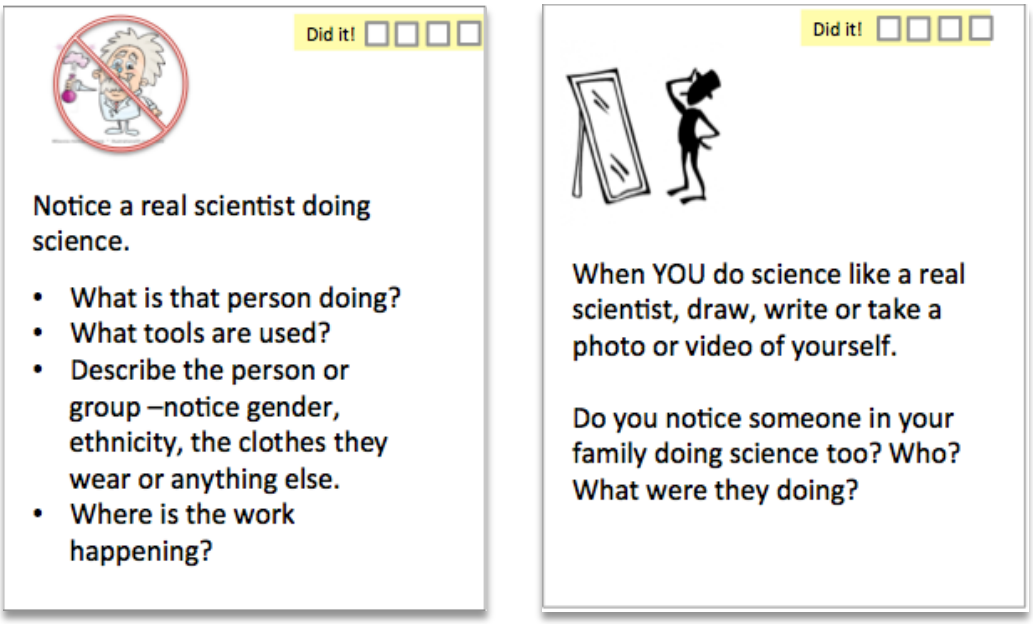


Figure 2-3: First iteration of "Real" scientist activity cards

When responding to the prompt on the activities, the six families who used the activities referred to museum interpretive staff or volunteers they saw at the Aquarium, the Burke Museum, or other museums they attended, such as the science center. The staff that were specifically noted to complete the activity cards included a man who presented the cornsnake at the science center, an attendant at the mammoth tusk display at the Burke Museum (who considered himself an aspiring historian, and made that quite clear to the family who called him a scientist), two staff fossil preparators also at the Burke Museum and zookeepers. Three of the families said that a staff uniform and name badges were indicators that the person was a scientist, in response to the prompt on the activity card.

When responding to the activity prompt: “Notice when you do science like a real scientist” or when a family member does science, the person completing the task noted when another family member was doing science – but not themselves. This was surprising, given the

current popularity of taking “selfie” photographs, and leads to questions for further research about identification with science: are the photographers not identified with science themselves, but wanting to highlight how others were? Two photos from the app version of the activities I provide as example. In one, Tina, came to me to ask excitedly if she could take a photo of her family doing science; this was her second visit using the app and I knew she was referring to the activity prompt. I replied yes, and she took a photo of her 3 year-old brother Bukie looking for sharks, pressing his full body against the glass of the aquarium tank (Figure 2-4). She tagged it as “aquarium” “cool” and “science” and typed the description “Science. WOW!!!!!” The affordances of the place – the dramatic presentation of the sea animals, and the capability to document the activity, support this moment framed as “doing science.”

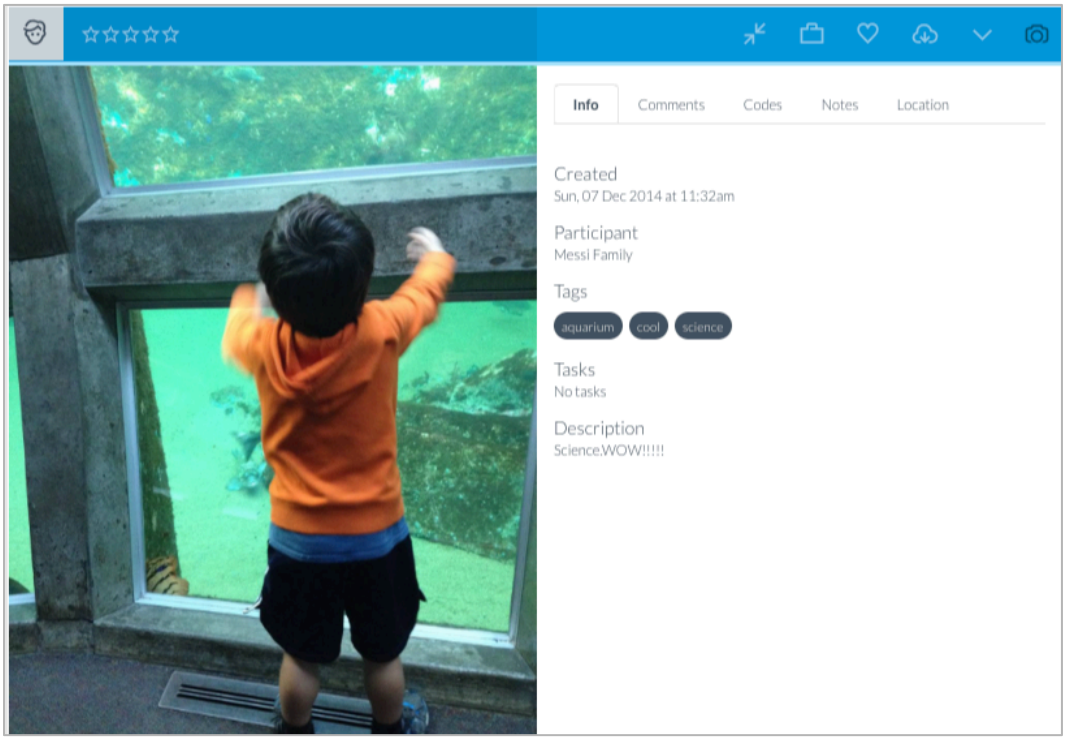


Figure 2-4: Tina Messi’s photo of her 3-year old brother Bukie "doing science"

Another mother and daughter took photos of what they were curious enough to look at more closely: Gloria looked carefully at a decomposing tree while daughter Hope captured her

investigation in the photo (Figure 5), and tagged it as someone in her family doing science. This particular photo is posed, at Hope's direction, because she realized her mother was "doing science" just after Gloria stood up and Hope wanted to capture her mother looking carefully at the decaying tree and looking for insects. Hope recognizes Gloria's observations as science and wants to capture her mother doing science, and they use the framing of the image to make sense of what it means to do science, and how they observe and describe the objects they engage with.

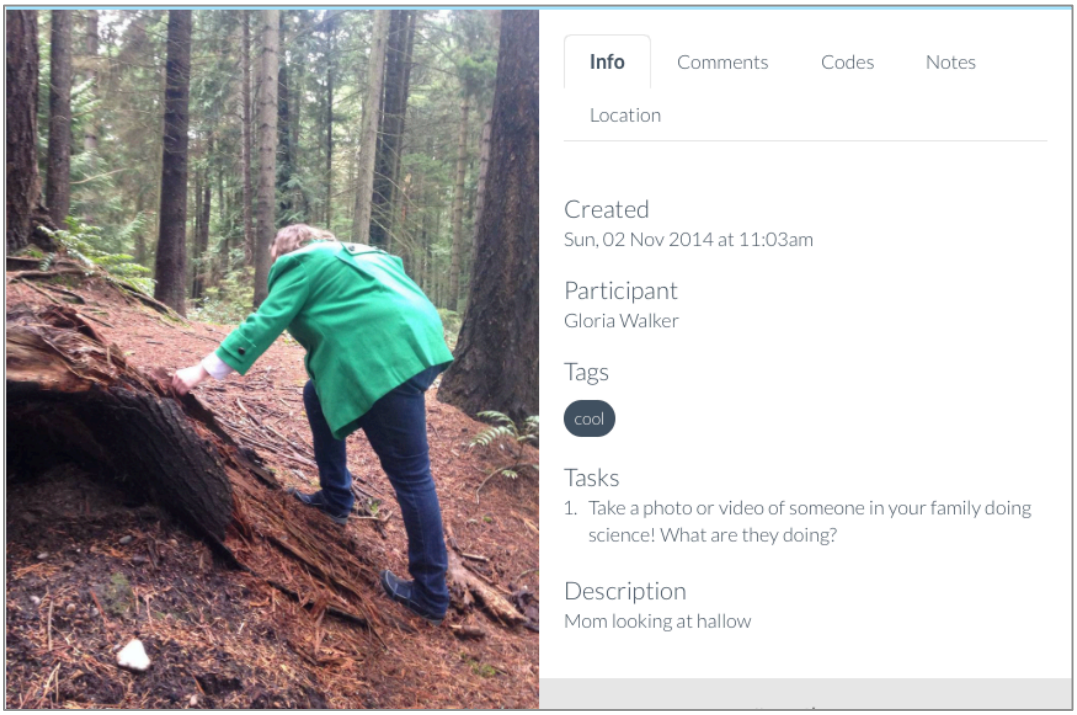


Figure 2-5: Gloria Walker investigating a decomposing tree that she was curious about, photo taken by her daughter

In the paper card version of the activity, the three families all did the activity, checking the "done" boxes on the cards. Lily Gordon wrote that "Daddy did science when he was cooking or hooking wires up in the house" –notable because it is again a reference to someone who wasn't present, and Lily did not include any activities of themselves doing science during their visits – again, leading to questions of their identification with science, or a recognition of their

own activity during these study visits as engagement with science. The Kim family did not write anything on their card, but the mother checked off they did the activity while the children played at a Children's Museum veterinarian office with a microscope and bandaging stuffed animals. The variety of places and activities that the families related to the activity show that the activity prompt is applicable across a range of places, but in each of the paper card cases, it was the parent making the connection and noting it on the cards, while in the App, the child was making the connection jointly with an adult. This holds true again for the third family who used the cards, who are profiled in the following case study about the positioning of family members doing "real" science and being "real" scientists.

Case Study: The activities spark questioning of "Real" Science. One family received the first version of the activities with "real" in the text, and this issue of "real" was a topic that arose for the Knots family across the settings, and was directly prompted by their use of the activities as they negotiated the meaning of who was a "real" scientist, the merit of "real" objects in the museum, and what counted as doing "real" science. The Knots strongly identify with science, and noted in their opening interview that they do science activities and watch science shows on television for fun.

In the opening interview with all the families, I asked the parents about how they talked about science with their children. Elizabeth answered this question at length, saying:

> Sometimes we will watch a show or read a book and say this is about whatever we're reading about or watching about and talk about that…we talk about it in terms of, if they have a question, like 'oh how could we test that' or … if they have a question about something, asking them more questions, like how we would figure it out…. And then really trying to be observant about, you know, what's going on around us, and paying

> attention to it. And sometimes we do it a better job than other times 'cause as I noticed this morning as I was asking them ‘what do we do…learning about science?’ and so forth. They were stumped for a moment, and then I realized I'm not sure that we explicitly say ‘oh look we're talking about science now,’ that was an interesting realization in our conversation this morning. But I'm very interested in it [science] as well, so oftentimes, it'll be me going ‘Hey, did you know this?’ or ‘This is sort of interesting!’ or trying to point something out that I see.

For Elizabeth, teaching science was about asking questions, thinking about how to figure out the answer to the question, paying attention –observing and commenting on – the things around them. Elizabeth’s statement was very self-aware of her style of asking the boys to observe and notice, her own enthusiasm for science (especially paleontology), as well as her style of persuading their interest by saying that things were “cool” or interesting was observable throughout the three study visits. This sense of teaching her children science in ways that are more like the practices of science specific notion of science is somewhat in tension for her, as Elizabeth also looks for specific criteria of what counts as science. The activities, and participation in the study, had a direct influence on Elizabeth’s construal of “real” science.

While having a snack at the Burke Museum Café, the boys were interested in my video camera and the audio through the microphones. Shawn and Brady playfully trying various ways of making the sound quiet and loud by rolling the microphone inside their shirts, and hearing how the audio split though each side of the headphones. The boys were enjoying it, making silly faces into the camera, when Elizabeth exclaimed partly to herself and partly to the boys: “Wow, this is investigating, like in the cards. This is being like a scientist. Doing an investigation but it’s not big, just doing it, asking questions and messing around.” At the end of their visit they sat on a

bench near the exit and reviewed the cards together, and Elizabeth wrote on the card "Playing w/the video recorder." This came across as an epiphany moment for her, which is how I noted it my fieldnotes. The moment is an expansion of what "science" means to her, from a formal system to a recognition that science can be "asking questions and messing around." This expansion may be momentary or contextual, since Elizabeth later denies that she is a scientist and requires Shawn and Brady to justify why their choice of activity for the study is science.

In the transcript selections that follow, the exchanges between Elizabeth and Shawn show a tension in Elizabeth's conception of who is a scientist. Shawn tries to position Elizabeth as a "real" scientist, which she resists, yet she also tries to show Shawn how his activity is like "real" science. Just a short time after the Café, a few minutes into the next exhibit space, At the Burke Museum, Elizabeth and Shawn approached a demonstration table, where the geology collections manager was preparing to remove a mammoth fossil from its fieldjacket cast. Elizabeth was very interested in paleontology and encourages her children's interest in science, and had been to Montana during a previous summer to participate in a fossil excavation for teachers led by the Burke Museum paleontology staff. To Shawn, this makes her a scientist:

Elizabeth ((to Shawn, while flipping through the cards)): Ah, yeah, he's a real scientist! Remember it was one of our things we could do? Was talk to a real scientist.

Shawn: You are a real one, you did the Burke thing.

Elizabeth: Well I suppose in that ((inaudible)). Hey hey ((reading the activity card)). Notice a real scientist doing science. What is that person doing? What tools are used? Describe the person or group. Notice gender, ethnicity, the clothes they wear, or anything else. Where is the work happening?

Shawn: They're working on a table

Elizabeth: On the table

Shawn: and…

Staff ((holding up the tool)): My special scientific tool, it's a disposable pipette

Shawn: ok

Elizabeth ((to Shawn)): You've used that before

Staff ((laughing)): It costs about 19 cents

When Shawn calls her a real scientist, Elizabeth says "I suppose" but her intonation was that of disavowal, distancing herself from Shawn's vision of her as a scientist. Standing within earshot of the museum staff, she may not want to have made claim to being a scientist, distinguishing an interest from practicing paleontology, although she is deeply interested in science. She then more animatedly reads the activity card aloud, redirecting Shawn's attention to the task. When the preparator points out the tool he is using, even though he laughingly notes how inexpensive it is, Elizabeth reminds Shawn that he used a tool just like the one the scientist is using – positioning Shawn as having engaged in authentic science by using the same (if cheap and disposable) tool.

A few minutes later, as they walk away from the demonstration table, Elizabeth excitedly talks to Shawn and Brady about a second paleontology fossil preparator who talked to them, as if she'd had a celebrity sighting. She tells them he was the lead on her fossil dig (a summer professional development program for teachers run through the Burke Museum), an influence from the past influencing the present moment, and the following exchange between Shawn and Elizabeth shows how she doesn't consider herself a scientist. They have stepped away from the table where the preparators were working, and both boys stand next to Elizabeth.

Elizabeth: Do you remember when I was in Montana? He was working on those

hadrosaur bones. ((Smiling, glances back towards the preparators)) He won't remember

me, because there were a lot of us, but um he was there with some other scientists and he was digging out that hadrosaurus I showed you pictures of.

((They talk about the photo))

Shawn: Maybe you could introduce yourself?

Elizabeth: I could, but he's busy //and it's not worth it.

Brady: //oh

Shawn sees his mother as a scientist, since she went on the fossil dig, she has photographs of the fossils she excavated, and she says she knows these scientists. She may have been developing a science identity that summer, yet the large scale of the short summer experience also meant she didn't make a deep connection with the scientists involved, keeping them at a distance from herself and keeping an image of scientists as different. Elizabeth does not identify herself as a scientist, even as she tries to encourage Shawn's and Brady's interest in science and their alignment with science activities, such as using the same tools they see the scientist using.

Elizabeth needed to be persuaded when they were deciding on their choice of place for their study visit. Though she was willing to be persuaded, Shawn had to argue with the all the "official" language he could muster when the boys proposed riding bikes at the BMX bike park. Elizabeth did not want to allow watching *MythBusters* or *Cosmos*, because that would be boring for purposes of the study. Shawn suggests the beach, but when Brady quietly suggests riding bikes Shawn takes up the idea:

Shawn: beach beach beach

Andy: Riding bikes? ((looks to Suzanne))

Shawn: Riding bikes!

Elizabeth: beach riding bikes

Shawn: Riding bikes riding bikes riding bikes. I would love to do it. For science. Momentum. ((looks to Elizabeth and smiles))

Brady: Ahhh, speed.

Shawn: No momentum ratio ((looking at Elizabeth)) like the speed of turning pedals, speed, the speed of the bike.

Elizabeth: okay. So then my question becomes then when we ride bikes generally they just go ride bikes and we don't stop and talk about what's going on. so would we want to sort of frame it as what are we doing here as scientists while we're ...

Shawn: Momentum. Maximum velocity. On BMX bike parks, we can talk about gravitational pull, like, what how much momentum would you need to make it go up a slope like this with the gravitational pull working against you ((holding up one hand upright, flat, and running flat hand up)) cause you slow down ((nodding head to "slow down")) like this you couldn't do this, but you could normally do whee ((gesture of "bike" going over the hand, off a jump))

Elizabeth: So what do you think, does that appeal to you?

Brady: What?

Elizabeth: Riding bikes...this idea of riding bikes, we could meet at the BMX park but that there would be some amount of just riding around having a good time, but then could we sort of then look at the practices...

Shawn: After every few times we run through we would talk about it like what scientists

((Side conversation))

Elizabeth ((to Suzanne)): What do <u>you</u> think?

Suzanne: I'm fine going to BMX park, the connection to science doesn't have to be obvious

Elizabeth: oka::y ((sounding skeptical))

When they propose the idea, Shawn immediately knows he has to justify the connection to science (Line 28) so that this entertaining activity will be counted as science (Rosebery, Warren, Ballenger, & Ogonowski, 2005), and Brady jumps in too – and Elizabeth calls Shawn on it after their riding at the BMX bike park. The following is a transcript of Elizabeth, Shawn and Brady talking about what makes bike riding science at the end of their rides and when we together reviewed their video at the park.

Elizabeth: Before we came here, when you guys were convincing me this was the place to come, you listed like 5 or 6 different scientific things, ideas that you felt the BMX bike park supported.

Shawn: What were they?

Elizabeth: Momentum was one of 'em, but you talked about some other things too, do you remember any of 'em?

Shawn: Um, like, ((rotating his index fingers around in a circle)) um, what speed you can get up to, with like, specific pedal strategies?... So how like, you could accelerate?

Elizabeth: Like if I were to say, you had to convince me again, to come back, what would you think about, what scientific merit does this track have?

Shawn: definitely still momentum,

Elizabeth: Ok we got momentum, yeah

Shawn: But like, umm, how much harder it is to get up the hills than down

Elizabeth: What do you attribute that to?

66 Shawn: Hum, I don't know, gravity.

67 Elizabth: Yeah. What do you think ((looking at Brady))

68 Brady: ummm

69 Elizabeth: Sooo gravity, momentum acceleration ((Shawn is now making faces and

70 singing into the camera, we soon ended))

Shawn doesn't seem to have the words to explain the sensations and physical movement he associates with physics in justifying his rationale, so he uses gestures to explain the sensations of movement (Line 58-59). He has done this several times already in our conversation about riding bikes, using gestures to describe the movement of the bike. However, Elizabeth does not seem satisfied with his explanations and arguments about bicycling, since she continues to prompt for the language she wants Shawn to use. Participating in the activities has a direct influence on her conception of science, that relate to what and who does "real" science.

Key Practice 3: Adults Modeling Learning

In the third family practice I wish to examine, this section looks at how parents socially and physically modeled learning for their children, and their how their social practices in guiding their children prompted reactions to the activities.

One of the activities asked: "Grownups: What is something YOU are curious about? Take a picture or video, or make a note. How can you find out more?" All but one of the families completed that task, and the children were interested in what their parent had to say, prompting them. In one exchange, mother Lily Gordon said to daughter Ruby, as she pondered her answer to the prompt:

71 Lily: What was I curious about? What *was* I curious about? What about all the…

72 Ruby: What are you curious about mom? ((smiling))

> Lily: I was curious about all the Ripley's stuff because it's real, but it's stuff that you don't expect, what I thought was cool was the history of the guy who started that, what he did before he did cartoons, sports, he drew pictures, that was like before TVs. It was kind of interesting to see, he did all that before internet."

Lily wrote down: "All the Ripley's [Believe it or Not! at the Pacific Science Center] history and stuff," next to what she had written at the Aquarium: "How sea creatures are taken care of properly. Asking helpers." These were two areas that this mother seemed interested in, as notable in the video data as well – at the Aquarium on their second study visit, she had been persistent in asking the staff about feeding the animals in the touch pools and care of the harbor seals. Another mother, Gloria Walker, took one turn from her daughter to take a photo and share it to the EthosApp site during her urban forest walk. Before taking the photo, Gloria and Hope tried to identify the growth, unsure if it was fungus, lichen, moss, but it was the bright yellow color that caught their attention. When they could not identify it, the photo was meant to prompt their memory later and Gloria tagged it as "gross" and wrote "Fungus?" (Figure 2-6). The adults were making explicit their own curiosity and ways of investigating the things they wanted to know more about, modeling learning for their children.

The way learning and doing science was modeled in the Evans family meant that mother Donna did not like the study's activities based on the practices of science. Their family's social practices and pedagogical approach to science was more traditional for Donna Evans: science for her, and for how she engaged with her daughter, was to identify and share factual information during their experience, and she did not connect the practices as presented in the study activities to science learning. When asked about the nature of the activities, Donna did not find value in them, saying in her concluding interview "they were too general." As an informal science

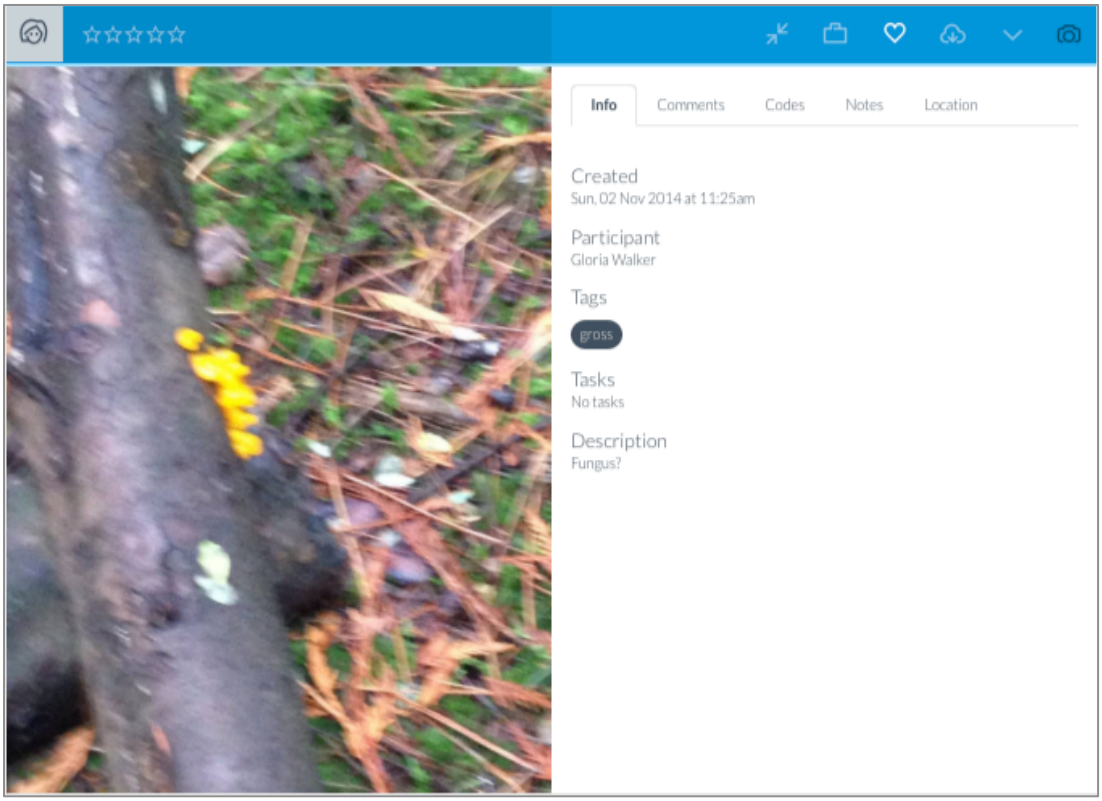


Figure 2-6: Gloria Walker's photograph of something she was curious about

educator herself, and from their family practices of sharing information on exhibit labels, Donna was interested in communicating facts and content about science, and were expecting a more structured guide. They used the EthosApp, but Sofia took only three photos to load onto the App in two study visits, although they both took many photos. They did not use the app or the activities at all on their third study visit to the Aquarium; during that visit, Sofia had her own digital camera and took photos she said she would later show her grandfather. Donna Evans and her daughter Sofia liked to identify and name animals, plants and objects during their study visits, which was consistent with how Donna said she would like to be able to use technology in her work. Donna and her daughter Sofia frequently used Donna's smartphone to look up information to their own questions that were not available through the exhibit labels or by talking

to interpretive staff. For example, at the zoo, Sofia asked why some flamingos had more black coloring than others. The zoo label only addressed the flamingo's pink color, so Donna did a Google search to find out, holding the phones and reading aloud to Sofia from a webpage. In another instance, at the Aquarium, Donna looked up the hooded nudibranch, a kind of sea slug, because she thought she remembered that they smell like watermelons when taken out of the water, and wanted to confirm that (more discussion on this is in Chapter 3). When asked about using the smartphone, Donna said she was interested in using mobile technology in her work as a professional educator, leading school tours at an informal environmental education center, so that she could look up information to student's questions in the moment, or show pictures of animals when they weren't available or in easy viewing during tours.

Conclusions & Implications

The aim of the project was to help families generate and recognize continuity across their science learning experiences, across the boundaries of place and time, through an object along with practices that mediate activity and sense-making interactions. To stimulate those connections, I hoped to relate social practices to epistemic practices. Given the findings presented here, I would refine my original design conjectures to reflect the three key findings with design implications. First, participation in practices can build a better understanding of the nature of science, but it must be made explicit how the practices, or ways of thinking scientifically, are a worthwhile part of science and how they can be performed in an informal setting. As in school settings, transforming the conception of science as a collection of facts into a collection of practices that involve ways of thinking and doing, requires a willingness to engage with materials and through activity in ways that may be resisted when it is a different form of social practice.

The division of labor tied to mode of engagement has implications for the design of interactions in designed, informal learning settings. Implications of the finding that using the mobile app did not lead to repeated engagement with the tasks, since the child was directing the activity, leads to design considerations: if the leading design intention is for the child to take up or direct the activity, then taking photographs is a practice that can be leveraged for children, even if they complete a less diverse range of activities related to science – which could lead to repeat use. Repeated engagement leads to deeper learning - given scaffolds for reflection (Land et al., 2013), and additional design element could facilitate parent-child talk and interaction around scientific practices.

Finally, awareness of the social or scientific practices, such as the behaviors of parents modeling learning behaviors or when they began to think about science as "messing around" happen at a metacognitive level, that requires reflection at a level of sophistication and time-involvement that may not be reasonable in leisure activities. The nature of these designed activities mean that the families are at the boundary of what counts as science, who counts activity as scientific, and how to translate everyday social practices into scientific practice.

References

Akkerman, S. F., & Bakker, A. (2011). Boundary crossing and boundary objects. *Review of Educational Research*, *81*(2), 132–169. doi:10.3102/0034654311404435

Alexander, E. (1996). *Museums in Motion*. Walnut Creek, CA: AltaMira Press.

Allen, S., & Gutwill, J. P. (2009). Creating a program to deepen family inquiry at interactive science exhibits. *Curator: The Museum Journal*, *52*(3), 289–306. doi:10.1111/j.2151-6952.2009.tb00352.x

Ash, D. (2003). Dialogic inquiry in life science conversations of family groups in a museum. *Journal of Research in Science Teaching*, *40*(2), 138–162. doi:10.1002/tea.10069

Bang, M., & Medin, D. (2010). Cultural processes in science education: Supporting the navigation of multiple epistemologies. *Science Education*, *94*(6), 1008–1026. doi:10.1002/sce.20392

Banks, J. A., Au, K., Ball, A., Bell, P., Gordon, E., Gutierrez, K., … Zhou, M. (2007). *Learning In and Out of School in Diverse Environments: Life-long, life-wide, life-deep*. Seattle.

Barab, S. A., Thomas, M. K., Dodge, T., Squire, K., & Newell, M. (2004). Critical design ethnography: Designing for change. *Anthropology & Education Quarterly*, *35*(2), 254–268. doi:10.1525/aeq.2004.35.2.254

Barron, B. (2004). Learning Ecologies for Technological Fluency: Gender and Experience Differences. *Journal of Educational Computing Research*, *31*(1), 1–36. doi:10.2190/1N20-VV12-4RB5-33VA

Barron, B. (2006). Interest and self-sustained learning as catalysts of development: A learning ecology perspective. *Human Development*, *49*(4), 193–224. doi:10.1159/000094368

Bell, P. (2004). On the theoretical breadth of design-based research in education. *Educational Psychologist*, *39*(4), 243–253. doi:10.1207/s15326985ep3904

Bell, P., Bricker, L., Lee, T. R., Reeve, S., & Zimmerman, H. T. (2006). Understanding the cultural foundations of children's biological kowledge: Insights from everyday cognition research. In S. A. Barab, K. E. Hay, & D. Hickey (Eds.), *Proceedings of the seventh international conference of the learning sciences (ICLS)* (pp. 1029–1035). Mahwah, NJ: Lawrence Erlbaum Associates.

Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (Eds.). (2009). *Learning Science in Informal Environments: People, Places and Pursuits*. Washington D.C.: National Academies Press. doi:10.17226/12190

Bell, P., Tzou, C., Bricker, L., & Baines, A. D. (2012). Learning in diversities of structures of social practice: Accounting for how, why and where people learn science. *Human Development*, *55*, 269–284. doi:10.1159/000345315

Brewer, W. F., & Lambert, B. L. (2001). The theory-ladenness of observation and the theory-ladenness of the rest of the scientific process. *Philosophy of Science*, *68*(3), S176–S186.

Bricker, L. A. (2008). A sociocultural historical examination of youth argumentation across the settings of their lives: Implications for science education. Unpublished doctoral dissertation. University of Washington, Seattle, WA.

Bricker, L. A., & Bell, P. (2014). “What comes to mind when you think of science? The perfumery!”: Documenting science-related cultural learning pathways across contexts and timescales. *Journal of Research in Science Teaching*, *51*(3), 260–285. doi:10.1002/tea.21134

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of the Learning Sciences*, *2*(2), 141–178. doi:10.1207/s15327809jls0202_2

Cahill, C., Kuhn, A., Schmoll, S., Lo, W., McNally, B., & Quintana, C. (2011). Mobile learning in museums. In *Proceedings of the 10th International Conference on Interaction Design and Children - IDC ’11* (pp. 21–28). New York, New York, USA: ACM Press. doi:10.1145/1999030.1999033

Callanan, M. A., Shrager, J., & Moore, J. L. (1995). Parent-Child Collaborative Explanations: Methods of Identification and Analysis. *Journal of the Learning Sciences*, *4*(1), 105–129. doi:10.1207/s15327809jls0401

Crowley, K., Callanan, M. A., Tenenbaum, H. R., & Allen, E. (2001). Parents explain more often to boys than to girls during shared scientific thinking. *Psychological Science*, *12*(3), 258–61. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11437311

Dawson, E. (2014). “Not Designed for Us”: How Science Museums and Science Centers Socially Exclude Low-Income, Minority Ethnic Groups. *Science Education*, *98*, 981–1008. doi:10.1002/sce.21133

Dudzinska-Przesmitzki, D., & Grenier, R. S. (2008). Nonformal and informal adult learning in museums. *Journal of Museum Education*, *33*(1), 9–22. doi:10.1080/10598650.2008.11510583

Eberbach, C., & Crowley, K. (2009). From everyday to scientific observation: How children learn to observe the biologist’s world. *Review of Educational Research*, *79*(1), 39–68. doi:10.3102/0034654308325899

Edelson, D. C. (2002). Design research: What we learn when we engage in design. *Journal of the Learning Sciences*, *11*(1), 105–121. doi:10.1207/S15327809JLS1101_4

Fender, J., & Crowley, K. (2007). How parent explanation changes what children learn from everyday scientific thinking. *Journal of Applied Developmental Psychology*, *28*(3), 189–210. doi:10.1016/j.appdev.2007.02.007

Fortus, D. (2009). The importance of learning to make assumptions. *Science Education*, *93*(1), 86–108. doi:10.1002/sce.20295

Gleason, M. E., & Schauble, L. (2000). Parents’ Assistance of Their Children's Scientific Reasoning. *Cognition and Instruction*, *17*(4), 343–378. doi:10.1207/S1532690XCI1704

Goodwin, C. (1994). Professional Vision. *American Anthropologist*, *96*(3), 606–633.

Goodwin, M. H. (2007). Occasioned knowledge exploration in family interaction. *Discourse & Society*, *18*(1), 93–110. doi:10.1177/0957926507069459

Henkel, L. a. (2014). Point-and-shoot memories: the influence of taking photos on memory for a museum tour. *Psychological Science*, *25*(2), 396–402. doi:10.1177/0956797613504438

Hidi, S., & Renninger, K. A. (2006). The Four-Phase Model of Interest Development. *Educational Psychologist*, *41*(2), 111–127. doi:10.1207/s15326985ep4102_4

Housen, A. (2002). Æsthetic thought, critical thinking and transfer. *Arts and Learning Research*, *18*, 99–132.

Housen, A., & Yenawine, P. (2001). Basic VTS at a Glance. New York: Visual Understanding in Education.

Houston), (Children's Museum of. (2010). *Visitor Smartphone Interest Inventory*. Houston. Retrieved from http://www.21-tech.org/wp-content/uploads/2012/03/CMH-Visitor-Interest-Inventory-for-Blended-FINAL.pdf

Hsi, S. (2003). A study of user experiences mediated by nomadic web content in a museum. *Journal of Computer Assisted Learning*, *19*(May), 308–319.

Hsi, S. (2004). *I-Guides in progress: Two prototype applications for museum educators and visitors using wireless technologies to support informal science learning*. San Francisco. Retrieved from exploratorium.edu

Ito, M., Gutierrez, K., Livingstone, S., Penuel, B., Rhodes, J., Salen, K., … Watkins, S. C. (2013). *Connected learning: An agenda for research and design*. Irvine, CA: Digital Media and Learning Research Hub.

Knorr Cetina, K. (1999). *Epistemic cultures: How the sciences make knowledge*. Cambridge, MA: Harvard University Press.

Land, S. M., Smith, B. K., & Zimmerman, H. T. (2013). Mobile Technologies as Mindtools for Augmenting Observations and Reflections in Everyday Informal Environments. In J. M. Spector, B. B. Lockee, S. E. Smaldino, & M. Herring (Eds.), *Learning, problem solving and mind tools: Essays in honor of David H. Jonassen* (pp. 214–228). New York: Routledge.

LeCompte, M., & Schensul, J. (2013). *Analysis and Interpretation of Ethnographic Data: A Mixed Methods Approach* (2nd ed.). Lanham: AltaMira Press.

Lee, C. D. (2008). The Centrality of Culture to the Scientific Study of Learning and Development: How an Ecological Framework in Education Research Facilitates Civic Responsibility. *Educational Researcher*, *37*(5), 267–279. doi:10.3102/0013189X08322683

Lemke, J. L. (2000). Across the scales of time: Artifacts, activities, and meanings in ecosocial systems. *Mind, Culture, and Activity*, *7*(4), 273–290. doi:10.1207/S15327884MCA0704

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching*, *38*(3), 296–316. doi:10.1002/1098-2736(200103)38:3<296::AID-TEA1007>3.3.CO;2-I

McClain, L. R., & Zimmerman, H. T. (2014). Prior experiences shaping family science conversations at a nature center. *Science Education*, *98*(6), 1009–1032. doi:10.1002/sce.21134

McManus, P. (1994). Families in museums. In R. Miles & L. Zavala (Eds.), *Towards the Museum of the Future: New European Perspectives* (pp. 81–97). London: Routledge.

Miles, M., Huberman, A., & Saldaña, J. (2014). *Qualitative data analysis: A methods sourcebook* (Third.). Thousand Oaks, CA: Sage Publications.

National Research Council. (2012). *A framework for K-12 science education: practices, crosscutting concepts, and core ideas*. Washington D.C.: The National Academies Press.

Osborne, J. F., & Patterson, A. (2011). Scientific argument and explanation: A necessary distinction? *Science Education*, *95*(4), 627–638. doi:10.1002/sce.20438

Palmquist, S., & Crowley, K. (2007). From teachers to testers: How parents talk to novice and expert children in a natural history museum. *Science Education*, *91*(5), 783–804. doi:10.1002/sce.20215

Penuel, W. R. (n.d.). Theorizing learning in practice: A research agenda for studying science learning across settings and time.

Penuel, W. R. (2014). Studying science and engineering learning in practice. *Cultural Studies of Science Education*, (August). doi:10.1007/s11422-014-9632-x

Reeve, S., & Bell, P. (2009). Children's self-documentation and understanding of the concepts "healthy" and "unhealthy." *International Journal of Science Education*, *31*(14), 1953–1974. doi:10.1080/09500690802311146

Rosebery, A., Warren, B., Ballenger, C., & Ogonowski, M. (2005). The generative potential of students' everyday knowledge in learning science. In T. Romberg, T. Carpenter, & F. Dremock (Eds.), *Understanding mathematics and science matters* (pp. 55–80). Mahwah, NJ: Erlbaum.

Rouse, J. (1994). Engaging science through cultural studies. In *Proceedings of the Biennial Meeting of the Philosophy of Science Association* (Vol. 2, pp. 396–401). doi:10.2307/192951

Sandoval, W. (2013). Conjecture mapping: An approach to systematic educational design research. *Journal of the Learning Sciences*, *23*(1), 18–36. doi:10.1080/10508406.2013.778204

Sandoval, W. A., & Bell, P. (2004). Introduction Design-Based Research Methods for Studying Learning in Context: Introduction. *Educational Psychologist*, *39*(4), 199–201. doi:10.1207/s15326985ep3904

Sandoval, W., & Reiser, B. J. (2004). Explanation-driven inquiry: Integrating conceptual and epistemic scaffolds for scientific inquiry. *Science Education*, *88*(3), 345–372. doi:10.1002/sce.10130

Siegel, D. R., Esterly, J., Callanan, M. A., Wright, R., & Navarro, R. (2007). Conversations about science across activities in Mexican-descent Families. *International Journal of Science Education*, *29*(12), 1447–1466. doi:10.1080/09500690701494100

Star, S. L., & Griesemer, J. R. (1989). Institutional ecology, `translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science*, *19*(3), 387–420. doi:10.1177/030631289019003001

Yenawine, P. (2013). *Visual Thinking Strategies: Using Art to Deepen Learning Across School Disciplines*. Cambridge, MA: Harvard Education Press.

Zimmerman, H., Perin, S., & Bell, P. (2010). Parents, science, and interest: The role of parents in the development of youths' interests. *Museums & Social Issues*, *5*(1), 67–86. doi:10.1179/msi.2010.5.1.67

Zimmerman, H. T., & McClain, L. R. (2013). Intergenerational learning at a nature center: Families using prior experiences and participation frameworks to understand raptors. *Environmental Education Research*, 1–25. doi:10.1080/13504622.2013.775219

Zimmerman, H. T., Reeve, S., & Bell, P. (2008). Distributed expertise in a science center: Social and intellectual role-taking by families. *Journal of Museum Education*, *33*(2), 143–152. doi:10.1080/10598650.2008.11510595

Zimmerman, H. T., Reeve, S., & Bell, P. (2009). Family sense-making practices in science center conversations. *Science Education*, *94*(3), 478–505. doi:10.1002/sce.20374

CHAPTER 3: The Beauty of Learning Together: Families' Aesthetic Experience in the Practices of Science

The important ideas, behaviors and dispositions science educators often seek to instill in students are drawn from a particular view of the discipline of science – involving characteristics such as being analytical, logical, objective and methodical—so students come to believe that to be good scientists, they should removed, critical observers of objects, events and the world (Darby, 2006). The study of "beauty and the understanding of that which is beautiful as known by the senses and emotional effects" (Root-Bernstein, 2002) does not at first seem to have much to do with science when science is considered an endeavor founded on the principles of logic, reason and objectivity. However, many scientists acknowledge the creative wonder, the sensual and emotive components of their drive to experience and explain an intellectual and physical beauty, as expressed by Henri Poincare: "The scientist does not study nature because it is useful to do so. He studies it because he takes pleasure in it; and he takes pleasure in it because it is beautiful. If nature were not beautiful, it would not be worth knowing and life would not be worth living.…intellectual beauty is what makes intelligence sure and strong" (Poincare, 1946, pp. 366–367, as quoted in Root-Bernstein, 2002).

As the study of beauty and pleasure, the aesthetics of science is the sense of wonder, of awe, an expansion of perception, a sense of ideas enriching our lives, and contributes to meaning-making and sense-making while driving a passion and motivation to discover and learn. Aesthetic language is a means of communicating value throughout the activity, a value that is intrinsically tied to understanding science, yet is not often recognized in science and science learning. By ignoring the aesthetic aspects of learning science, or devaluing it as mere

entertainment, educators/researchers miss a way of understanding how people connect with the scientific enterprise while learning science - and of cultivating a very real way that scientists find their work a creative endeavor, understand phenomena, and make judgments about their work. Indeed, the first overarching goal of the *Framework for K-12 Science Education* is that "all students have some appreciation of the beauty and wonder of science" (NRC, 2012, p. 1) and many science educators recognize and try to cultivate the positive emotion that acts as a hook to inspire interest and motivation. Emotional engagement can be seen to be a constituent feature of making sense of the natural world.

To more accurately reflect the practice of science and broaden the range of participation in science, Lemke (2001) called for the consideration of aesthetics and the emotion of the humanities in science education:

> I do not think we in science education have paid much attention to understanding the aesthetics of science or of learning. …Why do we not?...Who is attracted to science presented as purely rationalistic and affectless? …What kinds of identities are recruited and what kinds excluded by this narrow view of science – one that is contradicted repeatedly by creative scientists? (p. 310).

A narrow, dexcontextualized view of when science happens and who is capable of doing science science can alienate people of all demographics from participating in science (Bennett & Eglash, 2013), excluding those people who might have a stronger identification with science if only the affective and creative aspects were not overlooked in the learning and teaching of science.

What is the role of aesthetic experience in learning science and in identifying with the scientific endeavor? This is the broad question I address in this paper through two focused research questions: What are the varied meanings of aesthetic words and the nuance associated

with them in science learning? How does aesthetic experience position science as a valued way of knowing?

As I will use it here, aesthetics is not art nor the relationship of art to science, although that is a frequent intersection explored in science education. I take aesthetics as a particular take on science, the practice of engaging with and making sense of natural phenomena, and the process of learning science that takes into consideration the emotional, cognitive and social/cultural situatedness of the doing of science along with the norms and values that must be communicated or negotiated while coming to an understanding of what counts as science. I do not wish to take the tack of integrating art and science, but rather, I desire to understand and examine the particular aesthetic of science learning and how aesthetic aspects of experience, judgment and an understanding of science come to be communicated, appropriated and negotiated through one's identity in everyday moments of family learning. In order to accomplish this, highlighting some of the central dimensions of this view of orienting to an aesthetics of science learning is helpful.

Three Dimensions of Aesthetics in Science and Science Education

The aesthetic experience of doing science has been described as the exhilaration of discovery, creativity and innovation, the anticipation of solving a problem – the thrill of challenge, of grappling with the unknown, and mastering it – and coming to satisfying and appropriate conclusions within the epistemic value systems of science. Often considered separate from cognition, aesthetics is typically classified within the affective domain, along with beliefs, values, attitudes, emotions and feelings, self-concept and identity (Allen, 2002; Darby, 2006). However, the intertwining of emotion and cognition in aesthetic experience (Zembylas, 2005) is an important part of conceiving how aesthetics is a fundamental part of science: the aesthetic

experience of science is a combination of immediate perception and of intellectual analysis of phenomena (Flannery, 1992). Scientists combine the affective state along with the cognitive to come to an appreciation of their experience as intellectual beauty.

Aesthetic dimensions of learning science communicate epistemic values (such as simplicity and elegance) and function to issue normative judgment (Östman & Almqvist, 2011), all while a creating deeper understanding and appreciation of the phenomena or object. Three primary dimensions of aesthetics in science became evident to me through a review of the philosophical and science studies literature and an analysis of how aesthetics has been used in science education: experience, appreciation or understanding, and judgment of epistemic value. These dimensions are intertwined, so that an experience leads to understanding and appreciation, but making judgments makes that understanding possible within a particular frame of scientific value, that in turn shapes ones' positive or negative experience.

Aesthetic experience. Experience is a commonly used term in education—one that doesn't invite much reflection because it is so common. Yet an experience, and an aesthetic experience in particular, once theorized, has a deeper meaning (Roth & Jornet, 2014). Experience is category of thinking, defined by Roth and Jornet (2014) building on the theories of Vygotsky and Dewey, in a sense that is useful here: Experience encompasses change and transformation itself, that extends across space and time, and across individuals and setting in the course of societal relations that are perfused with affect. Everyday experience, or experience in general, is distinguished from one more momentous, termed "An Experience" by Dewey as event that is complete, is easily remembered, and is differentiated from other events and experiences, that brings about a transformation of one's relationship with the world (Pugh & Girod, 2007, p.11). This meaning of experience is associated with moments of anticipation and

develop towards consummation and fulfillment (Dewey, 1934; Jakobson & Wickman, 2007). Educators might recognize "An Experience" as the behaviors and intellectual engagement that brings about that so-called "ah-ha moment," where having an idea seizes learners and transforms them, moving an event forward with dramatic energy so the person is inspired to act either physically or in their imagination (Wong & Pugh, 2001). Experience is inseparable from *doing*– this doing coming in the form, for example, of reading about science in books, watching or recreating demonstrations, or in solving a novel problem. Problem solving, or science-in-the-making from first conception of a project, through analysis and concluding with a scientific discovery, involves intuitions, guesses, daydreams, and thematic commitments (Flannery, 1992) that hold the excitement of the creative and speculative process, which make up aesthetic experience.

Understanding and appreciation. The phases of an aesthetic experience lead to a greater sense of "knowing" what one is experiencing. Aesthetic understanding "is a rich network of conceptual knowledge combined with a deep appreciation for the beauty and power of ideas" that results in a change in perception of the world and future experiences (Girod, Rau, & Schepige, 2003, p. 577). In coming to deeper understanding or appreciation of an object or idea, one must have had both the preliminary perception of an object in combination with a reflective investigative-cognitive attitude that is rational and analytical - so that when one comes to ultimately "know" the object of study, it has a quality which is felt as much as known so that it becomes "more beautiful" (Ingarden, 1961, p. 301).

Appraising the *merit* of an object is a way of evaluating the beauty or worthiness of the object. As an example from the context of this study, an object is perceived to have a greater value in a museum if it is 'real' rather than a replica, or, that "real" science can only be done by

"real" scientists (as in the Knots' family case in Chapter 1). To take an analogy from art by McAllister (1996), an artwork may not be beautiful but still might possess artistic *merit* by virtue of having originality. Or, an object may be beautiful but it is a replica – so that even though it is perceptually indistinguishable from another beautiful object, so it too must be considered beautiful, nonetheless, the replica has less merit because of other, relational properties that are not manifest in the replica. For example, the properties attributable to the original, such as having had a particular history, or standing, such as having had an influence on the development science (McAllister, 1996) imbibe the original with a value that is not present in a replica. Differentiating models from an authentic object, not only has abstract philosophical aesthetic connotations, but has important implications for learning about, developing and using models of all kinds in science.

Judgments of epistemic value and form. Intellectual analysis comes in the form of epistemic values, which must be taught and learned in science education. Scientists and philosophers have long discussed the role of aesthetics in science—with aesthetic considerations almost a hidden aspect of practice that should not have a place in a rational, logical and empirical mode of inquiry into nature. The logical positivist concession that aesthetic factors could have a role in the context of discovery, but reject aesthetic evaluation of theory is a view that continues to overshadow the discussion of the roles of aesthetics in science (McAllister, 1996). Yet, many scientists attribute beauty or sensual modes of engagement with their work as motivation and some scientists argue that beauty is an indicator of the truth of a theory (Chandrasekhar, 1987).

The aesthetic evaluation of *experiment* and veracity of *theory* are the two leading areas of discussion in the philosophy of science that is grounded the historical development of Western science, which leads into a consideration of epistemic value. Aesthetic aspects in physics and

mathematics are recognizable as elegance, unity, economy, symmetry, harmony, order, coherence, simplicity, fruitfulness; biology might have other attributes such as diversity, complexity and organicism (McAllister, 2002). As epistemic evaluation criteria that otherwise might be disregarded as non-empirical, they are still "significant as an indicator of understanding and a justification for believing a theory is important" (Kosso, 2002, p. 47). By having such an epistemic role (Kosso, 2002), they may more accurately be considered "epistemic assessments" (Todd, 2008, p. 61) or values. Such aesthetic properties are not inherent to the object or phenomena, but are projected onto it by the cultural and epistemological orientations of the scientist, the community of scientists, or other learners as they make sense of nature (Bang & Medin, 2010; Medin & Bang, 2014). An aesthetic value such as beauty "has an evaluative component, implying judgments about the object's goodness, importance, or desirability" (McAllister, 1996, p. 30), where the very definition of beauty is culturally shaped.

In education, aesthetic judgments serve a normative function, as such appraisals direct what is appropriate and to what learners are expected to pay attention. Taking a pragmatic view of aesthetic experience, how people proceed with activity has consequences for what they learn – and a close study of aesthetic language and subsequent actions reveals the connection in the process of meaning-making (Wickman, 2006). In classroom-based studies, positive and negative aesthetic experience directed student actions, for example, a freshman college chemistry teacher used phrases such as: "Let's see you've got many…chlorides that are *fun* here. Could you find out the silver nitrate?" and " What more do you've got here that is *exciting."* Calling the chemicals "fun," and framing the transition of metals as "exciting" is both an encouragement to proceed and an evaluation the enjoyment of the activity (Wickman, 2006, p. 82). Later, as the students proceed with their investigation, the teacher shows that doing fewer tests is not just a

matter of getting points towards their grade on the assignment but "It's a game, this, when it comes to the practical that…using as little equipment, as few tests as possible. The fewer tests you use the more…" A student interrupts: "Points" (as on a test). The teacher continues "…*elegant* it is, you see" (Wickman, 2006, p. 85). In this example, we see the epistemic value of parsimony being taught – not only as points awarded on an assignment, but as a desirable practice in science.

Aesthetic Experience as Doing and Being in the Epistemic Practices and Material Culture of Science

For learners, the experience of doing and interacting with practices and material culture of science is meant to be more than the transmission of established facts and passive acquisition of knowledge on the part of the learner. Regarding science as both collection of ideas and a way of thinking means regarding science as both a product and a practice (National Research Council, 2012; Wickman, 2006). From a science and technology studies perspective, the increasing emphasis on "practice" rather than merely "product" accommodates how what is considered established knowledge can change with new experimental evidence and the influence of new material tools. An emphasis on science as a collection of purposeful sociocultural activities conceptualizes learning and development as changing participation in activities as an active process of doing and becoming (Bell et al., 2012; Rogoff, 2003; Herrenkohl & Mertl, 2010). As a part of this experience of doing and becoming, when science is approached as an identity and habit of mind, "as a practice and a life, aesthetic experiences are an inescapable part of *doing* science" (Wickman, 2006, p. 3).

If practices in science incorporate thinking and doing, then the materials that are bound up in this interaction must have a role. As Rouse writes, "practices are not just patterns of action,

but the meaningful configurations of the world within which actions can take place intelligibly, and thus practices incorporate the objects that they are enacted with and on and the settings in which they are enacted" (Rouse, 1996, p. 135). In learning environments, physical objects are a way for the learners and teachers to focus attention, to share perception and be immersed in a sensual mode of engaging with phenomena while learning. The role of artifacts and objects in teaching and learning science are socially negotiated and framed by institutional and organizational goals, especially in places such as traditional collections-based museums where the artifacts are in the collection because they have scientific or cultural significance (Alexander, 1996).

Learning by engaging with objects and in practices is a way of tracing and linking the constellations of events, people and locations that make up the extended learning pathways that contribute to the development of identity and interest. Linking the aesthetic aspects of learning adds another dimension to recognizing and understanding the continuity in sense-making and learning across time and place that create learning pathways—in ways that are akin to a Deweyan sense of 'experience.' The Cultural Learning Pathways model frames such events as being situated materially and socially, demonstrating that learning is made up of "connected chains of personally consequential activity and sense-making – that are temporally extended, spatially variable, and culturally diverse with respect to value systems and social practices" (Bell et al., 2012, p. 270). That learning is accomplished across by persons acting within diversities of structures of social practice settings draws on the theorizing of Dreier (2009), which Bell et al. summarize:

> [People] live their lives by participating in many diverse contexts. These contexts are local settings which are materially and socially arranged in particular ways to allow for

> the pursuit of particular social practices within and beyond them; *they are re-produced and changed by their participants and separated from and linked to other social contexts in a more comprehensive structural nexus of social practice* [emphasis added] (p. 270).

Here, I consider how aesthetic dimensions of learning are a part of those value systems and the social practices that are negotiated, communicated and linked across space and over time for families as they make sense of natural phenomena of interest.

Methods

To study how aesthetic dimensions of science learning occur over time and in multiple settings, this study is situated in the social practices of family learning in settings that support a significant degree of voluntary learning.

Study Design

Ten families visited three informal learning environments as a part of the study. During the entirety of their visits, the families were video- and audio recorded. As a part of a design-based research study, six families were asked to incorporate a set of eleven activities into their visits. These activities were based on the epistemic practices of science in the Framework for K-12 Science Education and resulting Next Generation Science Standards, and each family chose to do the activities either in a smartphone-based app or paper-based card format. Four families did not use the activities, providing a baseline for how families interacted across the three settings.

Participants

Participants were recruited from the Seattle Aquarium, the Burke Museum, two elementary schools, and a University of Washington college preparatory program for low-income students of color. Families with at least one child entering 3rd-6th grade were eligible to participate; as inter-generational groups, the families defined their significant relationships, and

the groups included parents, siblings, friends, grandparents, and other significant caregivers. At least one parent and one child were asked to be consistent through the three study visits, and other family members could participate as desired. Ten families completed all three visits.

Settings

The families were asked to visit the Burke Museum of Natural History and Culture at the University of Washington, the Seattle Aquarium, and a place of the family's own choosing. The families could choose any kind of place or activity, with the stipulation that it had to be something they liked doing together and they felt it had to do with science in some way. The places the families chose included a Zoo, a local museum of history and industry, walks on nature trails in urban forests, the local science center, bicycling at a BMX bike park, and a children's museum.

Analytical Methods

To analyze how the families convey meaning across the three dimensions of aesthetics in science (experience, understanding and judgment), I use a mixed-methods approach that incorporates ethnographic-descriptive approaches to systemic functional linguistics known as functional grammar (Halliday, 2004) and appraisal analysis (Martin & White, 2005) with the traditional Learning Sciences method of Interaction Analysis (Jordan & Henderson, 1995).

I take mixed-methods approach to address concerns that qualitative approaches seek out phenomena of interest to prove a pet theory (Heath & Street, 2008) and I wish to demonstrate the presence of aesthetic language; yet such quantitative analytical approaches can miss some of the nuance of the data (Guest, MacQueen, & Namey, 2012), that are important here because aesthetics is more than discourse that can be converted to text (Wickman, 2006).

I used qualitative discourse analysis to draw attention to the "micro-negotiations" involving language and silent bodily actions, such as smiles and gestures, to create a more nuanced understanding of aesthetic dimensions in learning processes. To closely analyze the talk and gesture of the participants during the course of their interactions in the research sites, I used Interaction Analysis (Jordan & Henderson, 1995) to analyze the multimodal aspects of communication, with special consideration to multisensory and phenomenological aspects of communication (Pink, 2011) prevalent in aesthetic experience, and Appraisal Analysis (Martin & White, 2005) to elicit the stances towards science conveyed through discourses of solidarity.

Interaction Analysis. In an ethnographic context, Interaction Analysis provides a micro level of analysis of human activities with each other and with objects in their environment. "The first assumption of Interaction Analysis is that knowledge and action are fundamentally social in origin, organization and use, and are situated in particular social and material ecologies" so that the basic data for analysis is found in the details of naturally occurring, everyday social interactions within a community of practice (Jordan & Henderson, 1995, p. 39).

In the process of Interaction Analysis, analytic categories emerge from a deepening understanding of the participants' interactions over the course of multiple re-playings. Short segments of video and audio are selected as a representative and productive event between the participants who share some common task, and both talk and gesture are analyzed moment-to-moment, and turn-by-turn in "micro-negotiations" involving sensory modalities. It is important to note that participants' intentions, motivations, understandings and other internal mental states can not be assumed by the researcher, but can only be referenced by evidence on the video (Jordan & Henderson, 1995), anchoring the interpretation and findings directly from the video evidence.

Appraisal Analysis. Appraisal analysis is concerned with how speakers adopt stances towards the material they present and those with whom they communicate: how the speaker or writer constructs their speech or text to create a shared community of feelings, values and how they position the listeners/readers to do the same. The analysis is traditionally concerned with the linguistic mechanisms for the sharing of emotions, tastes and normative assessments (See Appendix D for Appraisal Resources). I extend the linguistic evidence to include the "paralanguage" - gesture, facial expression, laughter, voice quality and loudness - that Martin and White note are understudied in linguistics research on attitude as the method moves from a functional linguistic to social semiotic perspective (Martin & White, 2005, p. 69), yet are familiar in Interaction Analysis and Leaning Sciences traditions.

Appraisal analysis as developed by Martin and White (2005) is a discourse semantic framework for analyzing feeling conveyed in speech. This form of systemic functional analysis attends to the interpersonal area of attitude and affect, so that the analysis is of how the speaker positively or negatively evaluates the entities, happenings and state-of-affairs of their subject. But this approach goes beyond the presenters' overt encoding of their own attitudes, to an examination of how a speaker positions the listener to respond and take up the same stance (Martin & White, 2005, p. 1-2). Appraisal comprises attitude, engagement and graduation, but this framework focuses on attitude, which is made up of three semantic areas: affect, judgment and appreciation (See Figure 3-1).

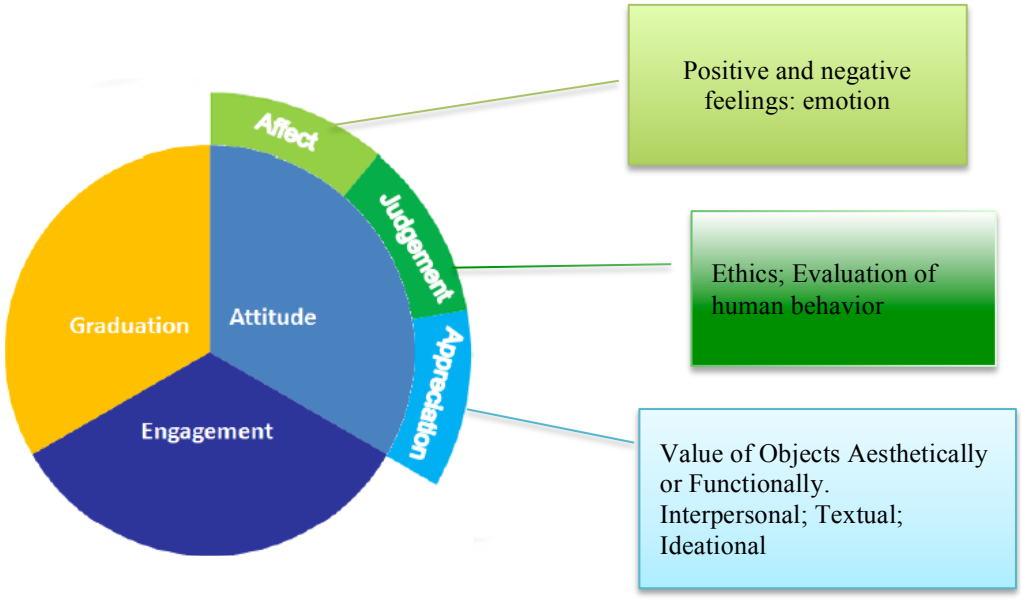


Figure 3-1: Categories of Attitude in Appraisal Analysis (adapted from O'Donnell, 2011)

These are different from the categories that make up my aesthetic dimensions; however they are complementary to understanding how language conveys meaning. In appraisal analysis: *judgment* is an evaluation of human behavior; *affect* is an emotional evaluation of things; and, *appreciation* is the aesthetic or functional evaluation of things, happenings or states. As it relates to the study of aesthetic experience in this paper, it is the conveyance of attitude toward science as a way of knowing, through particular moments of interpersonal experience that conveys positions towards certain identities and values that are socially available.

Functional Grammar Analysis. A linguistic corpus analysis was conducted to examine the frequencies and significance of potential aesthetic discourses, including particles functioning as discourse markers, within the spoken data corpus from the video recordings. Data was taken from the corpus of the six families that used the activities created in the design-based research portion of the study. At 5-minute intervals, all talk was fully transcribed for one minute, including all discourse between the family participants and any interpretive staff they encountered during their study visits. This interval sampling serves to establish that aesthetic

language was being used, without my searching for it: “such a random and detached selection of transcribed material ensures that the ethnographer does not simply select for illustration data that meet or ‘prove’ a pet theory or preconceived idea” (Heath & Street, 2008, p. 90).

The resulting text data was analyzed with T-Lab version 9.2 (Lancia, 2012), a software program with linguistic, statistical and graphical tools designed to execute automated thematic analyses of linguistic data corpuses.[1] From the transcript intervals, concordances were generated to first analyze the contexts of the corpus and then a specialized concordance was generated of key terms. Key-terms refer to lexical units (words, lemmas, lexies, categories) that generally are known as “content words”, such as nouns, verbs, adjectives and adverbs (Lancia, 2012). Procedurally, key-terms were first selected automatically and then customized based on theoretical reasons for deeper examination. The key terms were selected because of their frequency in the corpus and their aesthetic meaning, which is detailed further in the analysis.

Results and Findings

The findings are in two parts, from the two analyses. First, nuances of aesthetic experiences are examined deeply through case studies, using Interaction Analysis and Appraisal Analysis. These approaches reveal shared feelings and aesthetic values as they relate to the objects and experiences of learning science. The exchanges were selected for analysis based on several criteria: (1) They include explicit exclamations of pleasure, displeasure and intrigue; (2) the participants express emotion through the talk or through paralanguage; or (3) they are representative of how that particular family interacted with each other (such as positioning, questioning patterns, seeking information).

---

[1] Acknowledgment and gratitude to Giovanna Scalone for running the T-Lab analyses and her guidance in interpretation of the results.

In the transcripts presented in the Interaction Analysis, many simple expressions of aesthetic evaluation become apparent (for example, “wow” and “cool”). The second part of the analysis investigated if such utterances could be considered discourse markers used to identify aesthetic experience from a linguistic perspective. The results are presented from the linguistic corpus analysis, using concordance analysis through T-Lab of the transcripts from the sampled talk transcripts of six families. These findings indicate the frequency of key-term occurrences and examine the uses in relation to how aesthetic language can be identified through the particular utterances and discourse markers that signal aesthetic evaluation in interaction with the people and objects (specimens, cultural artifacts, and live animals) in each kind of place.

Aesthetic Experience

In this first section of analysis and discussion of the findings, I turn to Interaction Analysis and Appraisal Analysis of short segments of video to examine the three aesthetic dimensions—experience, understanding and appreciation, and judgment—of learning in an informal science setting. I start with two conversations from one family that have strong positive and negative aesthetic judgments, that include many of the common linguistic markers that will be examined later using functional grammar analysis.

In the first family presented, the Evans family has both positive and negative aesthetic experiences, demonstrating a tension between the affective and cognitive dimensions while the young girl in the family is coming to understand animal specimens’ scientific value in research. This tension again is demonstrated by the Hawkins family while they touch the sea cucumbers at the Aquarium, but they use few of the aesthetic linguistic markers. In the following transcript excerpts, words in bold highlight the aesthetic dimensions of the family’s engagement and the

appraisal analysis codes are embedded in the transcripts in italicized brackets ([*Appraisal*]), which I will discuss following each segment of the episode.

Positive and Negative Aesthetic linguistic markers in conversation. Mother Donna Evans is an educator at informal environmental center, and frequently engages in outdoor nature leisure and learning pursuits with her two children. Sofia is entering the 5th grade at the time of the study visits, and the mother-daughter pair are the study participants, although they mention Sofia's older brother at regular intervals during their study visits. They chose the Zoo as their optional study site, a place that Sofia had visited regularly when she was younger. This first segment of transcript comes from their Aquarium visit, their third and final visit in the study, and has a strong positive emotional tone. The second segment of their conversation has a negative connotation, and comes from the Burke Museum, their first study visit.

In the following segment, as their discourse unfolds Donna calls attention to a sea creature she finds interesting, has some knowledge of, and desires Sofia to see and to investigate.

Donna: …they're relatives **oh wait a minute! Oh my gosh! Oh my goshohmygosh.** //okay. *[Appreciation: Reaction: impact]*

Sofia: //what.

Donna: Do they tell you? ((looking around, holding up sign)). These are **so cool**. *[Attitude: Appreciation: Valuation]* Um. And I can't remember exactly what they are. And we don't have anybody here ((looking around)) or do we? Um.

Sofia: We have her, there's someone right there

Donna: We found these when we were doing the um when we found, we were doing the uh critter move at Seahurst beach, um, so that when they came in and removed that

seawall, right, so we found some of these. They are usually **kind of hard to find**. *[Attitude: Appreciation: Valuation]*

Sofia: What are they?

Donna: I can't remember.

Sofia: Are those feet?

Donna: I can't remember if they are a kind of nudibranch? Um, hafta ask.

Sofia: Let’s go ask ((turns around)) where's somebody I could ask?

Sofia ((turns and leans back over the tank)): They're **kind of cute.**

Donna: Let me, while we are waiting for her to come back ((her hand moves to her coat pocket))let me see if I can, I want to say lion is part of their name, but you know what? They **smell like watermelon**, if I remember correctly and they **really do** smell a lot like watermelon.

((Donna types on smartphone. Silence for 7 seconds.))

Sofia: **They're cute**

Donna: ((laugh)) **They're really //pretty**

Sofia: //What's that one? **It's cute, it's not pretty, it’s cute**.

Donna: So it's a hooded nudibranch, so you can see they do have that projection on them that looks a lot like a hood.

Sofia: **They're cute, I like this one.** *[Attitude: Affect]*It looks kind of like a nose and a body.

Donna: It looks **like some kind of a Japanese animé ((laughing))** character.

((Sofia walks on to the next exhibit, Donna continues reading, scrolling on her phone)).

To first interpret this episode as aesthetic experience, we see that this exchange has aspects of aesthetic understanding and appreciation, epistemic judgments, as well as continuity across over time and place, as Donna invokes both her prior experience and prior knowledge. Donna is talking about something else when she notices the animal in the tank and she excitedly calls out "oh my gosh" to get Sofia's attention (Line 1). She says "these are so cool" but Donna doesn't remember what the critter is called, which, for this pair, identification and naming is their social practice for engaging in science activity. Donna explains that they are rarely found on the beach, "they are usually kind of hard to find" (line 10) showing that there is merit in their presence in the Aquarium. Showing her attitude towards them as valuable, Donna recalls when she learned about them and why they are so exciting to her: they smell like watermelon. Scent is an unusual attribute of a sea creature, plus that they like something as fun as fruit, instead of perhaps a more expected fishy smell, highlights a reason for appreciating them. While Donna looks up information about the animal on her smartphone, Sofia continues to look at the nudibranch. She calls them cute, and disagrees with her mother when Donna calls them pretty, although we do not know how she distinguishes the meaning of "cute" from "pretty."

Negative Aesthetic Experience. In contrast to the overall positive tone of the previous example, Donna and Sofia had an exchange in which Sofia was distressed by animal specimens on display from the Burke Museum's collection. This is their first study visit, and the segment takes place within the museum's temporary exhibit *Imagine That*, featuring exhibits about the role of the museums collections in scientific research. The following exchange is continuous, but I have broken the conversation into three segments for the analysis.

Segment 1

Sofia: Mom come look at this. ((Sofia reads the exhibit label aloud)). This skunk white skunk was dyed yellow by pranksters who then brought it to the museum our mammalotologists (sic) weren't fooled but they kept the skunk anyway because the specimen came with information like when ((hhh)) and where it was collected it can still be valuable to science after all a skunk is a skunk.

Segment 2

Sofia: Red squirrel. That's **aww the poor squirrels, look at that, the poor squirrels** *[Attitude: Affect]*

Donna: They do look a **little flattened** don't they? Otoliths.

Sofia: yeah they do

Sofia: **That's so sad I don't want to take a picture it's so sad.**

Donna: It's kind of **interesting actually.** *[Attitude: Appreciation: Valuation]*

Sofia: No it's not, they're **they're ripped and flattened their insides were ripped out** *[Attitude: Judgment: ethics-condemn]*((Figure 3-2))

Segment 3

Donna: you know they were dead *[Attitude: Judgment: ethics- praise]* ((kneels down and looks in lower part of the case))

Sofia: kahhah still isn't that a **little creepy**? ((Turns and walks away))Donna: We don't plan on doing it to you, don't worry.

We see a tension between Sofia's emotional reaction to the specimens and the way that her mother and the museum expects her to understand and value the squirrel corpses as scientific

specimens. Sofia and Donna have a difference in valuing the squirrel specimens on display. Sofia's affective reaction to the specimens on display– that of her expression "the **poor** squirrels" (Line 37) and "that it is **so sad**" (Line 41) shows that she evaluates the situation in a different frame than her mother, who calls them "interesting, actually" (Line 42) in taking a cognitive stance in her judgment – an institutionalized stance - toward the specimens.

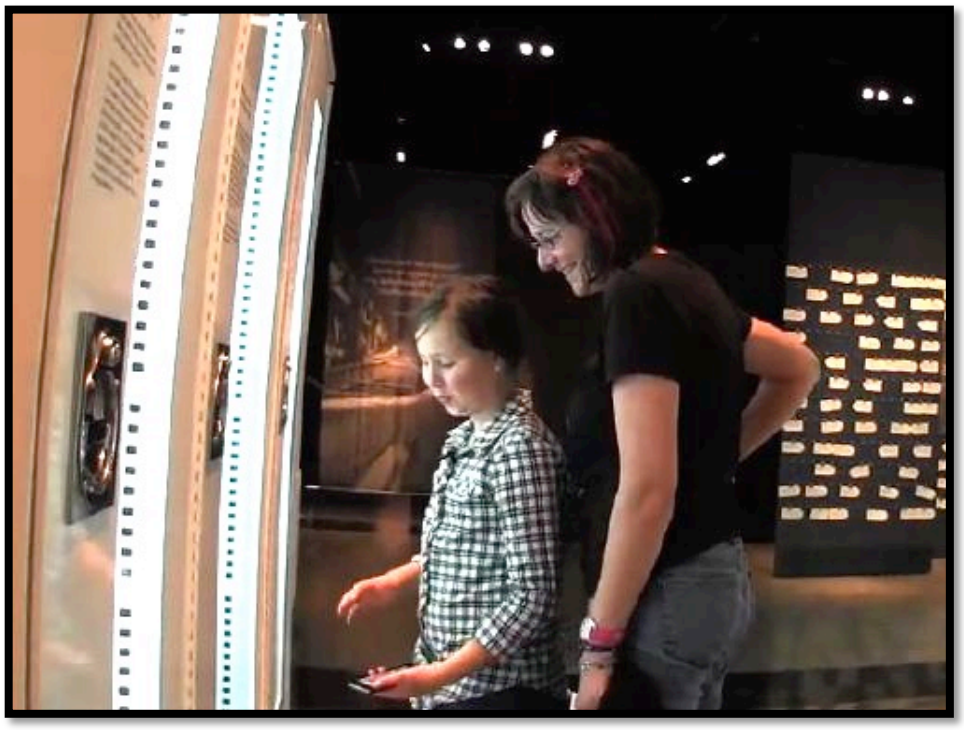


Figure 3-2: Sofia saying "...they're ripped and flattened"

In Segment 1, Sofia calls to her mother, inviting her to come to the exhibit case. Sofia reads the exhibit label aloud to herself and to her mother. The museum exhibit label communicates why the skunk specimen has value in the museum's collection despite the "pranksters" effort to fool curators by dyeing the white stripe on a skunk yellow-- the provenance of the skunk has a potential research value to science. But Sofia is distressed and saddened by the squirrel specimens in the display case (Segment 2). Sofia takes an emotional stance towards the death

and preparation of the animals, whereas her mother takes a disaffected, scientific stance that the animals in death have a value (Segment 3). Donna was trying to reframe Sofia's reaction to the specimens, so that Sofia would appreciate the specimen for their role in the museum collection and their scientific value rather than feel pity for them. Sofia's reaction to the flattened animals is that of immoral behavior in "flattening" the specimens and that they are creepy, while Donna communicates the position that the animals were dead, so it is ethical that their "insides were ripped out." As Donna says "We don't plan on doing it to you, don't worry" she reveals the differential value she places on the animals and her daughter, and by extension, humans in general.

Biological specimen collections in museums order and classify nature in all its variety, providing tangible arrangements of artifacts speaking for possible, if contested, natural orders (Ellis, 2008). Such arrangements convey commitments to certain ways of understanding and creating order that convey epistemic value – and through communicating the merit of individual objects, Donna and the museum are conveying the way they wish the specimens to be be understood. Such an understanding of the merit of the collection must be learned, in Sofia's case, as it is not the way she emotionally reacts to the squirrel specimens. External and intellectual beauty are not always coupled: the aesthetic beauty of a dead squirrel in a collection "is an acquired taste comes from understanding" (Flannery, 1992, p. 3).

Creating Understanding through Perceptual Knowledge: Touching the spiky sea cucumber.

In the following episode, I describe the experience of the Hawkins family touching sea cucumbers in the Seattle Aquarium's touch pool to call attention to how the aesthetic dimensions of engagement were integral to learning the scientific content communicated by the Aquarium.

The sea cucumber appears frightening to touch, but this fear can be overcome through learning about the value of the animal in a cognitive, or scientific, sense.

Anita (mother), Jenny (11), Melissa (6) have a membership to the Aquarium because it's an easy 40-minute ferry-ride away from their home in Bremerton. However, they are not very familiar with the place since they have not visited the Aquarium often, having just moved from Connecticut about 2 months prior to the day we visited the Seattle Aquarium. The father is a contractor at the naval base, and mother homeschools the girls because they move frequently because of his job. This visit to the Aquarium is their third and final visit as a part of the research study; we have been to the Burke Museum, and I went to their house where we picked blackberries in the area around their newly constructed housing development and made jam.

This analysis shows the family as they approach and use the Aquarium's touch pools, and interact with a volunteer educator. I chose this segment of video for several reasons: it is notable that Melissa takes several minutes to reach in and touch although she was excited to do it, Jenny and Anita never touch anything in the pools, and because the staff volunteer uses aesthetic qualities to convey information. These segments begin about 4 minutes into their visit, after getting set up for recording, and they have bypassed other large displays in the Aquarium to go directly to the touch pools at Melissa's behest.

This first segment shows how Melissa is interested in touching as the activity, and her concern about hand washing.

Segment 1

Melissa: Let's go. **I want to see what I can touch.** ((Laughs, walking and looking ahead to touch pools)).

Melissa: Do we have to wash our hands before touching 'em? //the animals

Anita: //I don't know. They'll probably tell us.

((They walk to the second touch pool, bypassing the closer pool from where they entered the room)).

Melissa: ((inaudible)) …touch the animals

Melissa: Wait, touch the animals. ((Reaches out to an animal identification card sitting on the edge of the pool wall. Volunteer presenter is talking to another visitor group from across the touch pool.))

Melissa: I wonder if we have ta...((she walks behind Jenny, to another side of the pool, leans over and looks along the wall)).

Melissa: ((reading sign)) Touch animals gently with one finger

Anita: You wanna touch that?

Melissa: Ohh it says wash your hands after

Anita: Okay

Melissa: Wash your hands AAFTer

Anita: Okay

((Melissa peers over the plexiglass tank edge without touching it, fisted hands pulled close to her chest – see Figure 3))

Jenny: **What do you want to touch?**

Melissa: **I don't know, this is kind of deep water.**

Jenny: You should probably come over here then. ((They walk around edge of the pool, Melissa again gets ahead of the group and leads)).

Figure 3-3: Jenny, Melissa and Anita (left to right). Notice Melissa's hesitation: her head and shoulders are leaning towards the tank, but her raised, fisted hands indicate she's not ready to touch.

Melissa is eager, yet hesitant. She leads her family to the touch pools, but does not reach out immediately. First she is concerned about washing her hands before she touches the animals, although we do not know what prompts this concern. The green sign on the rock wall reads "Touch animals gently with one finger. Wash your hands after" which ultimately answers Melissa's question (Lines 59-63). There are two volunteer interpreters positioned around the tank, both are engaged with other visitor groups. Those groups are adults, who are not reaching in or even leaning on the edge of the touch tank wall, so there is no one else modeling the touching behavior Melissa is excited to try. First, Melissa, Jenny and Anita have to find a good spot to stand; the section of the pool where they first stop is deep, so Melissa would not be able to reach anything – and it also holds fish that they are not supposed to touch. Even after finding out she can touch without washing hands, Melissa is still hesitant, and we see her head bending forward, yet hands held back in fists in Figure 3. Then, sister Jenny asks what Melissa wants to touch, and when the Melissa's reply is that she doesn't know, that the water is deep (Lines 69-

70), Jenny leads her away from that spot and around the corner of the pool. Although this could be interpreted as a stalling tactic—and may very well be—the water in this section of the touch pool is sparsely populated with animals aside from small fish, and is deep enough that Melissa would not be able to touch the few animals at the bottom.

In this next section, Melissa finds a spot on the naturalistic rock wall where she can stand and see the animals, although the wall is wide and it is a bit hard for her to reach far. Jenny and Anita stand next to her, and they all work to identify a sea cucumber. They notice that it looks spiky, and it keeps Melissa from touching it. Although she hasn't touched and won't, Mom justifies its safety by invoking the Aquarium, that they wouldn't have it available if it would cause harm.

Segment 2

Melissa: ((calling to Anita and Jenny to stand with her))**Oh looklooklook. Lookit, look** *[Appreciation: Reaction: impact]* **at that thingy.**
Anita: See, what is that?
Melissa: It looks like a sea cucumber
Anita: You think it's a sea cucumber? **Do you want to touch it?**
Melissa: Is that a sea cucumber?
Melissa: He's kinda **spiky**. *[Appreciation: composition]*
Anita: Yes it is ((looking at the animal identification cards))
Melissa: **Do they actually feel like spikies?** I wonder, do they actually feel like spiky? *[Appreciation: Composition]* ((Melissa looks to her mother as she asks, See Figure 3-4.))
Anita: I have no idea, I've never felt one *[Appreciation: Reaction: Quality-negative]* ((very flat intonation; she continues looking at the cards and flipping pages while talking))
Melissa: **uaah** ((half-laugh, half-groan)) *[Appreciation: Reaction: Quality]*
Anita ((reading from card)): It uses its sticky mouth like a vacuum to clean up decaying plant matter and then it licks the food off their feet.

Melissa: ohhh

Anita: Kinda **cool**, huh? *[Appreciation: Valuation]*

Melissa: I think I might want to touch it. I don't know (hhhh) ((finger hovering above water)).

Jenny: Go ahead touch it.

((Melissa pulls her hand back (Figure 3-5) and nervously brushes hair behind her ear *[Attitude: Affect]*)).

Anita: Melissa, **I don't think it's going to hurt you, or they wouldn't have it in here.** *[Attitude: Judgment: ethics]*

Figure 3-4: Melissa asking: "I wonder, do they actually feel like spikies?"

Figure 3-5: Melissa pulls her hand back

Anita is comfortable engaging with the touch pool by looking up information on the cards and reading it aloud to the girls, but not touching. She indicates through her tone of voice that she has not, and will not, touch a sea cucumber; this appraisal is a Reaction-Negative. Melissa then laughs or groans – she now knows that her mother hasn't touched one of these creatures and is not going to model how to do it, so she is on her own. Anita continues to look at the sea cucumber information card, and says it is "cool" that the sea cucumber licks its foot to get food. She is soliciting solidarity from Jenny and Melissa by saying "huh?" (Line 90), as well as making a positive valuation of a cognitive nature, which stands in contrast to her previous negative affective reaction in Line 83, where she indicated with her words and tone that she has not, and would not, touch the sea cucumber.

When Melissa continues to hesitate, Jenny wants her to get on with it - "Go ahead touch it" but Melissa keeps holding her hand back, and nervously pulls her hair behind her ear. The risk of touching something with spikes can't be high, Anita reasons, because the Aquarium has it in a touch pool – they wouldn't place something in it that would hurt people. The spiky cucumber appears scary and could hurt if touched, yet, Anita realizes that the Aquarium would not purposefully put people in a position to be injured. She knows that logically, touching the cucumber should be safe, yet she refrains.

They ask questions about how the sea cucumber feels that they could answer by just touching – which we see continue as a volunteer educator approaches and engages with the family in the following section (Segment 3) of their conversation. When the volunteer approaches, Anita and Jenny shift their bodies to angle towards the woman, shifting their attention in preparation to engage with her. After the volunteer says hi, Anita initiates a first question to the volunteer, asking if "those things are spiky" –hedging at first by calling them

"things", rather than calling it a sea cucumber right away. The volunteer skillfully turns this question – and the family's fear of touching the animal– into confirmation that the sea cucumber is using it's camouflage to "fool" predators.

Segment 3

98 Volunteer: Hi
99 Anita ((to the volunteer)): Are those things real spiky? The sea cucumbers.
100 Volunteer: No! That's what they're trying to fool you *[Appreciation: Valuation]* to
101 thinking that they are spiky, but watch. ((Volunteer reaches in, strokes sea cumber)).
102 They are **super soft, feel like a water balloon.**
103 Melissa: hhaa
104 Volunteer: That's their first defense, 'ooh it's spiky I better leave it alone.' If that doesn't
105 work, then it fills its body up with water, gorges itself with water, hoping whatever is
106 trying to eat it can't get it in its mouth and then if that doesn't work, it **eviserates, it spews**
107 **out its guts** //
108 Anita **((chuckles, leans back)): // ohhhhaah** *[Appreciation:Reaction:Quality]*
109 Volunteer: the water turns orange and it hopes that whatever is trying to eat it will eat that
110 and leave it alone. Then it will regenerate the digestive tract, but that takes a lot of
111 energy, that's a last ditch effort, if it does that it really thinks it's a goner.
112 Anita: hahah *[Appreciation:Reaction:Impact]*

At line 102, the volunteer turns uses the word *soft* – the opposite of *spiky* – to show that the sea cucumber is not going to hurt, and there is value in this deceptive camouflage. She makes an analogy to a water balloon, something pleasurable and fun in everyday life, conveying the soft, squishy qualities of a balloon. She affirms that the cucumber's defenses are working by preventing Melissa and her family from touching: scaring predators is their first line of defense. The volunteer then takes the next step to convey information about further self-defense for the creatures: that it will fill with water and eviscerate. Again skillfully, she uses a weaves in a

scientific term "eviscerate" and immediately defines it – "spews out its guts," in a graphic phrase meant to evoke the reaction she gets from Anita (Line 108), in the sense that it is engaging her, even if the reaction is probably a mix of positive and negative affect – a fascination at something gross.

This reframing of something potentially scary into something soft, and therefore interesting, provides entry into both a cognitive and physical appreciation of the sea cucumber's defense mechanisms, leading to a greater understanding of the defenses. This is not just an intellectual understanding – but the extent of nature's deception is one that Melissa comes to understand more fully when she touches the animal – the *doing* that is a part of aesthetic experience – in order to appreciate how soft and squishy it is despite its visual appearance. As we will see in the next section (Segment 4), the volunteer compares these spiky sea cucumbers to sea stars (Line 116), including information about both animals. By this time, the volunteer has reached into the water two times – and Melissa now gets up the courage to touch the sea cucumber.

Segment 4

Volunteer: **they're related to ah, sea stars,** they're from the same family and they have two feet like sea stars see those ((reaches in water to point)). See those two feet?
Melissa ((leaning over)): Yeah
Volunteer: **Just like the sea star** and if you looked inside of one it would have five sections, five strips of flesh and sea stars have five.
Anita: oh **wow**
((Melissa puts her hand in the water, see Figure 3-6)).
Volunteer: so this is ((she pauses to watch Melissa touch the sea cucumber))
Volunteer: That's the anus there

((Melissa pulls her hand out, rests it on the rock in front of her, keeps looking down for one second then laughs)): hhaa ((**She turns and looks up to her mother and smiles**. Figure 3-7.))

Anita: does it **feel cold**?

Melissa: yeeaah ((**laughing**))

Figure 3-6: Melissa reaches in and strokes the sea cucumber

Figure 3-7: Anita asks "Does it feel cold?"and Melissa smilingly answers "Yeah"

Melissa puts her hand in the water (Line 119), while the volunteer is talking about the sea stars (Line 113). She touches first with one finger (Figure 3-6). As she does that, Jenny and Anita

watch her, and when she looks up, she looks at her mother, smiling (Figure 3-7). Anita asks (Line 125) "does it feel cold?" and Melissa replies with a laughing "yeeah." Her laugh indicates her pleasure at overcoming her fear and the sensation of cold. The attention for the three of them is directed to Melissa's actions and her experience of putting her hand in the water and stroking the sea cucumber, not on what the volunteer continues to talk about. Meanwhile, the volunteer starts to say that what Melissa is touching is the anus of the sea cucumber – which Melissa does not respond to, perhaps because she may not know what that is or hear the volunteer – because if she knew she might not have wanted to touch it, as we see in Segment 5, following!

Overcoming timidity and fear of something that looks unusual, and could potentially be harmful, is an aesthetic experience for Melissa. She overcomes her discomfort at touching, when she sees someone else safely touching, and the specimen in question is related to something fun in everyday life (water balloon) and beautiful (sea star). Melissa's identity, as the kind of person, at least in this moment, who is courageous in doing something solo that is not a part of her family social practice (Carlone et al., 2015) was supported by the practices of another adult guide (the Aquarium volunteer interpreter), as she related the biological value of the spikes on the sea cucumber and compares it favorably with a more attractive looking animal. In this episode, we can see Melissa's identity and role in her family. She says she wants to visit the touch pools, and they all follow. Once Melissa has overcome her timidity about touching the animals in the pool, she invites her sister to touch, although Jenny turns her down. Jenny never touches, although she looks in the pool. Jenny's countenance throughout the 14 minutes at the touch pools is a mix of interest and disengagement, perhaps boredom. Touching is not her mode, and neither is it for their mother. We could attribute this to an orientation towards young children as the primary audience in designed settings such as the Aquarium, but it was also a way the girls engaged at

home. On the previous study visit to their home, Melissa was the one comfortable with reaching far into bushes while berry picking near their house, and showed excitement when she discovered a bright yellow spider on a berry bush. While Melissa was at first nervous, yet interested, in looking closely at the spider while outside, it was Jenny who later took up the internet search to find out what kind of spider they had seen and why it was yellow- and if it was poisonous. Of course there is an age and ability difference – Melissa is six years old and a beginning reader, while Jenny is eleven and more familiar using the family iPad.

Sensory pleasure (or displeasure) is a foundation of aesthetic experience, with aesthetics combining sensory with emotive and cognitive aspects. Multisensory perception can be a powerful and compelling means of learning and understanding. Touch and haptic feedback has been shown to increase engagement and improve how students understand abstract concepts (Bivall, Ainsworth, & Tibell, 2011; Jones, Minogue, & Tretter, 2006), as well as provide an important methodological process to creating perceptual knowledge in such fields as chemistry that use models in research (Candela, 2012). Physical engagement with objects they could touch or manipulate, for many of the children participants in this study was a prime driver of situational interest and directed children's attention (as we see with Melissa), or caused boredom, if they could not or did not touch and manipulate objects.

They continue to talk with the volunteer, who tells them about how two different animals gather plankton and food from the water by describing the different actions they use to collect food as it passes.

Segment 5

127 Anita: **What do they eat?**
128 Volunteer: It's eating the ((waving hand)) ah, the ah plankton that's…there's lots of food
129 in this water, if you go over to the microscope ((pointing to another exhibit)) they've got a

drop of the water and you'll see all the food, what it's eating. ((Volunteer turns to her head to talk to another visitor about a plankton tow))
Anita ((to Melissa)): You want to touch this one? ((pointing to sea cucumber in front of her))
Melissa: yeah ((Melissa reaches across Jenny and laughs; Anita looks closely))
Melissa: Jenny do you want to touch one?
((Jenny slowly shakes her head)) *[Appreciation:Reaction:Quality]*
Volunteer: **Oh here's something!** That cucumber just pooped, **that's sea cucumber poo** ((pointing to water)). That's what the, wave action will break it down and **the other animals will eat that.**
Jenny: **aah**
Melissa: **Eewww** *[Appreciation:Reaction:Quality]*
((Anita **smiles, shakes her head and leans back**)).

Seeking information, Anita asked what the animals eat, which, turns out to be an appropriate introduction to the topic – when the volunteer alerts everyone by calling out "Oh here's something" (line 137) and focuses shared attention by pointing out the sea cucumber has "pooped" and identifying the object of attention. She explains that the wave action will break it down and the other animals will eat it, describing an action. Acknowledging this information, and indicating their negative aesthetic reaction to that information, Melissa says "eeeww," Jenny says "aah" and after a pause, Anita shakes her head and smiles, leans back and looks out across the rest of the touch pool. This is when negative aesthetic experience comes in, as the volunteer points out that the sea cucumber has defecated, which will become food for other animals – an entirely relevant point as Anita had just asked what they ate. There is a tension in this moment between social and scientific norms. Defecation is a socially taboo topic which the family's reaction indicates, even if it is fascinating to children, particularly at Melissa's age as children learn it is not polite. However, the Aquarium volunteer tries to convey the normalcy of it in

nature as she provides the information that it will be broken up by wave action and becomes food for other animals. This pause signals the end of the episode for analysis, although Anita, Jenny and Melissa continue to engage with this volunteer for another 6 minutes, spending about 14 minutes using the touch pools.

This family's sense-making occurs in a series of discourse moves that communicate and negotiate aesthetic qualities, that involve sensory perception and cognitive engagement by taking up facets of situational interest (Hidi & Renninger, 2006). The aesthetic language alerts and then directs shared attention to an identified object. An important action is described, which is acknowledged and met with an emotional reaction. This series of moves offers a shared frame of meaning while exploring unfamiliar phenomena and a platform for introducing scientific knowledge. Coming to an appreciation of the sea cucumber's appearance and its protective mechanisms was a combination of aesthetic and epistemic valuations. Such perceptual knowledge – that builds on dissonance between senses of touch and sight, combined with epistemic information, lead to an experience making fuller, richer understanding of biology.

Discussion of aesthetic experience and perceptual knowledge. The aesthetic sense-making work of families involves jointly viewing, reacting, and making sense of phenomena. This provides a platform for families to explore unfamiliar natural phenomena and discuss related scientific knowledge. The aesthetic experience goes beyond noticing colors or appearance, although this is an entry point. For Sofia, this was being taught the scientific value of collected animal specimens; for Melissa, overcoming fear of touching a dangerous looking animal enables a fuller understanding of that animal's defensive camouflage. Reactions and appraisals at these entry points provide direction for how to proceed in the joint experience

(Wickman, 2006) with consequences for how that experience is remembered and understood in relation to one's own identity and interest in science.

There is an educational implication of this conclusion related to the design of museum experiences. Taking up the frame of aesthetic experience can help to design to extend beyond a first observation by incorporating a felt or emotional reaction (such as repulsion or fascination) while introducing content. Acknowledging and harnessing emotion with content leads to an increase in appreciation of the aesthetics of the phenomena, creating a deeper understanding.

Aesthetic Discourse Markers: Exclamations of Appreciation and Expressions of Value

Exclamations of wonder, interest, and curiosity – "wow," "cool," "ew," "gross," "look!" are frequently heard as families interact in informal education settings. Such talk is both frequent and "carr[ies] some significant aspect of … shared experience" (Allen, 2002, p. 23). In a study of the kinds of family learning talk at an exhibition at the Exploratorium the talk that Allen (2002) identified and coded as "affective dimensions" were broken into three categories:

- Pleasure was expressions of positive feelings or appreciation ("beautiful," "wonderful," "cool," "I like that one," and laughter);
- Displeasure included expression of negative feelings or dislike towards something, including sadness or sympathy ("poor thing," "ugly," "eeew," "gross," "yuck");
- Intrigue, as expressions of intrigue or surprise ("wow," "gosh," "woah," "ooooh").

However, these exclamations and utterances that are markers of performance and affect have not been investigated in science education for the intellectual work they do in conversation in informal settings. Here I investigate their role in marking aesthetic dimensions of sense-making. Not merely an expression of emotion, I argue these expressions serve an evaluative function as both cognitive and interactive signals, and are aesthetic in nature. Discourse markers can

function as a cue that speakers use to negotiate common ground through the presumptions or implications that are associated with the information that is delivered through the marker (but not the information itself) (Jucker & Smith, 1998). In this first portion of the analysis and findings, I investigate these utterances as potential markers of aesthetic language that meet the definition discourse markers being linguistically detachable in meaning from the rest of the sentence (Schiffrin, 1987).

The first analysis relies on corpus methods by using T-Lab software for generating concordances. Key-words-in-context (KWIC) searches provide lists of all the occurrences of words and context around it. The position and frequency of general and selected key-terms in context were used to detect and make inferences on patterns of usage and meaning of word-forms. One criteria used in the corpus was conducting a search by lemmas. The occurrences ranged from a minimum 4 to a maximum of 297 for the lemmas appearing within the corpus (see Appendix E for text parameters and corpus description). A minimum frequency threshold of 4 was used to select lemmas for the key-word list during the pre-processing phase—which establishes reliability of statistical computations. Results from specific key terms (n=201) were analyzed across the transcript intervals. Using specialized concordances, the specific key-terms were then grouped into Allen's kinds of affective expression: pleasure, displeasure, and intrigue.

Expressions of pleasure. As we saw examples of in the Interaction Analysis and Appraisal Analysis section, families used expressions such as "Cool", "Awesome", "pretty," "cute," "beautiful," and " aw" to express favorable judgments. In the results here, I grouped these key words into two categories that express beauty and approval: 'cool' and 'awesome' as words that express *a state of excellence*, but it is not clear what quality makes it that way; and, 'pretty', 'cute', 'beautiful', and 'aw', as *descriptors of appearance* that please the mind or senses. I show

these as frequencies by families and by setting in Figure 3-8 and Figure 3-9, to address the question if some families were more apt to use these key words than other families, and in which sites.

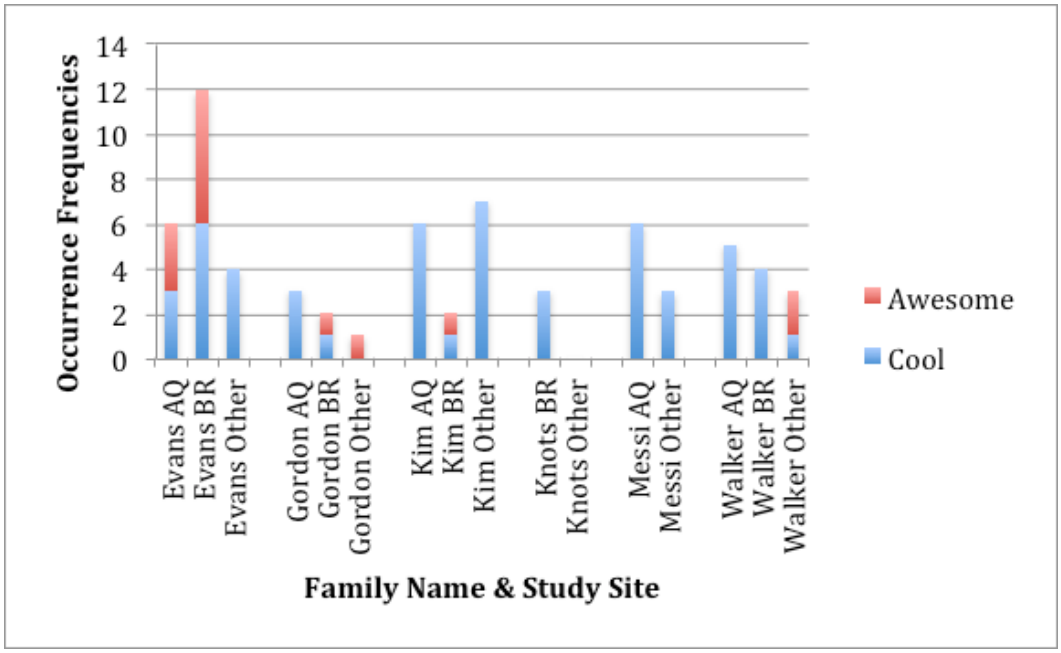


Figure 3-8: Occurrence of key words "Cool" and "Awesome" by family and location

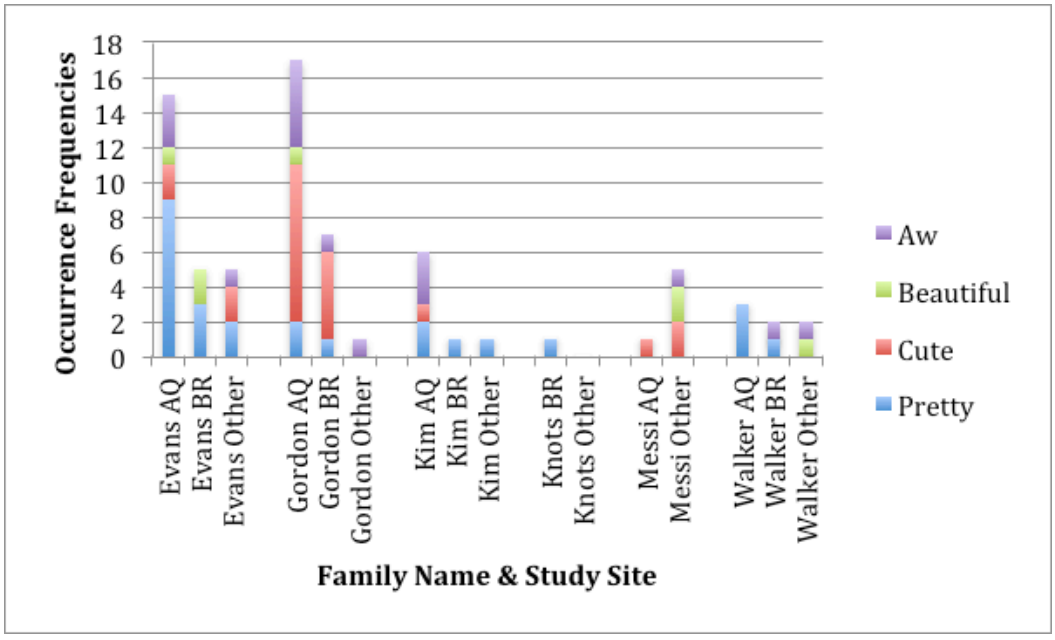


Figure 3-9: Occurrence frequencies of key words by family and location

All families made some kind of expression of attractiveness in at least one of the sites, although there is wide variation across the families in how many words were used, and in what places. However, in the case of "pretty," the concordance analysis shows that "pretty" is sometimes used as adverb that modifies an adjective, rather than as an adjective that describes the appearance of the subject. When we look at co-occurrences of the word pretty with cool and awesome (Figure 3-10), we see how "pretty" can modulate "cool." Examples of the associations are: "oh that's **pretty cool" "**I can hear the [orca whales] clicking can you? That's **pretty cool**" "I took a class in here once and took a bunch of pictures of that fossil 'cause I just thought it was **pretty cool**" "So **cool,** look at…I'm **pretty** sure that's like a baby puffin." Hedging using the words "pretty" and "kind_of" is notable as well—like they are seeking pleasure or calibrating what they mark as pleasurable. Pretty also co-occurs with "look" and more often with "cool" – calling attention to an object of interest through the role of visual perception is clear with "look".

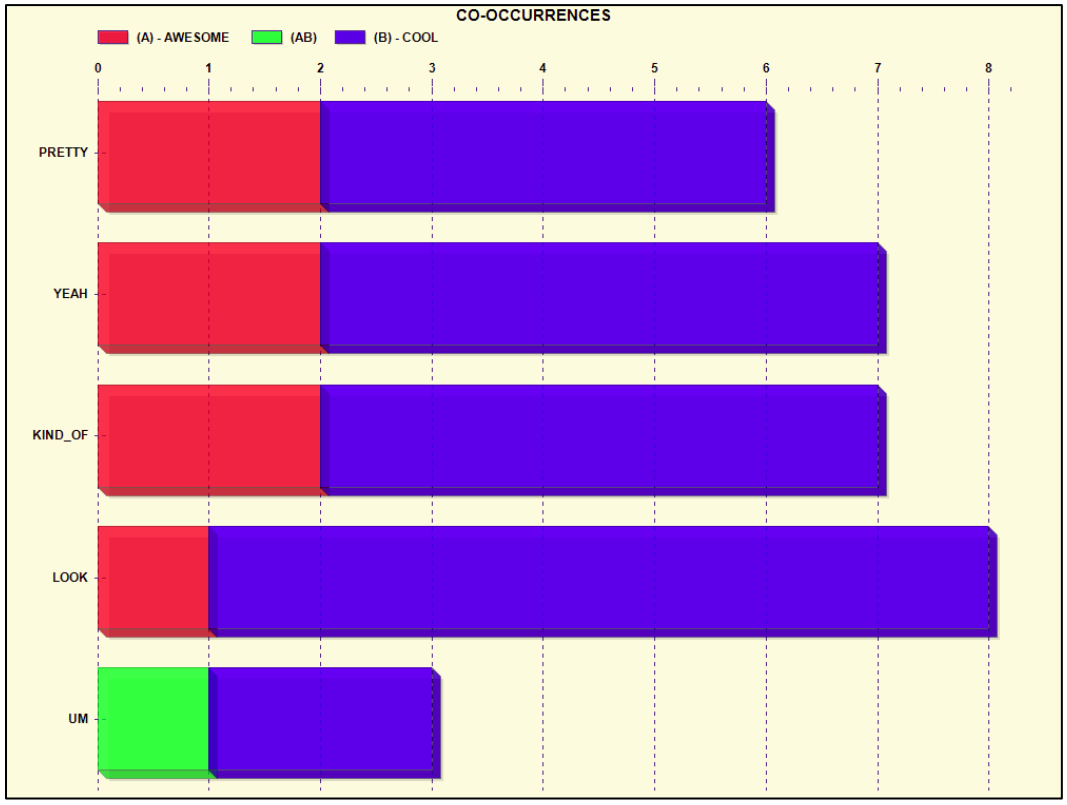


Figure 3-10: Words co-occurring with "awesome" and "cool"

In at least one family, using the word "cool" is a direct way of working towards solidarity and conveying a positive attitude towards a shared subject. Elizabeth Knots said she uses "cool" to get her boys to be interested and like what she's talking about or looking at. In our final meeting, she told me "You know its interesting, I went home after we met at the [Burke] Museum and I was thinking about that whole idea of gross and cool and everything…I was thinking, 'oh, but I'm really good about not saying gross, I feel pretty good about that but what I realized is that I'm heavy on the cool. I'm heavy on the, like, awesome, and I was like that's the same thing, that's placing value on it. So I just thought about it, it was very valuable for me to go home and go huh, okay. That was cool."

Expressions of displeasure. Utterances of "ew" "weird" and "gross" were key-words that fit the definition of negative appraisals of beauty, or "displeasure" in other studies (Allen, 2002; Wickman, 2006). Displeasure and negative aesthetic experience were noted in the Interaction Analysis, and their presence and occurrence across the data is examined here. The occurrence frequency shows (Figure 3-11) that some kind of negative appraisal is made in most of the settings, with the actual expressions variable across families (one phrase is not dominant), while somewhat site dependent. The particularity of site is notable here: the Gordon family with the highest frequency in their "other" location was at the Science Center while it hosted "Ripley's Believe it or Not" exhibit, which is designed to elicit such expressions.

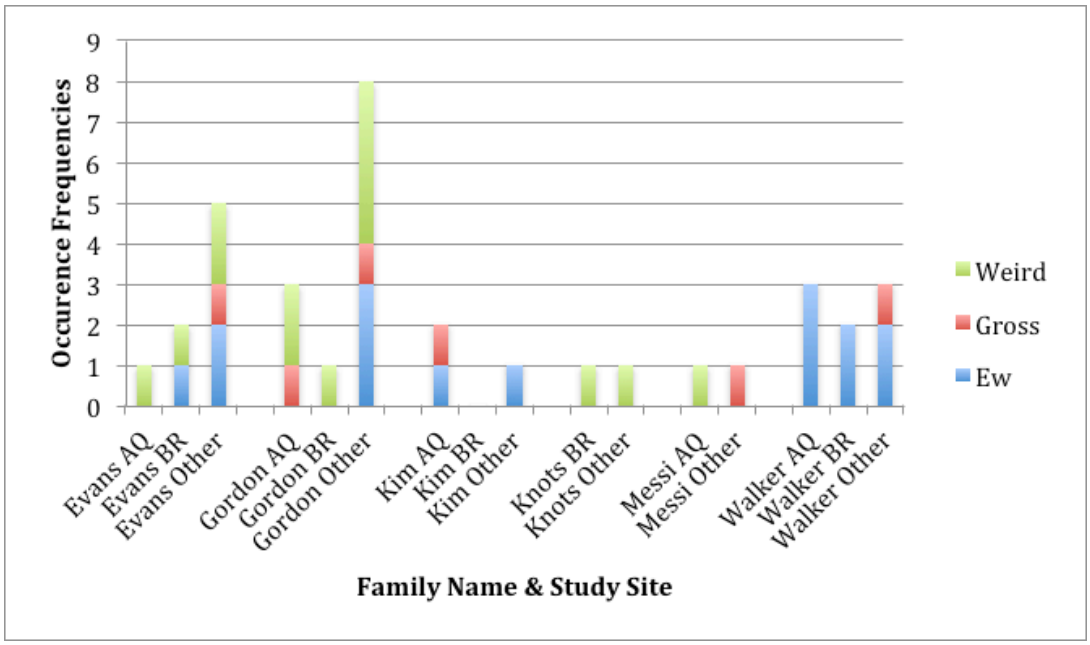


Figure 3-11:Occurrence frequencies for expressions of displeasure "weird" "gross"and "ew" by family and location

Concordance key-word analysis shows that expressions of displeasure reflect judgments on animal's behaviors, or mark descriptions of artifacts. These examples quoted below from the concordance tables show the role of these expressions:

1. Mommy, he showed me the WEIRDEST one, and I said it was it looked like a zebra mole, um um a zebra mole, a zebra mole, um mammoth, do you want to see it? It has stripes, it looks like a mole and it has tusks (Brady Knots, Burke Museum)

2. So WEIRD, EW is he eating his own poo? (Sofia Evans, Zoo)

3. GROSS ugly scary yucky (Lily Gordon, Aquarium)

4. Um one that has a big huge fat nose that has a straight nose that's like a horn but it's for a nose it looks WEIRD and he looks like he's a dork (Ruby Gordon, Aquarium)

5. That's the brine shrimp, see that pink stuff? Brine shrimp, ah, that smells GROSS (Sofia Evans, Zoo).

Rather than strict negative aesthetic assessments, the phrasing may show that there is a fascination aspect, instead of just aversion, creating a kind of aesthetic dissonance that prompts more attention to the object or behavior observed– true displeasure, in a free-choice environment may mean avoidance, and therefore would not be available to us through this type of quantitative analysis.

Expressions of intrigue. The key-words in the data corpus that were congruent with Allen's category of intrigue were "wow" and "woah," (Figure 3-12) and because of its frequency in the data, I add the word "look" to this category. Although very similar in sound and potentially in meaning, a difference in phrase could be heard between the words and were transcribed as "wow" and "woah."

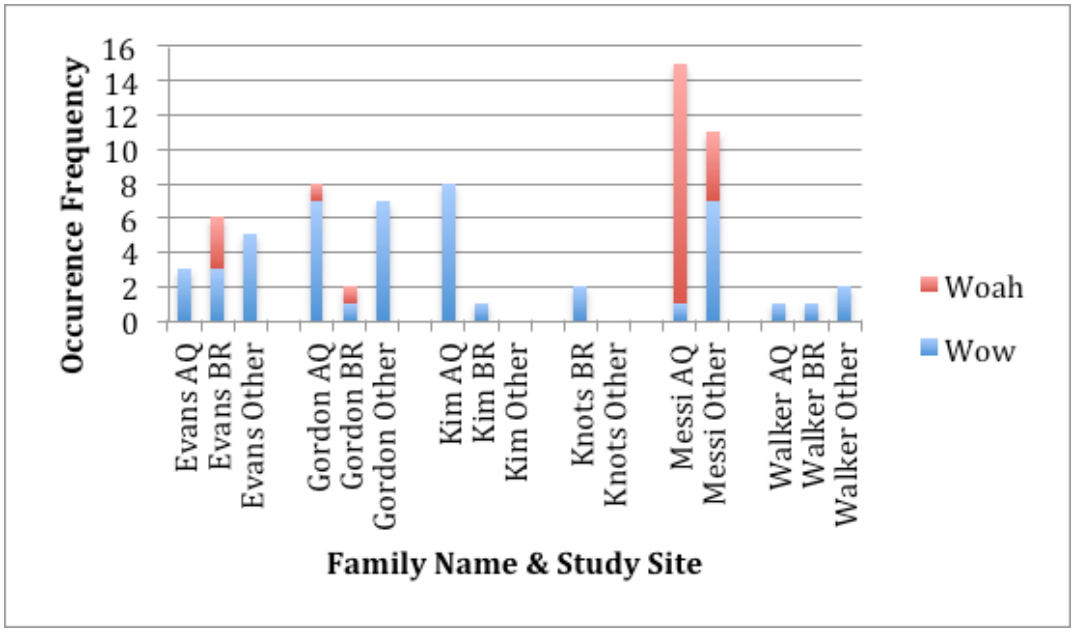


Figure 3-12: Occurrence frequencies of expressions of intrigue "wow" and "woah" by family and location

Concordance analysis of these two key-words show that “wow” and “woah” are associated both with negative and positive experience, such as “Wow” scary and awesome “wow.” Examples of these associations from the analysis are:

1. All right WOW look at the teeth guys WOW (Elizabeth Knots, Burke Museum)
2. WOW it keeps bringing his tentacle (Lok Kim, Aquarium)
3. So there's a big eruption and a teeny eruption look at that the layers of rock through it its different shoot.
4. WOW that's scary (Sofia, Burke Museum)
5. Touch the crystals, oh my god this is so awesome WOW these are real crystals you can touch (Ruby, Pacific Science Center)
6. WOW that's creepy (Lucy, Aquarium)
7. WOW that's so cool (Lucy, Aquarium)
8. WOAH they collect the eggs from the female and they squeeze out the sperm from the males and then they spread it all over that and that's how they get the fish.” (Lionel Messi, Aquarium)

The key-word “look” emerged from the corpus as a frequent utterance. So to these expressions of intrigue, I add the word “look” as a word that demonstrates interest that one wishes to share with someone else, provides a directive that attempts to focus joint attention, and is a sensory means of taking something in. “Look” (along with “look mom”) occurs frequently – more frequently than the other words in this analysis (Figure 3-13).

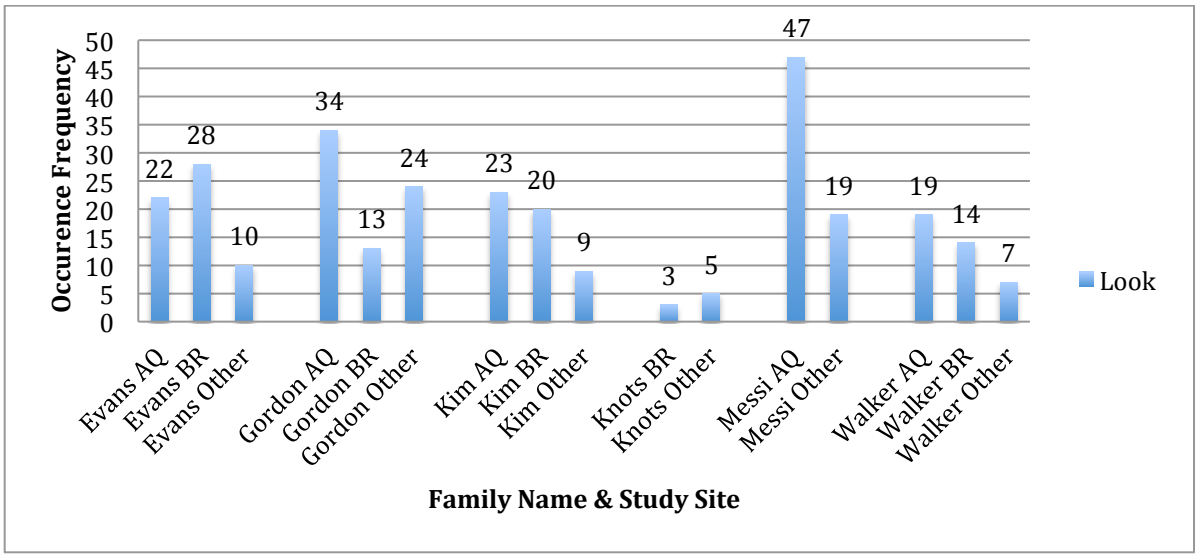


Figure 3-13: Occurrence frequency of "look" by family and location

Concordance analysis shows that "look" was associated with attention-directing activity ("Lookit" to mean "Look at _") or to prompt closer observation.

1. Take a look (Donna Evans, Burke)
2. Mom come here look look inside there (Lok, Children's Museum)

Analogies are a common occurrence in science talk, and "look" also reflects that useage.

1. That guy LOOKS like someone from cone heads (Sofia Evans, Zoo)
2. Because there's a stick on the log that LOOKS exactly like a salmon (Tina Messi, Carkeek Park)

The phrase "Look like" could indicate an analogy, instances of it didn't imply analogy to another thing, but better described what an object actually was:

1. That **LOOKS** like ah those are called picture agates because they do **LOOK** like a picture of some sort. What does it look like to you? (Donna Evans, Burke).

Discussion of aesthetic linguistic markers. Results from the corpus linguistics analysis, using key-word and concordance analyses, show that aesthetic expressions and utterances are present

throughout the families' visits to the museums, aquarium and the other science-learning sites they chose to visit. Such expressions serve an evaluative function as both cognitive and interactive signals. Allen's affective categories – pleasure, displeasure, and intrigue, can be interpreted as aesthetic markers in discourse. The category of "pleasure" can be further distinguished in an aesthetic interpretation as descriptors of a state of excellence (words such as awesome and cool), or as a description of appearance (cute, pretty, beautiful). However, I also found that while useful for demonstrating their presence throughout learning experiences, the exclamations and expressions removed from the context, gesture, bodily and facial expression in corpus analysis are not sufficient for identifying the aesthetic dimensions of learning within conversation. The deeply felt emotion and sensual-perceptual aspects of aesthetic are intrinsic to the experience may be better captured through methods such as Interaction Analysis.

A limitation of this study is the small size of the corpus sampled in the linguistic analysis. Further work to expand the data available for analysis could validate these interpretations against a larger corpus, as well as a broader demographic. In a future effort, corpus linguistics could offer opportunities to understanding place, as a comparison of key-words against places – formal schools, programs, kinds of informal educational institutions – that might also lend insight into nature of aesthetic experience of place and objects.

Conclusions & Implications

In this paper, I have investigated the role of aesthetics in families' informal educational experiences, and demonstrated how aesthetic understanding, epistemic values and aesthetic experience contribute to science learning. Aesthetic aspects of learning sciences adds to the processes that educational researchers recognize as being invoked in science meaning-making moments, alongside those established in the literature, such as making predictions, questioning

and observing, sharing memories of prior events, and bringing in external sources of information (Crowley & Callanan, 1998; Eberbach & Crowley, 2009; McClain & Zimmerman, 2014; Zimmerman, Reeve, & Bell, 2009).

Even in science, which places little value on "subjective" ways of knowing, aesthetic language is a way of making distinctions and conveying values. In communicating and soliciting solidarity with these values to others, "aesthetic experience can be expected to …have normative consequences, where we learn what counts and does not count as part of scientific practice" and "has consequences for people's social identity and prospects for participating in activities where science is practiced…" (Wickman, 2006, p. 49). Rather than subsuming the category of discourse under emotion, aesthetic considerations are more prominent in science learning and teaching than have been widely acknowledged. Aesthetic judgments have normative implications for identification with science (what is the nature of doing/practicing science?) as well as epistemological (what parts of an experience – ways of knowing and understanding - should be revealed and communicated), and in what kinds of places (informal contexts, such as conversation, brainstorming, museums, outdoors) are this kind of bodily and sensory knowledge/understanding relevant, valued, and count as evidence for scientific work in experiment, theory-making, discovery and learning.

Who makes these distinctions around aesthetics, and when certain distinctions are allowed has consequences for broadening participation in science. A significant limitation and concern I have with this data corpus is that the nature of aesthetic experience, judgments and understanding is identified and bounded by a traditional, Western, European-centric definition of aesthetics and of science. Expanding the participants, and working with other researchers who can help to expand and refine aesthetic meanings for a broader population will help to recognize

complementary and continuous ways of knowing. Developing and refining the aesthetic experience into a more rigorous framework for understanding science learning will require accounting for many ways of defining and interpreting beauty and finding pleasure in the natural world.

John Dewey (1934) believed that it is impossible to plan or design for aesthetic experience – but I don't think that will stop any educator from trying. If participation in science means grappling with the unknown (Flannery, 1992), then the demonstrations possible in educational settings do not capture or convey this feeling in an authentic sense – someone knows the answer or what will happen (Collins & Pinch, 1998). This becomes the challenge: design of learning environments means trying to keep a sense of awe intact. Designing for participation that incorporates all the senses provides a means for more coming to more fully understanding the phenomena under investigation – rather than merely collecting facts, applying those intellectual components with the emotional creates a felt knowledge.

Trying to capture awe and excitement and wonder by distilling the essence of felt emotion into words and description is surely inadequate for the power of these experiences. Studying the ratio of time spent in hard work to the moments of aesthetic wonder would surely find it skewed to the less fun side – yet it is these moments of awe that inspire and motivate scientists and non-scientists alike to explore and understand our world. Returning to Henri Poincare's quote at the beginning of this paper, that scientists study what they do because they take pleasure in it, and find that pleasure because it is beautiful, applies to scientists and nonscientists alike. Rather than diminishing the beauty, appreciation of the beauty of nature increases with increasing knowledge, as long as the sense of wonder and awe is retained and remembered through those moments of pleasure.

References

Alexander, E. (1996). *Museums in Motion*. Walnut Creek, CA: AltaMira Press.

Allen, S. (2002). Looking for learning in visitor talk: A methodological exploration. In G. Leinhardt, K. Crowley, & K. Knutson (Eds.), *Learning Conversations in Museums* (pp. 259–303). Mahwah, NJ: Lawrence Erlbaum Associates.

Bang, M., & Medin, D. (2010). Cultural processes in science education: Supporting the navigation of multiple epistemologies. *Science Education*, *94*(6), 1008–1026. doi:10.1002/sce.20392

Bell, P., Tzou, C., Bricker, L., & Baines, A. D. (2012). Learning in diversities of structures of social practice: Accounting for how, why and where people learn science. *Human Development*, *55*, 269–284. doi:10.1159/000345315

Bennett, A., & Eglash, R. (2013). cSELF Computer Science Education from Life: Broadening Participation through Design Agency. *International Journal of Web-Based Learning and Teaching Technologies*, *8*(December), 34–49. doi:10.4018/ijwltt.2013100103

Bivall, P., Ainsworth, S., & Tibell, L. A. E. (2011). Do haptic representations help complex molecular learning? *Science Education*, *95*, 700–719. doi:10.1002/sce.20439

Candela, E. (2012). Assembling an aesthetic. *Current Opinion in Chemical Biology*, *16*(5-6), 564–8. doi:10.1016/j.cbpa.2012.10.036

Carlone, H. B., Huffling, L. D., Tomasek, T., Hegedus, T., Matthews, C. E., Allen, M. H., & Ash, M. C. (2015). "Unthinkable" Selves: Identity boundary work in a summer field ecology enrichment program for diverse youth. *International Journal of Science Education*, *37*(10), 1524–1546. doi:10.1080/09500693.2015.1033776

Chandrasekhar, S. (1987). *Truth and Beauty: Aesthetics and Motivations in Science*. Chicago: University of Chicago Press.

Collins, H., & Pinch, T. (1998). *The golem: What you should know about science* (2nd ed.). Cambridge, England: Cambridge University Press.

Crowley, K., & Callanan, M. (1998). Describing and supporting collaborative scientific thinking in parent-child interactions. *Journal of Museum Education*, *23*(1), 12–17.

Darby, L. (2006). Negotiating mathematics and science school subject boundaries: The role of aesthetic understanding. In *Science Education in Focus* (pp. 55–82). New York, New York: Nova Science Publishers. Retrieved from http://hdl.handle.net/10536/DRO/DU:30051979 Reproduced

Derry, S., Pea, R., Barron, B., Engle, R., Erickson, F., Goldman, R., … Sherin, B. (2010). Conducting video research in the Learning Sciences: Guidance on selection, analysis, technology, and ethics. *Journal of the Learning Sciences*, *19*(1), 3–53. doi:10.1080/10508400903452884

Dewey, J. (1934). *Art as experience*. New York, New York: Penguin Group.

Dreier, O. (2009). Persons in structures of social practice. *Theory & Psychology*, *19*(2), 193–212. doi:10.1177/0959354309103539

Eberbach, C., & Crowley, K. (2009). From everyday to scientific observation: How children

learn to observe the biologist's world. *Review of Educational Research*, *79*(1), 39–68. doi:10.3102/0034654308325899

Ellis, R. (2008). Rethinking the value of biological specimens: laboratories, museums and the Barcoding of Life Initiative. *Museum and Society*, *6*(2), 172–191. Retrieved from http://eprints.lancs.ac.uk/33743/

Flannery, M. (1992). Using science's aesthetic dimension in teaching science. *Journal of Aesthetic Education*, *26*(1), 1–15.

Girod, M., Rau, C., & Schepige, A. (2003). Appreciating the beauty of science ideas: Teaching for aesthetic understanding. *Science Education*, *87*(4), 574–587. doi:10.1002/sce.1054

Guest, G., MacQueen, K. M., & Namey, E. E. (2012). *Applied Thematic Analysis*. Thousand Oaks, CA: Sage Publications.

Halliday, M. (2004). *An Introduction to Functional Grammar*. (C. M. I. M. Matthiessen, Ed.) (3rd ed.). New York: Oxford University Press.

Heath, S. B., & Street, B. V. (2008). *On Ethnography*. New York: Teachers College Press.

Hidi, S., & Renninger, K. A. (2006). The Four-Phase Model of Interest Development. *Educational Psychologist*, *41*(2), 111–127. doi:10.1207/s15326985ep4102_4

Ingarden, R. (1961). Aesthetic experience and aesthetic object. *International Phenomenological Society*, *21*(3), 289–313.

Jakobson, B., & Wickman, P.-O. (2007). The Roles of Aesthetic Experience in Elementary School Science. *Research in Science Education*, *38*(1), 45–65. doi:10.1007/s11165-007-9039-8

Jones, M. G., Minogue, J., & Tretter, T. R. (2006). Haptic augmentation of science instruction: Does touch matter? *Science Education*. doi:10.1002/sce.20086

Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *Journal of the Learning Sciences*, *4*(1), 39–103. doi:10.1207/s15327809jls0401_2

Jucker, A., & Smith, S. (1998). And people just you know like "wow": Discourse markers as negotiating strategies. In A. Jucker & Y. Ziv (Eds.), *Discourse Markers: Descriptions and Theory* (pp. 171–201). Amsterdam: John Benjamins Publishing Company.

Lancia, F. (2012). The Logic of the T-Lab Tools Explained.

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching*, *38*(3), 296–316. doi:10.1002/1098-2736(200103)38:3<296::AID-TEA1007>3.3.CO;2-I

Martin, J. R., & White, P. R. R. (2005). *The Language of Evaluation: Appraisal in English*. New York: Palgrave Macmillan. doi:10.1057/9780230511910

McAllister, J. W. (1996). *Beauty and Revolution in Science*. Ithaca, NY: Cornell University Press.

McAllister, J. W. (2002). Recent work on aesthetics of science. *International Studies in the Philosophy of Science*, *16*(1), 7–11. doi:10.1080/02698590120118783

McClain, L. R., & Zimmerman, H. T. (2014). Prior experiences shaping family science conversations at a nature center. *Science Education*, *98*(6), 1009–1032.

doi:10.1002/sce.21134

Medin, D., & Bang, M. (2014). *Who's Asking? Native Science, Western Science, and Science Education*. Cambridge, MA: MIT Press.

National Research Council. (2012). *A framework for K-12 science education: practices, crosscutting concepts, and core ideas*. Washington D.C.: The National Academies Press.

Östman, L., & Almqvist, J. (2011). What do values and norms have to do with scientific literacy? In C. Linder, L. Östman, D. Roberts, P.-O. Wickman, G. Ericksen, & A. MacKinnon (Eds.), *Exploring the Landscape of Scientific Literacy* (pp. 160–175). New York: Routledge. Retrieved from http://www.did.uu.se/literacypractices/documents/OstmanAlmqvist-literacynnatv.pdf

Pink, S. (2011). Multimodality, multisensoriality and ethnographic knowing: social semiotics and the phenomenology of perception. *Qualitative Research*, *11*(3), 261–276. doi:10.1177/1468794111399835

Root-Bernstein, R. S. (2002). Aesthetic cognition. *International Studies in the Philosophy of Science*, *16*(1), 61–77. doi:10.1080/02698590120118837

Roth, W. M., & Jornet, A. (2014). Toward a Theory of Experience. *Science Education*, *98*, 106–126. doi:10.1002/sce.21085

Schiffrin, D. (1987). *Discourse Markers*. Cambridge: Cambridge University Press.

Wickman, P.-O. (2006). *Aesthetic Experience in Science Education*. Mahwah, NJ: Lawrence Erlbaum Associates.

Wong, D., & Pugh, K. (2001). Learning science: A Deweyan perspective. *Journal of Research in Science Teaching*, *38*(3), 317–336. doi:10.1002/1098-2736(200103)38:3<317::AID-TEA1008>3.0.CO;2-9

Zembylas, M. (2005). Three perspectives on linking the cognitive and the emotional in science learning: conceptual change, socio-constructivism and poststructuralism. *Studies in Science Education*, *41*(1), 91–115. doi:10.1080/03057260508560215

Zimmerman, H. T., Reeve, S., & Bell, P. (2009). Family sense-making practices in science center conversations. *Science Education*, *94*(3), 478–505. doi:10.1002/sce.20374

CHAPTER 4: Learning through Continuity of Experience: A Case Study of a Family Learning about Salmon

From a STEM ecosystems perspective, learning is recognized as harnessing a rich array of learning opportunities supported by many different settings (Barron & Bell, 2015; Traphagen & Traill, 2014). In a learning ecosystem, each context provides a unique configuration of activities, material resources, relationships, and the interactions that arise from them (Barron, 2006) support learning and identity development. Families seek out the opportunities – both formal and informal, structured and unstructured, individually and together – that are available to them to support the family members' interests and needs.

But in educational research, particularly that of informal, out-of-school settings, these multiple contexts are rarely studied together for how each of their unique contributions make up a continuous learning experience. Empirical literatures tend to focus how learning occurs within a specific context, such as one summer camp program or a single museum exhibit (Bell, Bricker, Reeve, Zimmerman, & Tzou, 2012). Educational research taking place in designed informal learning settings, such as museums, environmental education, zoos, aquaria, children's museums, demarcate borders around the kind of activity taking place, noting that findings should not or can not be generalized across place (eg. Ash, 2003; Kisiel, Rowe, Vartabedian, & Kopczak, 2012; McClain & Zimmerman, 2014), or even within a genre of place such as a museum (for example, science centers versus natural history museums (Rader & Cain, 2008)).

Although it is unknown if visitors distinguish between these places in the way researchers do, some researchers are beginning to demonstrate how science museums, zoos, aquariums, and science centers, despite the stark difference such as live animals or hands-on activities, have much in common (Schwan, Grajal, & Lewalter, 2014) through presentation styles, science

education, and modes of participation on behalf of the audience. For families pursing leisure and educational opportunities in their region, such a range of places and activity potentially fall within a their own learning ecology, which are linked through the learning that takes place: families learn and teach cultural and cognitive values and meanings. Tracing how families make use of resources and foster connections across the various learning opportunities available to them in their communities is gathering increasing attention and importance (Bell, Bricker, et al., 2012), and in this paper, I address the suggestion that cumulative learning effects for learners across informal and everyday experiences need more attention (Bell, Lewenstein, Shouse, & Feder, 2009; McClain & Zimmerman, 2014). In order to understand diverse learning pathways that families construct across multiple sites of learning, I ask what are the connections families make across settings that make learning experiences continuous over time? How do different contexts contribute to learning from a more integrated perspective?

There are a number of studies that describe the cross-setting nature of STEM learning, and the connections that families make as they move in everyday and out-of-school learning settings. In a study of families at a nature center, researchers identified connections that contributed to learning as shared, common prior experiences, such as observations in the outdoors, various forms of media, other informal science education programs and camps, and through analogy (Zimmerman & McClain, 2013). In addition to those sources, the processes families used to reference a prior experience included reminding others of a shared event, explaining or defending a statement using a prior event as a reference, parental prompting of a child to display knowledge gained from a prior experience, or referencing an earlier part of the same visit (Zimmerman, Perin, & Bell, 2010).

Family support and engagement is critical for developing the information processing skills that maintain and foster long-term interest as children search out information and further their expertise in a topic (Palmquist & Crowley, 2007). On a longer timescale, youth's interest in a STEM topic can be cultivated and encouraged over months or years through practices that are recognizably scientific even in the family setting (Barron, Martin, Takeuchi, & Fithian, 2009). Such was case of a young girl, Brenda (Bricker & Bell, 2014), who carried out her perfume-making hobby with her mother among her other science-oriented pursuits, yet connections between her home practices and school activities were not known to her classroom teacher. It's in the flux of these many events, social positions and identities within everyday experience that some emerge as significant, memorable events that form a constellation of events, that in hindsight, can be recognized as making up a learning pathway.

Theoretical Framework

The Cultural Learning Pathways (CLP) framework is a means for examining how individuals and groups learning in ways that are meaningful to them, and where, how, why and with whom this learning occurs or obstructed. Drawing on social practice theory, life-long, life-wide and life-deep learning and a theory of persons, CLP maintains that learning is social, situated and distributed. People create cultural learning pathways, or chains of personally consequential activity and sense-making, that are temporally extended, spatially variable, and culturally diverse with respect to value systems and social systems (Bell, Tzou, Bricker, & Baines, 2012). With respect to various settings, activities, and social groups, individuals must navigate multiple and sometimes competing social expectations and cultural values that shape their identities and learning pathway over time towards or away from their engagement in making sense of natural phenomena, i.e., science. CLP has been a lens for taking a leading

emphasis on social positioning and identity development over time and across settings. Material and social arrangements can constrain or contribute to how individuals perceive themselves and take up doing science-related activities. They navigate through and across a web of contexts in which people and objects are situated and linked through activity. But in considering particular moments that mark points in "the constellation of situated events" that make up the CLP's framework, there are some experiences stand out as more meaningful or significant than others – what we might mark as those brighter stars in the constellation.

Continuity of Experience through the Aesthetics of Science

These meaningful moments as people participate in the varying contexts of their lives make up the vital experiences that shape identity and development. Experience, in its common meaning of participation an event or activity that leaves an impression, is recognized as intrinsic to meaningful learning. Learning through experience has been called "learning by doing" (Seaman & Nelsen, 2011), but I wish to take up a more expansive conception of the principle in the Deweyian sense. In many of the events we commonly call experience, which are composed of activities or things happening over time, there is no coherence, development or flow, so that the event never fully matures in such a way that it could be composed into "An Experience" (Dewey, 1934; Wong & Pugh, 2001). Although a part of everyday living, some experiences are distinguishable from the more general flow of experience, as John Dewey defined "An experience." Accounts of such experience are critical, Roth & Jornet argue, when providing holistic accounts, as I will here, of the relations of situational events and continuous aspects of learning and knowing, in which the learner and environment mutually determine each other (Roth & Jornet, 2014). no coherence, development or flow

Such a significant event is made up of phases of anticipation, consummation and closure (Dewey, 1934), such that an event becomes imbued with anticipation, development and unity, also becomes an act of thinking and meaning (Wong & Pugh, 2001). Dewey distinguishes his version of experience by how it relates to what preceded it, and how it comes to an end. All events comes to an end, but *an experience* closes through consummation not just cessation:

> …we have *an experience* when the material experience runs its course to fulfillment. Then and only then is it demarcated in the general stream of experience from other experiences. A piece of work is finished in a way that is satisfactory; a problem receives its solution; a game is played through; a situation, whether that of eating a meal, playing a game of chess, carrying on a conversation, writing a book, or taking part in a political campaign, is so rounded out that its close is a consummation and not a cessation. Such an experience is whole and carries with it it's own individualizing quality and self-sufficiency. It is an experience (Dewey, 1934, p. 37).

I find that such a definition of *an experience* is very much like the engaging experience that educators hope will be the result of their effort to design learning. But in warning against merely creating a series of exciting and fun experiences, Lemke reminds us that education is more than one great experience after another – that "each small drama of experience must somehow play a part in still larger dramas on longer time scales" (Lemke, 2001, p. 311). It is the continuity across many different experiences that I pursue in this paper – that the end of one event does not mean that an experience is over. In Dewey's *principle of continuity of experience* "every experience both takes up something from those which have gone before and modifies in some way the quality of those which come after" (Dewey, 1938, p. 19). This continuity has been understood as how people establish relationships in action and in communication (Wickman, 2006) – in such a

way to make them continuous and indistinguishable from everyday living (Dewey, 1934). To help conceive of Dewey's notion of experience, it is worthwhile to note that Dewey said he would abandon the use of the word *experience* to substitute the word *culture* as better able to carry his philosophy of experience (Seaman & Nelsen, 2011). Experience is situated within culture and history, in such a way that culture is not simply reproduced but is also transformed – a principle I see echoed in the transformation of culture in calls for broadening participation in the sciences (Bang, Warren, Rosebery, & Medin, 2012; Lee, 2008).

Within an experience are intellectual and emotional components that are inseparable from the experience (Dewey, 1934; Flannery, 1992; Lemke, 2000; Pugh & Girod, 2006). These are aesthetic aspects that shape and direct how the activity proceeds and is understood (Wickman, 2006). Aesthetics as the experience of beauty and pleasure (or displeasure) are an integral part of learning science, not just of artistic appreciation. Three dimensions of aesthetics in science learning—aesthetic experience, epistemic values and aesthetic understanding—perfuse the intellectual and emotive experience, shape how activity proceeds at varying time scales, is directed by cultural and social values, and enculturates learners into scientific ways of knowing about the world. Aesthetic experience is one in which aspects of beauty and pleasure perfused throughout. Epistemic values can be recognized as those that evaluate theory and experiment, such as elegance, simplicity, and fruitfulness. Aesthetic understanding comes from physical qualities, so that appreciation comes about through sensory and cognitive reflection in such a way that the object of study is felt as much as it is known, and it becomes "more beautiful" (Ingarden, 1961).

Given the framing of learning pathways and a particular meaning of experience, I turn to my investigation of the continuous aspects of learning, over multiple events in varying places

and over time, to address the question of what connections families make to form continuous learning experiences, in a learning ecosystems perspective.

Methods and Analysis

The data in this analysis stems from a broader ethnographic design-based research project aimed at facilitating and understanding how families engage in sense-making across settings while engaged in learning science in informal settings. Ten families each completed study visits to the Burke Museum of Natural History and Culture at the University of Washington, the Seattle Aquarium, and a place and activity of their own choosing. The settings for this study were selected as representative of the variety of places that families can utilize within the Puget Sound region for their leisure and learning. Two research sites, the Burke Museum of Natural History and the Seattle Aquarium, have extensive research collections, design programs and exhibits with the intention of communicating scientific ideas to family audiences, and curate and conduct research as a part of their mission. For one of their three study visits, families were asked to choose a place or activity of their own interest, in order to capture how families conceived of science activity in their everyday life as well as to gain a diversity of places and activities in the study. The participant families chose to visit a local history museum, science center (2 families), urban nature walks (3 families), pick berries and make jam at home, children's museum, BMX bike park, and a zoo. All 30 study visits were video- and audio-recorded, for approximately 60 hours of recordings.

The researcher accompanied the families as a participant-observer, and audio- and video-recorded the families for the duration of these visits, as well as conducted brief interviews before or after each of the visits. As a part of their visits, and the design-based research portion of the study, six of the families were asked to use a set of supplemental activities, delivered either as a

smartphone app or as paper cards. These scaffolding activities were designed to draw on the epistemic practices of science as outlined in the *Framework for K-12 Science Education* (National Research Council, 2012) in order to bridge content areas and to facilitate support cross-event meaning making from one family visit to the next.

Participants and Settings

The family profiled in this analysis is the Messi family, who were selected because they touched on a single, continuous topic—salmon and their lifecycle—in each of the three study visits. This was a unique situation for the range of families in this study, to have a single topic extend across all the study sites. The portions of their excursions that touch on salmon are the focal moments for analysis in this case study, in order to highlight how such cross-event meaning making occurs.

Robert, the father, is a financial analyst for a nearby county and the mother, Victoria, is a nurse. Victoria tells me she is from Japan, and she speaks Japanese with her children; Robert also speaks Japanese fluently, having studied Japanese and attended the Naval Postgraduate Defense Language Institute/ Foreign Language School in Monterey, California. At the time of our study visits, Tina was 9 years old and in the 4th grade, Lionel (no relation to the famous soccer player) was 7 years old and in 2nd grade, and Bukie was three years old. Tina is a ballet student, and our study visits had to be coordinated around her practices and performances in *The Nutcracker*. It emerges from their dialogue at Carkeek Park, the site that they chose to visit for the study, that Lionel's class the previous year in school had hatched and reared salmon eggs through a relatively popular Seattle "Salmon in Schools" program. Lionel and Robert had accompanied the class to the Carkeek Park stream to release the fish the previous spring.

The Messi family visited the Burke Museum, Carkeek Park in northern Seattle, and the Seattle Aquarium. Each of the three visits were about one month apart, with five weeks between the Burke Museum and Carkeek Park visits, and 4 weeks until the Aquarium visit (see Table 1). At least one member of the family had been to each of the places, although only Tina had visited the Burke Museum on a school trip.

Table 4-1: Messi Family Characteristics

Family Names	Recruitment site	Order of Visits	Time range between study visits
Messi Family Robert (father) Victoria (mother, Carkeek and Aquarium) Tina (9 years) Lionel (7 years, Carkeek and Aquarium) Bukie (3 years)	Elementary School (newsletter)	Burke Museum Carkeek Park salmon run Aquarium	October-December 5 weeks 4 weeks

Data Analysis

For this analysis, I use a case study approach (Yin, 2009) in order to understand the connections that were occurring across the study settings for the focal participants, and inductive thematic analysis (Braun & Clarke, 2006; LeCompte & Schensul, 2013) to understand the relationship of the moments and events to the settings in which they took place. Data consisted of video and audio recordings of the complete visit for each of the study sites, field notes, interviews at the beginning or conclusion of the study visits, and the emails scheduling the study visits. Upon returning from the field, content logs were created from the videos for each of the sites. The content logs were reviewed and initially coded for emergent themes specific to this

family, as well as to confirm in this dataset the presence of connections from prior experiences as described in McClain and Zimmerman (2014).

When salmon was identified as a topic connecting the three site visits for the Messi family, those portions of the video and audio that were related to salmon were fully transcribed; for the Carkeek Park site visit, this meant that the entire video was transcribed, while the Burke and the Aquarium had several minutes, representing only a portion of the entire visit. These selections ranged in the amount of time dedicated to the topic, from 57 seconds at the display at the Burke Museum, to one-and a-half hours on the walk along the creek at Carkeek Park, to 9 minutes at the Aquarium. I also reviewed other moments within the video that could be relevant to the family's questions and topics that could make connections across sites but were not directly related to salmon (for example, observations about missing salmon eyeballs in carcasses made at Carkeek Park may have been recalled at the Aquarium's Window on Washington Waters tank, where many rockfish are missing an eye).

I consider the family as the unit of analysis, where adults and children learn alongside each other, reciprocally, rather than conceiving of the family system as parents supporting and cultivating youths' interests and identities. In the CLP framework, social relationships are necessary part of learning experiences, as people learn in ways that relate to the interests and expectations of other people in their lives (Bell, Tzou, et al., 2012). Studies of family learning often take youth's learning as the focal phenomenon, tracing the youth's interests, opportunities, and identity development, and where the adults' role is supporting the youth by securing opportunities within their social networks, finding specialized classes and programs (Barron et al., 2009). As a family unit, expertise may lie in child or adult, or be distributed across family

members (Ash, 2003; Zimmerman, Reeve, & Bell, 2008) in such a way that each contributes knowledge to a joint learning experience.

Findings and Discussion

The findings are in two parts. First, the results of applying McClain and Zimmerman's prior experience analytical categories from families' nature center walks are discussed. Then, the following section shows the thematic analysis of the Messi family's activity and discourse at each of the study sites that relate to salmon. These themes are shown in relation to how each place supported learning about salmon as events within a holistic, family-based sense-making experience across settings.

Connections Through Prior Events and Experience

As I noted above, I use the sources and processes for invoking "prior experience" that were derived from families on walks at a rural nature center (McClain & Zimmerman, 2014), and apply them to other sites. These connections included named sources of prior experience (everyday shared experience, media, informal science camps and programs, analogy), and processes (reminding of past event, explaining using prior experience as reference, prompting display of child's knowledge, or orienting to something earlier in the same visit). In reviewing the corpus of data through review and coding of content logs, I found these categories were present in the data from the Aquarium and Burke Museum.

In addition to these categories, in order to address my research question about the kinds of connections being made across places and over time, I found there were other kinds of connections being made across settings that extended beyond prior experience. These included recalling or invoking associations that often prompted action of some kind: Other people, either family or friends who were present or not present at the moment; and references to other places

from travel, vacations or in nearby neighborhood; or future events, in anticipation of invoking this present moment in the future.

Connections to people. Families directed attention and prompted observations of an object or specimen at hand because it reminded them of another person. That person was either be a part of the conversation but not a part of that particular exchange, present on the visit but not engaged in the conversation, or not present at all and was invoked by others thinking about them. For example, in this exchange between one girl and her mother as they were discussing a cow's eating behavior while at the Zoo, the girl mentioned her brother although he was not on their visit:

> Mother: No, but ruminants, like, it takes a while to digest straw and things so they kind of have to barf it back up and chew it again.
>
> Sofia: Ew, that's probably why Jim [brother] is a vegetarian now, wow.

In other instances in the data, grandparents were invoked: one girl photographed sea anemones to share with her grandfather, who also enjoyed photography; another boy took a photo of an object at the history museum and texted it to his grandfather because he would like it.

Connections to place. Across the content logs of the data set, other places families visit in the course of everyday life, have lived in the past, or travel for special occasions such as vacation, were invoked to make the present moment meaningfully relate to that other place. For example, one mother recalled seeing large jellyfish while canoeing near Whidbey Island, and on the ferry ride on that trip:

> Mother: Dude, you remember those giant ones? ((holding elbows out, so arms make a large circle)). That we saw when we were canoeing with Dad out on Whidbey?

Shawn: Yeah, like this big ((holding his arms out in a circle))

Elizabeth: and then we went to the ferry, remember?

Shawn: yeah, Those were like adults of these, if these were babies

Elizabeth: I don't know if they were the same kind or not

Shawn: Me neither:

The place helped a connection to a time when they had seen jellyfish in its natural habitat, in a place relatively near their home. After discussing the size of the barbs on the jellyfish, this prompted the size comparison between the jellyfish in front of them and the one they remember, as well as reflection on whether the jellies in this exhibit display would get as large as they had seen before. As the family was making meaning through their connections to other places, the significance of seeing the jellies in the Aquarium display was connected to another place they had seen jellyfish. Also, there is a reference to their father, a person not present; again, a way of connecting the present moment through people.

Future events. Family members mention events that they expect to happen in the future, anticipating the link from the present moment to the future. In an example profiled in more detail later in the following case study, a mother reads an exhibit label aloud to her son, noting the significance of one of the places included on label through the mother's inflection while she speaks.

Victoria ((pointing as she reads exhibit sign, indicated in italics)): *The traditional range of Coho salmon runs from both sides of the north Pacific ocean. From Hokkaido Japan, to eastern Russia around the Bering Sea to mainland Alaska, all the way to Monterey Bay.* ((Inflection on "Monterey Bay"; raises eyebrows and turns to look at Lionel)).

Monterey Bay a place where they will be traveling in a month's time, which they mention to me later in their visit. This is a combination of place being significant, as well as a future event.

Discussion of Connections through Prior Events

Connections across time and place, where families noted past events and sourced content knowledge, were present in the data. This extends and confirms McClain & Zimmerman's findings from an outdoor nature walk in a rural settings also apply to a natural history museum and aquarium in urban settings, addressing one of the limitations they found in their study. However, "prior experience" in the everyday sense as participation in past events or activities is just one meaning, rather than in the more particular Deweyian sense of experience used here. Learning happens when memories of prior events are connected to new activities (Rennie & Johnston, 2004), yet, invocation of a prior event does little when that is considered in solely as a cognitive moment (Wong & Pugh, 2001). Experience as conceptualized by Dewey, an experience and connection that is significant is made up of action, feeling and thought. These connections between events were present, but their significance to learning in experience is still under theorized. How do these connections over time and place create continuous learning? That is the next step in addressing how continuity in learning is created, which I address in the next section of findings through the case study of the Messi family learning about salmon across the three study sites.

Contributions of Place to a Continuous Learning Experience

An ecological perspective on learning shows that everyday science learning is not restricted to one kind of place, but occurs across myriad settings and through engagement with many people and material objects. Each place contributes to the development of the individual and the family as a social unit learning together. By taking one subject – salmon – and seeing

how different settings contribute to the family's learning about it, the role and contributions of each place are recognizable.

During their study participation, the Messi family visits three places that each afford meaningful sense-making related to salmon. This link across places is serendipitous – the Burke Museum and Aquarium were not the choice of the family, and had small displays on salmon which the family came across, but did not search out during their visits. The Burke Museum was the site of the first study visit, and then the visit to Carkeek Park five weeks later, and the Aquarium four weeks later – more than two months separated the first study visit and the last. Going to Carkeek Park was Robert's suggestion. At the end of the first visit, Robert thought they might choose a visit at home where they like to do science experiments, which they told me about doing in their opening interview. But later when coordinating a time through email, he suggested a local park and natural area: "I hear the chum salmon are back at Carkeek. It may be rainy, but if your equipment can handle it, how about we do our science there looking for the fish? It is fun to see the fish and a tradition for us to go down there each year to see them return." Robert noted that he had heard the salmon were at the Carkeek stream through a Facebook posting from a friend.

Each of the places the family visited presented salmon in different ways. The Burke Museum had a diorama of a Pacific Northwest creek with salmon (Figure 4-1); Piper's Creek in Carkeek Park was a natural[2] setting outdoors (Figure 4-2), with a paved mile-long walking trail;

[2] Urbanization and blockage of the creek ended historical salmon runs, and the current population of salmon in Piper's Creek at Carkeek Park have been re-introduced through a stock supplementation program. Chum salmon are provided from Suquamish Tribe's Grover's Creek Hatchery as eyed eggs for the Salmon in the Schools program, and as fingerlings for release into Piper's Creek. This distinction did not arise in the family's conversation, although they did talk about identifying wild or hatchery fish. Because the setting is outdoors and Robert alluded to it as "real," I am considering it a natural setting.

and in the Aquarium was a salmon hatchery area (Figure 3), a video about salmon impacted by the Elwha Dam removal, and several display tanks of salmon.

Figure 4-1: Burke Museum diorama of Washington forest stream

Figure 4-2: Piper Creek at Carkeek Park, watching a salmon splash

Figure 4-3: Seattle Aquarium, looking at the young salmon in the tank

Each of these settings contributed to an integrated understanding of salmon for the whole family through the unique affordances of each place. Each setting supported different processes and aspects of learning to make up a greater understanding than one place alone could, the relationship of which are shown in Figure 4-4.

Each site contributes something unique and something shared. In the overlapping circles, the themes that were shared between sites are noted, as well as what was unique to each site. It is notable that there were no connections discernable in the data between the Burke Museum and the Seattle Aquarium. Each of the settings and the family's interactions will be discussed in the following sections.

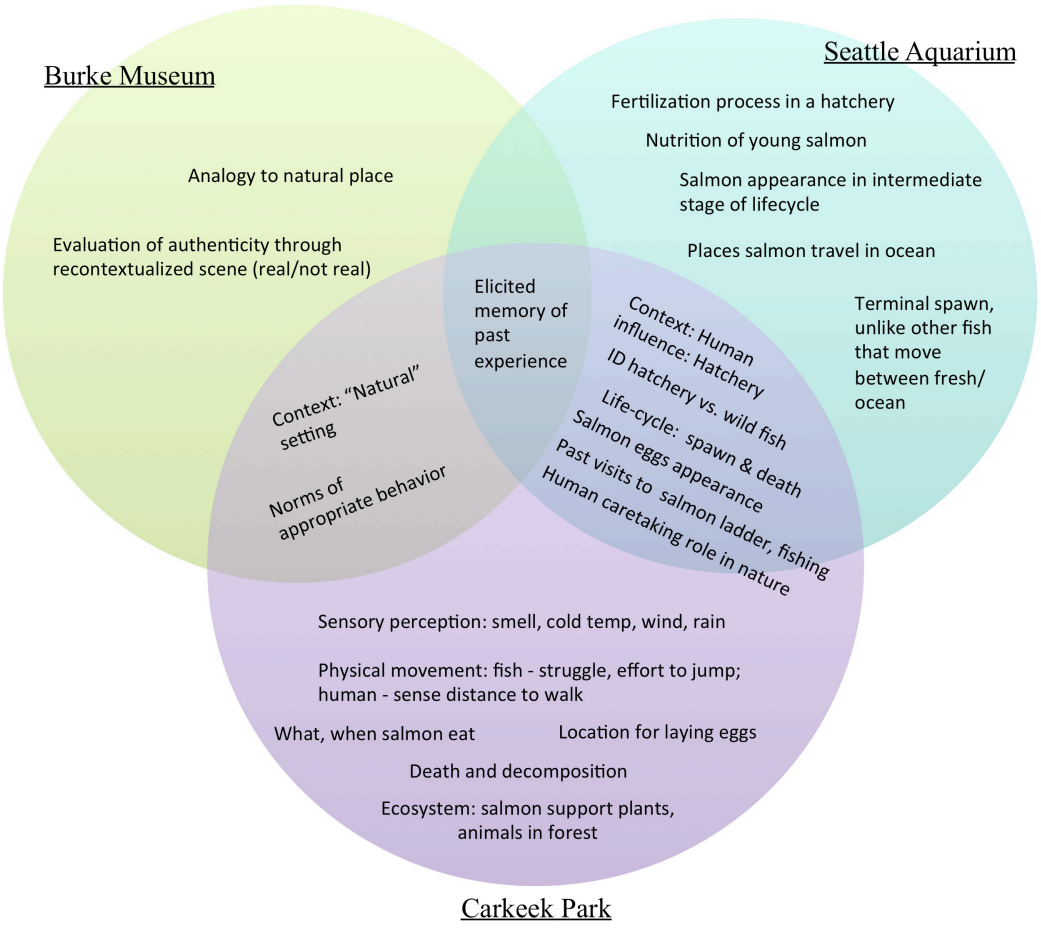


Figure 4-4: Unique and overlapping dimensions of family sense-making across study contexts

Burke Museum

At the Burke Museum, Robert, Tina, and Bukie stop to view a diorama of a forest stream in the Washington environment, climate and history section of the Museum that displays salmon swimming upstream, surrounded by cedar trees, ferns and mosses, and native birds. The diorama is bounded with a black metal fence and signs that direct visitors to stay out. Tina approaches the display first, and finds a foothold on the fencing to lift herself high enough to look over and into the display area. Robert and Bukie join her, and the transcript that follows is their dialogue during the 57 seconds they spent at the exhibit.

Robert: Woah

Tina: hhha ((smiles)) ((2 sec)) **It looks really real.**

Bukie: **It looks like glass.**

Robert: uh hum

Bukie: It's glass.

((4 seconds silence while they look))

Robert: It looks **like Carkeek park**

Tina: uh hum

Bukie: It's glassy

Robert: It is kind of glassy

Bukie: It's glass, **you couldn't jump in there**

Robert: Don't jump in there, no

Bukie: You just look at it, it's glassy ((points, then holds the railing)) those fish couldn't swim

Robert: no

Tina: ha ha

Bukie: Those guys couldn't swim if it's black is green and then that shark is glass shark ((Tina turns her head away, looks, walks to next exhibit)) Robert: hum

Bukie: It's a whale, **isn't real**. Oh look at that guy

Robert: Yeah, I don't think I've seen one of those before ((Robert and Bukie fully turn away and walk to next exhibit))

The diorama supports three themes (Figure 4-5): first, a connection through analogy to a natural setting the family is familiar with, and a connection through the limitations of appropriate behavior at this stream model.

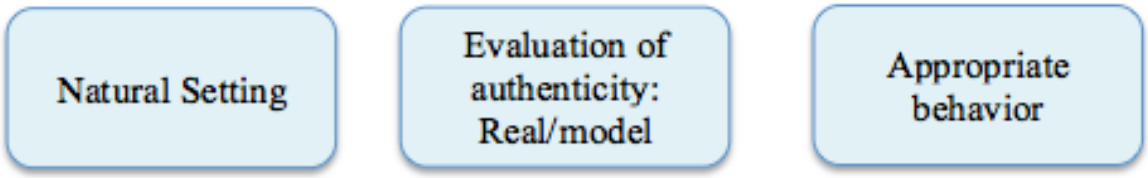


Figure 4-5:Topical themes at the Burke Museum

Tina's first comment is that it "looks really real" and Robert concurs by saying that it looks like Carkeek Park. This prior experience is simply stated here, but it does not do much more in conversation than make a connection to another place, affirming that this model does appear "real." (At this point in the study, it is unknown that the family has been to Carkeek Park or involved in the Salmon in Schools program, nor has the site been mentioned for a study visit.) Tina and Robert know what a stream in the out-of-doors looks like, and compares this model favorably. In contrast, it is Bukie, who says in his 3-year old language, that the display looks "glassy," directing attention to the plastic sheen and what is not natural looking about the display. Because it is acrylic and looks "glassy," Bukie's two comments reflect the distinctions he makes between this and an outdoor creek: "you couldn't jump in there" which is something he could do in a real stream, but this one is both acrylic and fenced; and "Those guys couldn't swim" because it's "glass". He shows he is learning to distinguish appropriate behavior in a museum versus outdoors. And in a model, he notices can't jump in the water because it is hard and that these fish can't swim, something he could do (or rather, often cautions his sister and brother against) while walking the creek at Carkeek Park.

The place supported observations appropriate to a museum. The discourse included an analogy to a real place known to someone in the family, a desirable connection from a museum design perspective. We see that this family is the kind that knows appropriate behavior in a museum, yet also is likely the kind (and age) of person to jump in a stream given the opportunity.

Carkeek Park

Viewing the salmon run at Carkeek Park supported many themes and topics of discussion, that reoccured in a non-linear discourse throughout the one hour and 30 minute walk. This visit was in the late afternoon on a rainy day, but was an active time for viewing the salmon in Piper Creek. A paved walking trail ran along more than a mile of the creek, with some viewing platforms built alongside the creek near the parking lot. We met at one of the viewing areas, and watched salmon before walking upstream away from the parking lot. We did not see any other park users on this walk into the forested area away from the parking lots, even though the viewing areas had been busy. On this visit, Lionel and Victoria (mother) joined, although they had not been at the previous study visit to the Burke Museum. The following selection of transcript an exchange between Robert and Tina at the viewpoint, within minutes of starting the recording. Several topics arise and familial processes that make connections to previous experience and family members, which are examples of those repeated throughout their time walking the creek.

Tina: Look at that salmon right there ((Robert says something inaudible)) They're like **fighting against the current**.

Robert: The thing I think is **really amazing is like their color**

Tina: yeah

Robert ((raising hand)): **How nicely matched they are**

Tina: ye::ah

Robert: **with the rocks**

Tina: So like **bears and predators can't find them**

Robert: um **you remember when we released those little baby ones**, we did it at night so the predators couldn't get the baby ones when we released them //but now not it's the daytime

Tina: //you did?

Robert: ye yeah yeah

Tina: When did we?

Robert: Didn't you come to that?

Tina: No

Robert: We released the babies.

Fighting against the current, and the struggle of the salmon as they swim upstream; the beauty and color of the salmon, which protects them from predators that would eat the salmon or their young; and participation in the release of young salmon the previous summer raised by Lionel's school class (even if Tina's presence was misremembered). These topics are integrated into conversation, were collaborative, and prompted by observations and excitement in watching the salmon, rather than through external incitement (signage or facilitators).

The topical themes (noted in Figure 4-6) arose at more than one moment during the visit, prompted only through the family's observations and conversation. Any information exchanged during the visit came from the family's own repertoire of knowledge, as there were no interpretive resources along the creek where the family walked.

Lionel was often positioned at the expert, as family members asked him questions and he often had an answer. Because of his prior experience with Salmon in the Schools program, Lionel knows answers to many of the questions his family asks, but this positioning as a

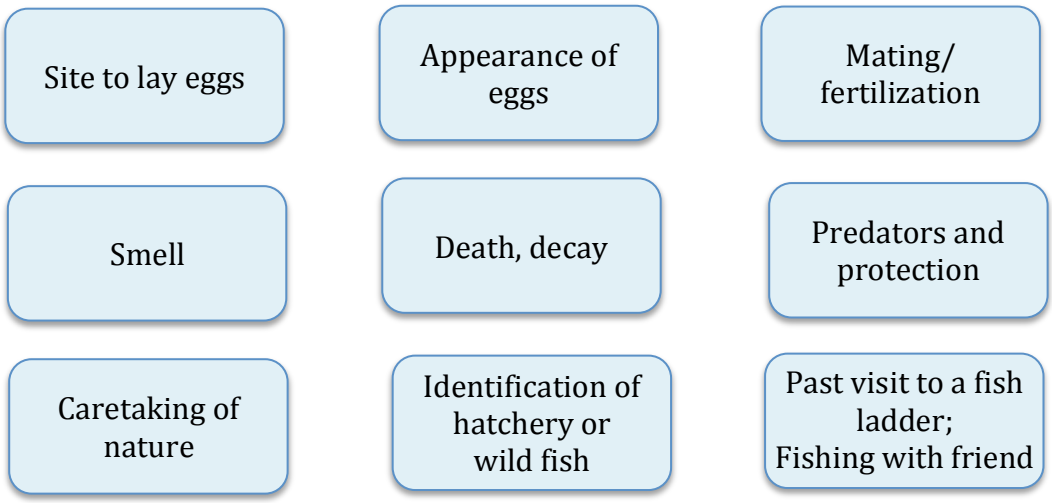


Figure 4-6: Topical themes at Carkeek Park

developing expert simultaneously expands his scope of possibility for learning – for developing his knowledge of salmon into an increasing island of expertise (Palmquist & Crowley, 2007). This expertise is revealed not by his parents prompting Lionel to display knowledge, but they often asked genuine questions they did not know the answer themselves, and the questions could go addressed and discussed, but unanswered in the moment. Even Tina, his older sister, often asked Lionel questions, as the two were often paired exploring along the stream together. In this section of transcript, we see how Lionel is positioned as the expert:

Robert: Is this a good spot to lay eggs, do you think?

Lionel: Yes.

Robert: **Where do they lay eggs**?

Lionel: 'cause it's gravelly

Tina: ((To Lionel)) The gravelly and it kind of has to be calmer, right? So like you know how where that where that its kind of slanted ((gesturing with forearm tilted)), wouldn't that be a good place? At the very end, you know how it has those leaves and that kind of wall. ((referring to a location in the creek in view))

Lionel: No! No.

Tina: No?

Tina: They need like, really gravelly strong?

Lionel: Yeah, there's a good spot

Tina: Right there?

Lionel: Yeah

Tina: Around there

Lionel: **In the sand is not good**

Tina: Uh hum, because the sand can get blown away

Tina: Bobby? I wonder if that big salmon will make it up?

Robert: ah what?

Tina: I wonder if that big salmon is going to make it up.

Lionel: **I think it's going to lay an egg and die**

Robert: ((inaudible))...back down they are all excited...

Bukie: ((inaudible))...die

Robert: one of 'em is going to make a break for it YEAH!

Tina: Why is it doing that?

Robert: I don't know ((inaudible))

Bukie: Hahaha that's funny he just went like this ((waves hand back and forth quickly))

Lionel: Yep, **that one's going to try to do it!**

Robert: Is he? **Wow!**

Tina: It's **getting pushed back, oh no!**

Robert: It's going the wrong way?

Lionel: Yeah sometimes they have to get a retry

Robert: Pretty fascinating

In this exchange, Lionel has an authoritative tone, and although Tina contributes to the discussion, she is asking Lionel questions. Discussing what kind of site is ideal for the eggs was only one aspect of their exploration along the stream –questions about the egg's appearance brought in shared past event of fishing with a friend, who used salmon eggs as bait, as well as eating salmon eggs in sushi, as resources for trying to find eggs buried in the stream.

As the salmon swim upstream, the family cheers for them or are disappointed when a fish makes an unsuccessful attempt to move forward. Obstacles the fish must pass include downed logs, shallow water, or human-obstacles such as a flow gate in the creek, all of which seem to be insurmountable for the salmon. The great physical effort of the salmon to pass these obstacles and the distance they traveled upstream, even as their bodies decayed, were noted repeatedly as the family walked the stream. The final lines of the transcript shows how the family's discussion of spawning, death, and the fishes' effort to swim are intertwined. Walking the stream meant gaining a sense of distance, following the turns and divisions of the creek as the family walks and clambers over logs themselves, and wondering if a salmon went the right way following the turns of the creek.

Two of the more striking themes in conversation and experience at Carkeek Park were the effort of the salmon to swim upstream and the death of the salmon. Many of the salmon's

bodies are decaying, becoming a splotchy yellow, even as they swim, making the effort all the more impressive (Robert: “Wow, that one is so beat up gosh!” And, minutes later, Tina: “Those two big ones are really beat up… I wonder if they are going to make it.”).

All along the creek are dead and decomposing fish, and the associated smell that the children complain about at intervals. In this selection of transcript, we see an example of how the death and decomposing fish are noticed:

Victoria: There is one right there, a live one

Tina: There's an alive one and two dead ones. **Come over here, it's easier to see right here. There's one live one and two dead ones.**

Robert: I see another live one, up there, further up.

((clambering over downed trees))

Tina: Oh Bobby, that one the eye came out. The eye came out of this one.

Victoria: Ah

Tina: Yeah it’s just bloody water. Bobby come see this one its like bloody water right there

Robert: Bloody water?

Tina: Yeah cause of the eye came out of its eye socket, it’s just bloody water in the eye socket

Bukie: The fish that big fish is dead right there

Victoria: Yeah

Tina: ((Japanese)) There's one dead there, it’s just bones, too.

Victoria: That one it means that one is not dead

Tina: No, it's just bones

Victoria: oh there is one more

Tina: yeah, back there, it's just bones, part of its just bones

Victoria: oh

Tina: Come over here, it's just bones or something like that

Bukie: **these fishies are dead**

Tina: ((Speaking in Japanese to mother))

Victoria: ((responds in Japanese))

Tina: Look at that one, look at that eye

Bukie: These eyes?

Victoria ((speaks in Japanese))

Bukie: **Ah yah that smells** (?) yuck

Tina: Hey lookit

Robert (inaudible)

Tina: yeah, come see. Isn't it? I don't want to fall.

((Robert takes photo))

Tina: And there's more over here, like it's body is still there, but there's like this pinkish stuff

Lionel: Wait, where's the bones?

Tina: It's **like is it it's bones or intestines**?

Robert: **Oh my goodness**

The dead fish are not ignored or dismissed as being distasteful—rather Lionel, Tina and Robert investigate them, looking carefully and talking about what they see. This is the first time the missing eyeballs are noted, but that characteristic of the carcasses comes up again several times

as they examine other fish carcasses – Tina proudly tells me she loved to eat fish eyeballs when she was younger; Lionel asserts at one moment that raccoons eat the eyeballs, and at another time that seagulls love them. Robert points out that the decomposition of the fish contributes to the whole forest ecosystem, for trees as well as animals. Confronting the death of the salmon provides an experience of the lifecycle that is experienced with all the senses, the smell and cold, rainy weather, combined with the emotion of the fishes' physical effort and the appearance of the fishes' decomposition into the soil.

Incorporated within their conversation about spawning and what makes good sites to lay eggs, the death and decay of the fish is inescapable – this is not just words in conversation or read on an exhibit label, but an experience that is full of meaning and emotion. These experiences could only be captured in the natural setting that the creek afforded, creating an aesthetic experience leading to a felt understanding about the salmon lifecycle that would not be achievable (or perhaps even desirable) in the designed settings of an aquarium or a natural history museum.

Aquarium

At the Seattle Aquarium, a dedicated salmon exhibit presents a small hatchery tank, a larger tank holding more mature fish, and an historic fish ladder runs alongside the building, viewable outside the window (now out of use). The small holding tank displays young salmon, which were in the alevin stage on this visit (still attached to the egg sac, but emerged and looking like small fish). Many of the themes at the Aquarium (Figure 4-7) were repeated from Carkeek Park, and elaborated during the Aquarium visit, such as fertilization of the eggs, noticing the dead fish in the tank, and Lionel identifying the fish as hatchery or wild fish by the notch in their fin. The ocean portion of their lifecycle was mentioned more at the Aquarium, in response to an

exhibit label at the Aquarium. However, it is notable that the themes that overlapped from Carkeek Park also extended or answered questions the family had, as the following section of dialogue demonstrates.

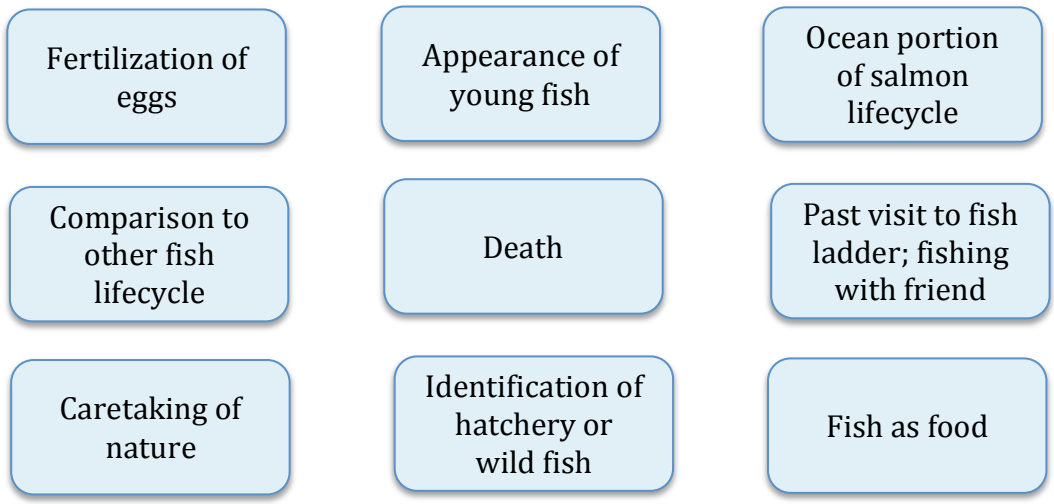


Figure 4-7: Topical themes at the Aquarium

In this conversation, Robert tells the rest of the family what he read on a sign about how hatchery fish are fertilized:

Robert: **Ohh, look at this.**

((Victoria points to sign on the wall))

Robert: Whoa they collect the eggs from the female //and they squeeze out

Lionel: // no they

Robert: the sperm //from the males and then they spray that all over that, and **that's how they get the fish. Wow.**

Tina: //milk

Victoria: Really?

Robert: Wow

Lionel: Wow.

(2 sec)

Lionel: **So *that's* how they get the**

Robert: ouch

Victoria: Whoa

The most striking thing about this visit, which occurred 4 weeks after the visit to Carkeek Park, was that it seemed like a conversation that continued without any interval of time between the two events, just with different resources to support exploration. Robert's direction to look at the sign was as if someone had just asked how the fish were fertilized, a question that was raised at Carkeek Park. There, Victoria, Lionel and Tina discussed it with me, where I brought in a prior event of my own at a salmon hatchery where I had heard during a tour about how the eggs were fertilized, but it was a long ago memory and again, my positioning with the family was not that of an exporter - and we left uncertain about how the eggs were fertilized. Here, the answer is presented with the authority of the Aquarium. Lionel's "*that's* how they get the..." comment indicates this is a continuing question that has now been addressed, with some closure.

Meaning-making through place can come through associations to other people, not just places directly visited. For example, Victoria Messi, reads an exhibit label and notes the places the salmon travel in the ocean portion of their lifecycle, marked in significance by the relationship of place to their own family members. The exchange that follows is the second time she has pulled one of her children aside to read the label showing that she finds it interesting and important. The first time she showed daughter Tina, and here it is with son Lionel:

Victoria: Lionel, Lionel ((wiggles finger to call him over)) come here.

Lionel: huh?

Victoria ((pointing as she reads exhibit sign, indicated in italics)): *The traditional range of Coho salmon runs from both sides of the north Pacific ocean. From Hokkaido Japan, to eastern Russia around the Bering Sea to mainland Alaska, all the way to Monterey Bay.* ((Inflection on "Monterey Bay"; raises eyebrows and turns to look at Lionel)). See it's all connected, ((pointing to map, inaudible while pointing to mainland Alaska)) your mother grew up in Japan, we live on the Pacific ocean. ((Gives thumbs up sign to him))

Lionel: ohh

Monterey Bay, California, is also significant place to this family, as the father studied the Japanese language there, and the family would be traveling there in another month to accompany him on a trip. By pointing out the places the salmon travel, Victoria was connecting Lionel's knowledge of salmon they gained through their other salmon-oriented learning to make the ocean portion of their life more significant for him. This is also an instance of a future event being used to anticipate a connection to the present moment – Victoria is also using the distance of the family's upcoming travel to mark how far the salmon travel in their lifetime.

Discussion of Family Sense-making of Science Across Settings

Each of the three settings supported observation and exploration in different ways, yet there were some topical themes about salmon that connected each of the places (Figure 4-8). These connections were not always explicitly sourced, yet with data from three settings, the nature of the conversation as one that was continuous exploration was apparent, as questions were answered in one place that had been asked in another. The connections were not just statements or recollections of events, but were an integrated part of an experience that occurred over varying scales of time.

Ultimately, the one learning process that was consistent across the three settings was invoking a past experience: an experience that contributed to the meaning-making in the present event, by using some significant aspect of the prior event. Perhaps using such an event for

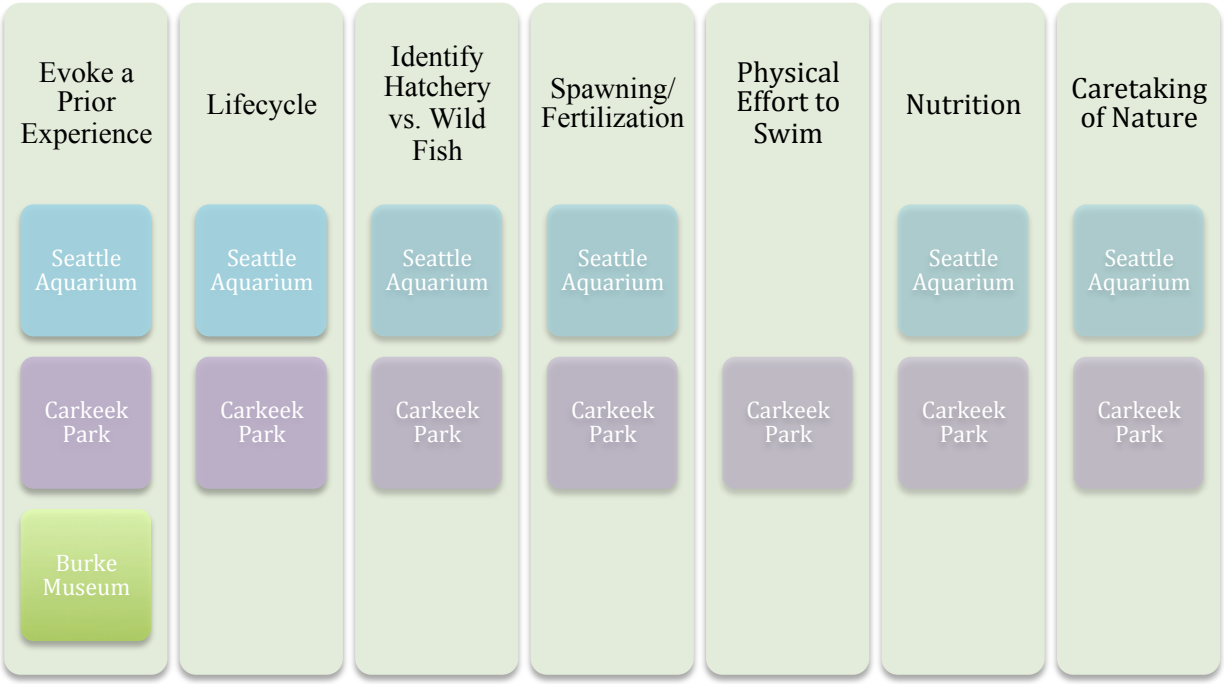


Figure 4-8: Contribution of place to the topical themes

meaning-making marks it as *an experience* in the Deweyian sense of aesthetic, intellectual and emotive encounter with material and physical objects. Invoking the past event in the present moment – through analogy in evaluating the "realness" of a replicated environment, through other events having to do with fish, knowledge sourced from school and joint family activity, has more meaning than the invocation alone, yet just *what meaning* is invoked through each memory is particular to the present and past context.

To conceive of a learning experience as a constellation requires acknowledging the contributions from multiple settings over time. Experience is not just a singular event or participation at one moment in time, expanding the conception of *an experience* to one that

includes identities and participation in social practices, the material contributions of place that together make up a deeper understanding in active relation to the world, in which learning is not just accumulation of facts, but to experience is to "change one's way of being in the world" (Wong et al., 2001, p. 325).

The timescales of this experience was variable; for Lionel, the continuing experience began with his school class participation in the Salmon in the Schools program and receiving salmon to watch as they grew and were released, starting the year prior to our study visits. We do not know his interest and engagement during the class, but the events during this study retrospectively reinforce Lionel's school experience, as he is positioned now within his family as a developing expert in such a way that we can see how his social reputation both marks and makes his expertise (Bell, Bricker, et al., 2012) and stimulates interest. Extending Dewey's conception from a singular event, *an experience* is one of many that is – or becomes – memorable because of other actions and social positions reinforcing that event. For Robert, too, releasing the salmon with Lionel's class was a past event that connected the study visits at the Burke and Carkeek Park. That the Messi family's excursion to Carkeek Park drew on Lionel's (and Robert's) experience with Salmon and in Schools program is an example of the integration of school, family and informal learning that are linked through sociomaterial arrangements and place and are a powerful means for interest cultivation – for both Lionel and for Robert. Given the balkanization of formal and informal learning literatures, and the emphasis on cultivating children's interests with little attention to adult (or parent) learning alongside their children, this case is an example of opening the scopes of possibility for both child and parent. Rather than individual events, each location contributed to a continuous experience learning about salmon –

knowledge that is likely not yet complete as the family continues to move in the future situated events of their lives.

Conclusion

The research question I pursed in this paper investigated an ecological perspective on the experiences of learning science: What are the connections families make across settings and over time, in a way that makes experience continuous? In this study, I took the view that families involved in their leisure pursuits, taking advantage of the opportunities available to them within their region– choosing activities that appeal to one family member or another, that are jointly experienced, that are planned or serendipitous—all contribute to knowledge development and stimulate interests and learning as connections are made across discrete events. More than connections of events over time and place, I take up a frame that the significant events that make up the stars in the cultural learning pathway constellations have Deweyian qualities of *an experience* that help generate continuity.

As people travel across the settings of their lives, they invoke recollections and invocations of shared events to support meaning-making. Taken together these events have coherence, development and flow across them, marking them as experiences that are far from singular moments. In this study, starting with the framing of Dewey's *principle of continuity of experience* and the Cultural Learning Pathways model, I sought to explore how *experience* is marked as both a momentary vibrant event full of emotion and cognitive attributes, and created through many events that draw on the sociomaterial arrangements of place, actions, social positions over time.

Validating the McClain and Zimmerman framework for understanding the kinds of past events and processes that connect a learning moment to other settings, shows that there although

there are many differences in the nature of informal science institutions (such as zoos, aquariums, science museums and science centers, there are still many similarities in social practices (Schwan et al., 2014). In addition, my finding that future events, other people, and places that are invoked extends their categories to additional processes that families use in sense-making. In addition, my finding that a past experience or event was the one processes that occurred at all three of the study sites reinforces the importance of this social practice as a tool for learning. Such shared experience may be unique to families because of their extensive shared time together. Parents and siblings are not able to invoke shared memories or knowledge when it relates to in-school knowledge, something also seen here as we see that Lionel and Robert were both interested in the salmon from their participation in the Salmon in the Schools program, yet Victoria and Tina did not have as much knowledge of salmon and asked Lionel for information about salmon.

Informal science education as a field tends to focus on single sites of sense-making while families do not take such a narrow approach to their leisure activities. Engaged in life-wide learning (Banks et al., 2007), families integrate what they learn across many informal educational settings, as well as draw on school sources, as they participate in knowledge-building experiences. Implications for the informal science educational designers is in considering what is unique about their *place* that can teach people something they might not learn from other places. Designing structured educational offerings through an experience-based (in the Deweyian sense here) or with an ecological perspective on learning, requires recognizing the affordances of a geographic region and the contribution of a single institutional or designed learning setting to the region as a whole – this means considering the unique ways that the diverse offerings in that region can create complimentary – instead of repetitive – offerings. For

example, educational designers could pursue through their educational offerings the highlights of what is it about a natural, outdoor setting that is different from what can be learned about in an indoor setting. The natural outdoor setting, for the family profiled in this case study included an aesthetic and kinesthetic experience unattainable in the indoor places: cold, rain, bad smells from death and decay. Such elements are a part of lifecycle that aren't pleasant and might not be given the depth of treatment in a family-friendly museum or aquarium, but such sensory engagement is an important aesthetic means leading to a deeper *understanding* of the lifecycle. Indoors, the Aquarium enabled the family to look closely at the alevin life stage of the salmon they would not be able to see up close in the stream, as well as information not available in a natural setting from signs. Each setting had unique affordances that contributed to an overall understanding of the salmon lifecycle, rather than repeating the same basic, or introductory information. Such contributions integrate learning over time – so that intellectual, sensory, aesthetic, and affective components of knowledge are contributed from multiple sources and places, making the experience cumulative over time.

Rather than leading with identity as a primary concern, I emphasize the materiality of place, such that the sociomaterial arrangements are foregrounded, so that when we look at a constellation of situated events, each place is perceived as contributing to a continuous experience of learning. I associate this with the cultural learning pathways concept of "constellations of situated events" which link context and time, and which activity, rather than being *in* a particular time or place, instead helps construct a *relationship* as space-time (Bricker & Bell, 2014). Rather than considering one event a culminating moment, considering the many potential everyday moments as continuing exploration and learning about a topic is one that has been recognized as occasioned knowledge exploration (Goodwin, 2007). The findings in this

paper suggest that expanding the notion of "experience" from a singular event, to one that is continuous across moments and events, requires a slightly different interpretation of Dewey's *experience*, since in creating a relationship over space and time, just when an experience comes to its closure is on a much longer timescale than when an event ends.

References

Ash, D. (2003). Dialogic inquiry in life science conversations of family groups in a museum. *Journal of Research in Science Teaching*, *40*(2), 138–162. doi:10.1002/tea.10069

Bang, M., Warren, B., Rosebery, A. S., & Medin, D. (2012). Desettling Expectations in Science Education. *Human Development*, *55*(5-6), 302–318. doi:10.1159/000345322

Banks, J. A., Au, K., Ball, A., Bell, P., Gordon, E., Gutierrez, K., … Zhou, M. (2007). *Learning In and Out of School in Diverse Environments: Life-long, life-wide, life-deep*. Seattle.

Barron, B. (2006). Interest and self-sustained learning as catalysts of development: A learning ecology perspective. *Human Development*, *49*(4), 193–224. doi:10.1159/000094368

Barron, B., & Bell, P. (2015). Learning environments in and out of school. In L. Corno & E. Anderman (Eds.), *Handbook of Educational Psychology* (3rd ed., pp. 323–336). New York: Routledge, Taylor & Francis.

Barron, B., Martin, C. K., Takeuchi, L., & Fithian, R. (2009). Parents as learning partners in the development of technological fluency. *International Journal of Learning and Media*, *1*(2), 55–77. doi:10.1162/ijlm.2009.0021

Bell, P., Bricker, L., Reeve, S., Zimmerman, H. T., & Tzou, C. (2012). Discovering and supporting successful learning pathways of youth in an out of school: Accounting for the development of everyday expertise across settings. In *LOST Opportunities: Learning in Out of School Time* (pp. 119–140). doi:10.1007/978-94-007-4304-5

Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (Eds.). (2009). *Learning Science in Informal Environments: People, Places and Pursuits*. Washington D.C.: National Academies Press. doi:10.17226/12190

Bell, P., Tzou, C., Bricker, L., & Baines, A. D. (2012). Learning in diversities of structures of social practice: Accounting for how, why and where people learn science. *Human Development*, *55*, 269–284. doi:10.1159/000345315

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. doi:10.1191/1478088706qp063oa

Bricker, L. A., & Bell, P. (2014). "What comes to mind when you think of science? The perfumery!": Documenting science-related cultural learning pathways across contexts and timescales. *Journal of Research in Science Teaching*, *51*(3), 260–285. doi:10.1002/tea.21134

Dewey, J. (1934). *Art as experience*. New York, New York: Penguin Group.

Flannery, M. (1992). Using science's aesthetic dimension in teaching science. *Journal of Aesthetic Education*, *26*(1), 1–15. doi:10.2307/3332723

Goodwin, M. H. (2007). Occasioned knowledge exploration in family interaction. *Discourse & Society*, *18*(1), 93–110. doi:10.1177/0957926507069459

Ingarden, R. (1961). Aesthetic experience and aesthetic object. *International Phenomenological Society*, *21*(3), 289–313.

Kisiel, J., Rowe, S., Vartabedian, M. A., & Kopczak, C. (2012). Evidence for family engagement in scientific reasoning at interactive animal exhibits. *Science Education*, *96*(6), 1047–1070.

doi:10.1002/sce.21036

LeCompte, M., & Schensul, J. (2013). *Analysis and Interpretation of Ethnographic Data: A Mixed Methods Approach* (2nd ed.). Lanham: AltaMira Press.

Lee, C. D. (2008). The Centrality of Culture to the Scientific Study of Learning and Development: How an Ecological Framework in Education Research Facilitates Civic Responsibility. *Educational Researcher*, *37*(5), 267–279. doi:10.3102/0013189X08322683

Lemke, J. L. (2000). Across the scales of time: Artifacts, activities, and meanings in ecosocial systems. *Mind, Culture, and Activity*, *7*(4), 273–290. doi:10.1207/S15327884MCA0704

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching*, *38*(3), 296–316. doi:10.1002/1098-2736(200103)38:3<296::AID-TEA1007>3.3.CO;2-I

McClain, L. R., & Zimmerman, H. T. (2014). Prior experiences shaping family science conversations at a nature center. *Science Education*, *98*(6), 1009–1032. doi:10.1002/sce.21134

National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington D.C.: The National Academies Press.

Palmquist, S., & Crowley, K. (2007). From teachers to testers: How parents talk to novice and expert children in a natural history museum. *Science Education*, *91*(5), 783–804. doi:10.1002/sce.20215

Pugh, K. J., & Girod, M. (2006). Science, Art, and Experience: Constructing a Science Pedagogy From Dewey's Aesthetics. *Journal of Science Teacher Education*, *18*(1), 9–27. doi:10.1007/s10972-006-9029-0

Rader, K. A., & Cain, V. E. M. (2008). From natural history to science : display and the transformation of American museums of science and nature. *Museum and Society*, *6*(2), 152–171.

Rennie, L. J., & Johnston, D. J. (2004). The nature of learning and its implications for research on learning from museums. *Science Education*, *88*(S1), S4–S16. doi:10.1002/sce.20017

Roth, W. M., & Jornet, A. (2014). Toward a Theory of Experience. *Science Education*, *98*, 106–126. doi:10.1002/sce.21085

Schwan, S., Grajal, A., & Lewalter, D. (2014). Understanding and engagement in places of science experience: Science museums, science centers, zoos, and aquariums. *Educational Psychologist*, *49*(2), 70–85. doi:10.1080/00461520.2014.917588

Seaman, J., & Nelsen, P. J. (2011). An Overburdened Term: Dewey's Concept of "Experience" as Curriculum Theory. *Education and Culture*, *27*(1), 5–25. doi:10.1353/eac.2011.0005

Traphagen, K., & Traill, S. (2014). *How cross-sector collaborations are advancing STEM learning*. Los Altos, CA.

Wickman, P.-O. (2006). *Aesthetic Experience in Science Education*. Mahwah, NJ: Lawrence Erlbaum Associates.

Wong, D., & Pugh, K. (2001). Learning science: A Deweyan perspective. *Journal of Research in Science Teaching*, *38*(3), 317–336. doi:10.1002/1098-2736(200103)38:3<317::AID-TEA1008>3.0.CO;2-9

Yin, R. K. (2009). *Case Study Research: Design and Methods* (4th ed.). Los Angeles: Sage Publications.

Zimmerman, H. T., & McClain, L. R. (2013). Intergenerational learning at a nature center: Families using prior experiences and participation frameworks to understand raptors. *Environmental Education Research*, 1–25. doi:10.1080/13504622.2013.775219

Zimmerman, H. T., Perin, S., & Bell, P. (2010). Parents, science, and interest: The role of parents in the development of youths' interests. *Museums & Social Issues*, *5*(1), 67–86. doi:10.1179/msi.2010.5.1.67

Zimmerman, H. T., Reeve, S., & Bell, P. (2008). Distributed Expertise in a Science Center. *Journal of Museum Education*, *33*(2), 143–152. doi:10.1080/10598650.2008.11510595

CHAPTER 5: Conclusions and Implications

In this dissertation, I investigated a broad question about how family science learning extends and connects across place, time and people. By asking "How can scaffolding everyday science learning experiences by supporting and extending the existing social practices within families lead to more sustained investigations and a deeper understanding of science?" To approach that broad question, I identified three key components: existing social practices in families that pertain to science; the nature of the experience of learning within families; and how connections are made across time and place. First, I built on the strengths of family learning by linking existing social practices to the practices of science, and capitalized on these similarities by designing family learning activities that could scaffold activity regardless of the empirical content of the setting. Next, I explored the notion of experience through the lens of the aesthetics of science, to show how empirical values, aesthetic appreciation and understanding, and aesthetic experience, reciprocally shape and are shaped by expressions and feelings of beauty, pleasure or displeasure, while learning science. Finally, a case study of one family's sense-making throughout the three study excursions showed how they invoked prior knowledge, associated the present moment with future events, and carried ideas and questions across settings and over time. In this conclusion, I synthesize the findings from across the three papers to address the broad research question, and to discuss the implications that can be drawn for the learning sciences field as well as informal educational practitioners.

I found that the idea of a sustained investigation for these families was less formal than we might think: that questions asked at one point in time, in one setting can be answered in another setting weeks later (as in the case of the Messi family) so that sense-making was a continuous endeavor. Families lead sustained investigations over time – as in the case of the

Messi family, families investigate topics that come to them through serendipitous opportunity (such as when the Messis were at the diorama at the Burke Museum) and those that they search out (such as visiting the creek). This continuity in learning experiences has a varying association in the relationship between everyday setting and more formal science learning contexts, as seen in other studies of language use transferring between settings (Brown & Kloser, 2009). A continued area of interest to me is how to help families make a more formal connection to the practices of science: to help them recognize that their in-the-moment questions lead to investigating and discovering answers in books, school, media, or other everyday settings as the opportunity present themselves. Creating a deeper understanding of science can not occur through a single moment, or through but through a series of experiences that are extended over time and place.

By generalizing the family activities to the "practices of science" and to be applicable in many settings, I also generalized "science" itself. The *Framework for K-12 Education* argues the core of inquiry and problem-solving across the many domains of science share certain common features that make up the practices – argumentation, analysis, appraisal of data, modeling, development of questions – that are taken up through collective norms within the social system of science. However, the domains of science have particular norms and values that are specific to the domain, as in physics or biology – and these distinctions are a direction for future analysis of this study data.

Questioning and thinking about a deeper understanding of science itself – where science happens, what the nature of science is, who does science and *when* science happens (McDermott, 2013) was instigated through the family activities included as part of the study, especially apparent in the context of the natural history museum for the Knots family, as the mother

grappled with the boundaries of her own participation in the Museum's paleontology dig as scientific yet feeling different from the professional scientists they encountered, even while encouraging her two children to think of themselves as scientists as they "messed around" with the microphone to investigate a question. Recognizing where and when science takes place, beyond the normative view that dominates formal education, means taking a more expansive view of science and of learning. Rather than a hard boundary, this requires recognizing a continuous relationship between informal and formal knowledge and the settings in which that knowledge is created and re-created for individuals and in the social relationships in which they learn.

Scientific knowledge is often positioned as a superior way of knowing about the world because of characteristics of objectivity and reliability. This image of science reinforces an idealized version of who can do science properly and who should hold scientific knowledge, which often sets up an exclusionary system to reinforce who makes up the "core set" and who is outside of it. For science education, overcoming idealized visions of science is a means of diversifying who thinks of themselves as capable of doing science and contributing to the foundations of scientific knowledge. These norms are reflected in the language and ways of knowing that are considered appropriate for science – yet in this dissertation, I have shown that aesthetic experience is a vital way of fostering understanding and interest in science.

Aesthetic experience is filled with sensory and tactile perception, filled with emotion, and create a deeper understanding, yet how these sense-making and meaning-filled moments are communicated and received by others convey values about what is acceptable as scientific knowledge. Such experiences are tied to socialization and enculturation in a way that shapes identification with science on a life-long time scale. The framework I present here of aesthetic

experience provides a means of expressing the awe and wonder that scientists experience, and that educators hope they can convey to lay audiences, that keeps them inspired to discover and research and teach. For the field of learning sciences, including analysis of language to understanding how beauty and pleasure inspire, enculturate and direct learning will open new avenues of understanding motivation and learning pathways.

Aesthetic experience is enjoyable or stimulating, which does not mean that it therefore is not educative: learning and entertainment are not mutually exclusive (Packer & Ballantyne, 2004) although in museum and other leisure-oriented settings frivolous "edutainment" is often lamented. The experience of discovery, whether creating new knowledge or discovering something new to oneself, can be exciting, pleasurable and fun – a feeling that drives scientists to creatively pursue their work, even when discouraged. "Learning for fun" is a combination of discovery, exploration, mental stimulation, and excitement for museum visitors (Packer, 2006). This kind of experience is more like Dewey's description of aesthetic experience – there is a combination of intellectual and emotional stimulation that makes *an experience*. This has implications for museum educators and school-based educators lamenting that making science fun makes it less scientific or meaningful: rather than superficial or flippant entertainment, figuring out and building on the aspects of what makes doing science "fun" in this particular sense of engaging with the content as an idea in a Deweyian, aesthetic sense (Pugh & Girod, 2006) builds a more accurate understanding of the practice of science. It is the pleasure of learning, and the learning experience itself that is crucial, transformative, and may have an impact on one's life or worldview and can inspire one's personal capabilities (Schwan, Grajal, & Lewalter, 2014).

The aesthetic experience of learning science involves critical cultural questions of taste, which become an issue of identity and belonging (Wickman, 2006). In this study, the three dimensions of the aesthetics of science that I use – experience, epistemic values, and understanding – are grounded in sciences studies and history of science literatures, which take a Western, European view of science and scientific research. As a culturally – or, specifically, a class (eg. Bourdieu, 1984), defined way of drawing distinctions about what is valued, the normative implications of defining aesthetics in this single sense this has two primary and related implications: it limits the conception of aesthetics from a research perspective and for broadening participation in the sciences. Understanding aesthetics in relation to science may have as much cultural influence as does science itself (Medin & Bang, 2014; Nasir & Bang, 2012) and taking a normative view of aesthetics – through language use, what is worthy of attention, and what and how ideas and objects are considered beautiful or not – limits the relevance and contributions of indigenous and non-Western culturally-linked ways of knowing. Aesthetic appreciation of science deepens *knowing* and knowledge, which can make such an experience much more motivating to a broader range of people. Using aesthetic experience overtly – building on the sensations of enjoyment and pleasure in the learning experience – can motivate those who might feel alienated by the common conception of science as merely a dispassionate assembly of facts, discrete procedures or inaccessible theory.

The *ways* of experiencing are what become important as links across settings and over time, not just content and cognition, in a view of learning that is captures the breadth of identity, agency, and expands our notion of the "practices of science" to the patterns of behavior an thinking that go beyond the scientific method. To connect learning across settings "…our curricula must work to ensure greater continuity in students' ways of experiencing as they move

from one classroom to another and from classroom to hallway to neighborhood to home …There is no more reason to believe that the habits of vital experiencing will automatically transfer to the rest of students' lives than that habits of technical reasoning will do so. What lasts for the long term in us is what we have learned how to remake for ourselves across many contexts" (Lemke, 2001, p. 310). It is the *way* of experiencing – the interpersonal participation structures, the sense of emotion, feelings of beauty and ways of *being* – that makes a deeply felt *knowing* able to be invoked across places and over time, and that will help us better understand learning that is life-wide, life-deep and life-long.

References

Bourdieu, P. (1984). *Distinction: A Social Critique of the Judgement of Taste*. London: Routledge.

Brown, B. A., & Kloser, M. (2009). Conceptual continuity and the science of baseball: Using informal science literacy to promote students' science learning. *Cultural Studies of Science Education*, *4*(4), 875–897. doi:10.1007/s11422-009-9198-1

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching*, *38*(3), 296–316. doi:10.1002/1098-2736(200103)38:3<296::AID-TEA1007>3.3.CO;2-I

McDermott, R. P. (2013). When is mathematics, and who says so? In B. Bevan, P. Bell, R. Stevens, & A. Razfar (Eds.), *LOST Opportunities: Learning in Out of School Time* (Vol. 23, pp. 85–93). New York: Springer. doi:10.1007/978-94-007-4304-5

Medin, D., & Bang, M. (2014). *Who's Asking? Native Science, Western Science, and Science Education*. Cambridge, MA: MIT Press.

Nasir, N. S., & Bang, M. (2012). Conceptualizing Cultural and Racialized Process in Learning. *Human Development*, *55*(5-6), 247–249. doi:10.1159/000345311

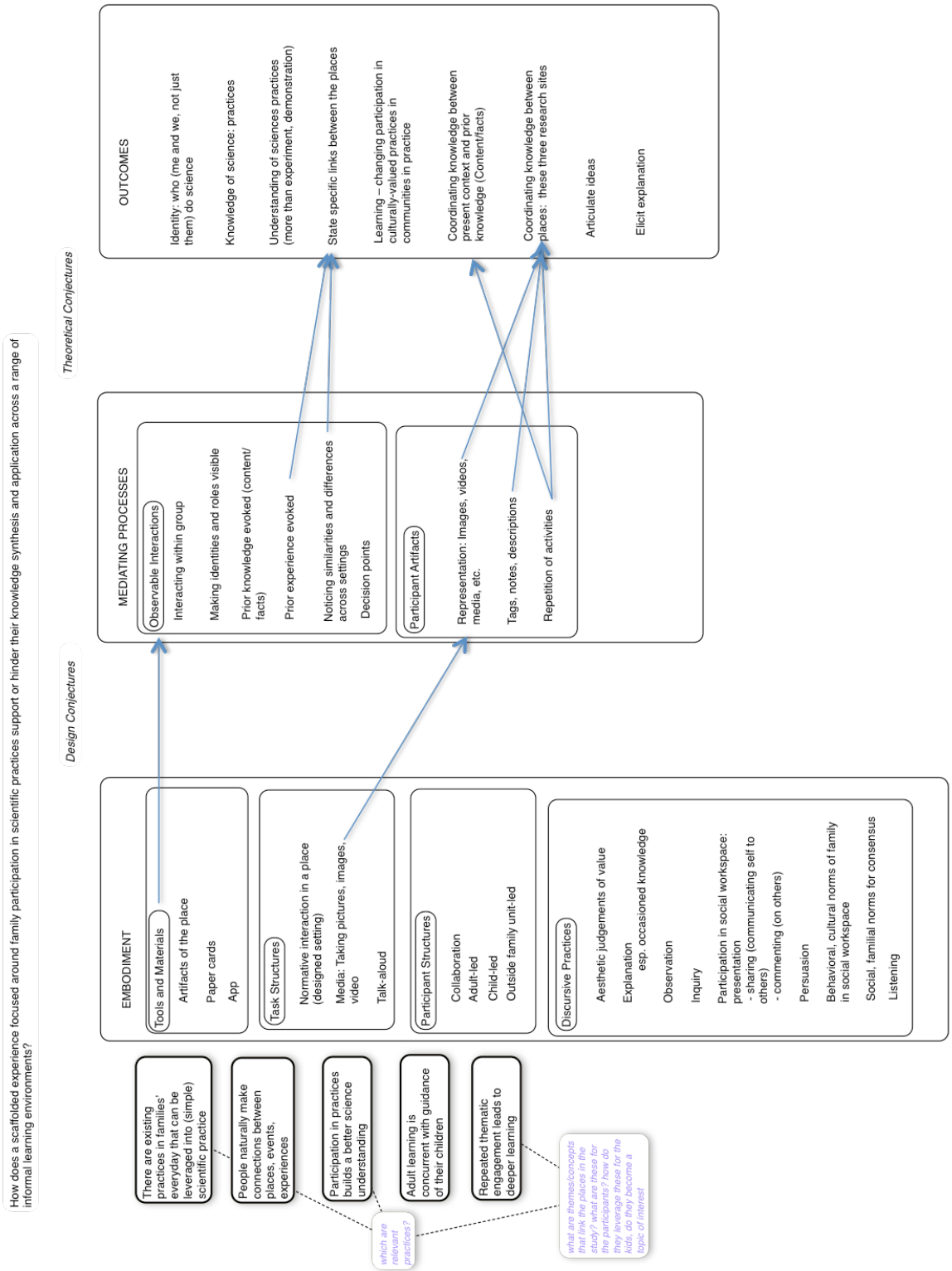
Packer, J. (2006). Learning for Fun: The Unique Contribution of Educational Leisure Experiences. *Curator: The Museum Journal*, *49*, 329–344. doi:10.1111/j.2151-6952.2006.tb00227.x

Packer, J., & Ballantyne, R. (2004). Is Educational Leisure A Contradiction in Terms? Exploring the Synergy of Education and Entertainment. *Annals of Leisure Research*, *7*(1), 54–71. doi:10.1080/11745398.2004.10600939

Pugh, K. J., & Girod, M. (2006). Science, Art, and Experience: Constructing a Science Pedagogy From Dewey's Aesthetics. *Journal of Science Teacher Education*, *18*(1), 9–27. doi:10.1007/s10972-006-9029-0

Schwan, S., Grajal, A., & Lewalter, D. (2014). Understanding and engagement in places of science experience: Science museums, science centers, zoos, and aquariums. *Educational Psychologist*, *49*(2), 70–85. doi:10.1080/00461520.2014.917588

APPENDIX A: Conjecture Map highlighting one selected pathway



APPENDIX B: Images of Activity Cards

Tasks

These cards contain a series of activities, questions or tasks to try during the study visits. They get you to *think* or *talk* like a scientist would – so they aren't site or content specific.

- Finish at least 6 tasks
- Do at least one of each color
- The same card can be done more than once
- Do the task during the visit or right after it with the researcher
- Record the task in your own way – talk, take photos, draw, map…
- Kids OR grownups can choose and lead the task

Practices of Science

The tasks here help you do *practices of science* - ways of thinking and reasoning that apply to science regardless of the content.

The scientific method helps plan an experiment, but scientists also search for patterns, classify objects, make generalizations from lots of observations and figure out explanations using evidence.

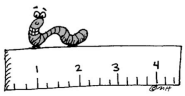
These practices are a foundation for the Next Generation Science Standards schools are adopting.
Learn more about them at: www.nap.edu

What are these "practices"?

The 8 practices of science build on each other but don't have to happen in specific order.

1. Asking questions that can be investigated
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematic and computational thinking
6. Constructing explanations
7. Engaging in argument with evidence
8. Obtaining, evaluating and communicating information.

Did it!



Math is an important part of science.

Find some math or notice when you're talking about math. It might be a graph, numbers, *you* use math to measure or compare sizes, or you see a pattern.

What is the math telling you?

Did it!

When someone asks a question– think about an explanation together.

- Make an observation using something you both can see, touch, smell or hear.
- Does someone notice something else? Something different?
- How can you use that data in an explanation?

Did it!

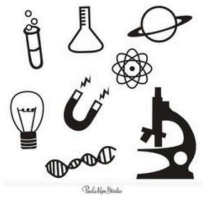
What is something **gross, ugly, scary or yucky**? What makes you say that?

Even if you don't like this thing, why might it still be important to a scientist?

Did it!

I saw something pretty or cute. Talk about what makes you like it, and share a picture of its best feature.

Did it! ☐☐☐☐



Did you remember something today that you did our last visit together? What?

Record what made you think of it.

Did it! ☐☐☐☐

Notice a scientist doing science.

- What is that person doing?
- Is the person alone or with a team?
- What tools are used?
- Describe the person or group –notice gender, ethnicity, the clothes they wear or anything else.
- Where is the work happening?

Did it! ☐☐☐☐

When YOU do science like a real scientist, draw, write or take a photo or video of yourself.

Do you notice someone in your family doing science too? Who? What were they doing?

Did it! ☐☐☐☐

Take a photo, draw, or just talk about **something you want to take home** (but not from the gift shop!).

Describe why you'd keep it. What makes it so special?

Did it! ☐☐☐☐

Grownups: What is something YOU are curious about? Take a picture or video, or make a note. How can you find out more?

Did it! ☐☐☐☐

This is something interesting! Share what it is.

What do you see, smell, touch or hear that makes it interesting?

Did it! ☐☐☐☐

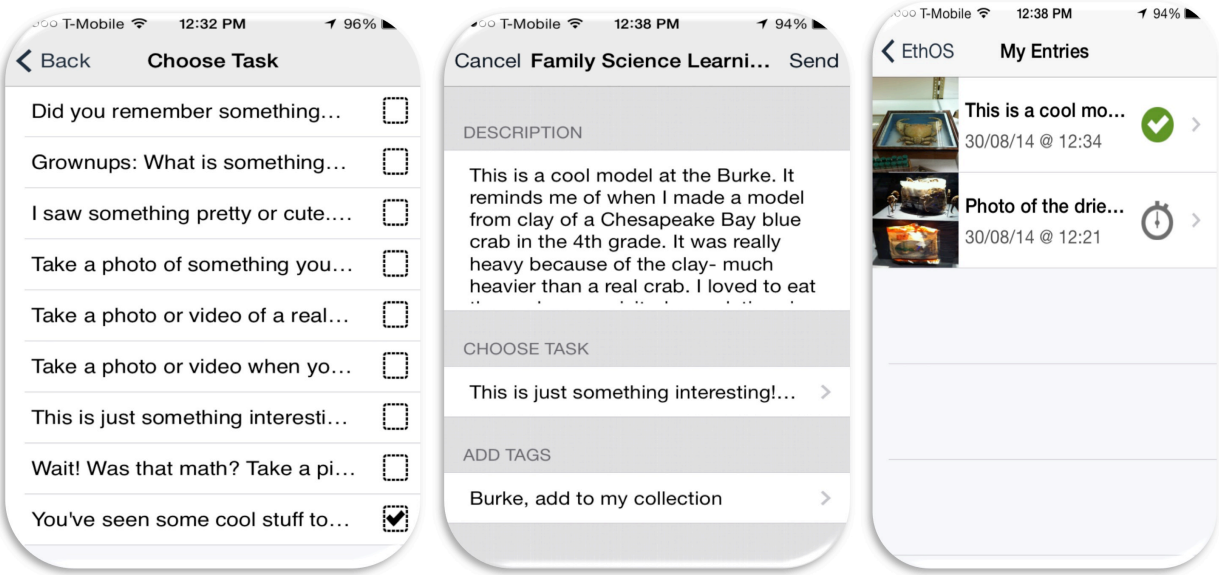
You've seen some cool stuff today. Think of two of those things - then choose only ONE you would add to your own collection. (Scientists have to do this all the time!) Share what it is. Why did you pick that one instead of the other? What makes it special? Why does it belong in a collection?

Did it! ☐☐☐☐

When someone explains something, Ask questions and share *evidence* from what you can all sense together:

- Why do you think that?
- How do you know?
- What else do you notice?
- What do you see, smell, touch or hear that makes you say that?

APPENDIX C: Mobile App (EthosApp) Screen Images



APPENDIX D: Appraisal Resources

Appraisal is comprised of Attitude – Engagement – Graduation

Under Attitude is Affect, Judgement and Appreciation

1. Attitude = Affect (resources for construing emotions and emotional reactions to text/process, phenomena)
2. Attitude = Judgement (resources for judging human behavior morally/ethically: rules and regulations "institutionalized feelings"
3. Attitude = Appreciation (resources for valuing objects, processes or states of affairs aesthetically or functionally)

Types of Attitude: Appreciation (Adapted from Martin & White, 2009, p. 56)

Meta-Function	Mental Process Type	Type of Appreciation	Positive Examples	Negative Examples
Interpersonal	Affection	Reaction: Impact *(did it grab me?)*	Arresting, captivating, engaging…; Fascinating, exciting, moving…	Dull, boring, tedious…; Dry, ascetic, uninviting…
		Reaction: Quality *(did I like it?)*	Okay, fine, good… Lovely, beautiful, splendid…	Bad, yuck, nasty… Plain, ugly, grotesque…
Textual	Perception	Composition: Balance (*did it hang together?)*	Balanced, harmonious, symmetrical, proportioned…; Consistent, logical…; Shapely, curvaceous…	Unbalanced, discordant…; Contradictory, disorganized….
		Composition: Complexity *(was it hard to follow?)*	Pure, simple, elegant…; Lucid, clear, precise…; Intricate, detailed, rich…	Ornate, extravagant, byzantine…; Arcane, unclear…; Plain, monolithic, simplistic…
Ideational	Cognition	Valuation *(was it worthwhile?)*	Penetrating, profound, deep…; Innovative, original, creative…; Authentic, real, genuine…;	Shallow, reductive, insignificant…; Everyday, common…; Fake, bogus…

APPENDIX E: Descriptive Statistics

T-Lab Text Parameters

Texts: 16 Primary Documents
Lemmatization: Yes
Text Segmentation: Chunks
Key-Term Selection: TF-IDF
Stop-Word Check: Advanced
Multi-Word Check: Advanced
Key-Term Selection: 1000

Description of Corpus:

Contexts
Texts: n=3112
Variables: ID; Place
Elementary Contexts: 3112

Words
Occurrences (tokens): n=25137
Words (types): n=2664
Lemmas: n=2166
Hapax [A hapax legomenon refers to a word occurring or appearing once in a text or corpus.]
(Occ=1) n=1229
Threshold Frequency: 8

Vocabulary
Key terms: n=201

VITA

Suzanne Perin was born in Washington, D.C. and grew up in Altadena, California. She received a Bachelor of Arts in Anthropology from the University of California, Santa Cruz in 1999. After working in museum visitor research, exhibit evaluation and exhibition development at the Exploratorium in San Francisco, California, and the Museum of Life and Science, in Durham North Carolina, she earned a Master of Arts in Museology from the University of Washington in 2008. In 2015, she completed a Doctor of Philosophy in Learning Sciences and Human Development from the College of Education at the University of Washington.