FAMILY LEARNING WITH MOBILE DEVICES IN THE OUTDOORS:
DESIGNING AN E-TRAILGUIDE TO FACILITATE FAMILIES’ JOINT
ENGAGEMENT WITH THE NATURAL WORLD

A Dissertation in
Learning, Design, and Technology

by
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ABSTRACT

This study describes the implementation of a self-guiding mobile learning tool designed to support families’ engagements with the natural world as they explored the flora and fauna along one nature trail at an environmental center. Thirty-one family groups (n = 105 individuals) participated in this study during the summer season and used an iPad-based e-Trailguide during their nature walk. Design-based research methods guided this study’s design, which focused on the third iteration of the e-Trailguide. Data included evaluation of families’ content knowledge gains related to the local biodiversity as revealed through post-hike interviews, while video-records of each family’s nature walk experience were also collected. Qualitative analyses focused on the design features within the e-Trailguide that supported the families’ technology-mediated engagements with nature and their interactions with each other at one Discovery Spot along the nature trail. Findings include: (a) open-ended interviews after the e-Trailguide experience provided a descriptive understanding of the families’ conceptual knowledge gains; (b) four place-based design features within the e-Trailguide enabled and supported families’ observational, pointing, and tactile investigation engagements with the natural world; (c) parents took on teacher-like roles for their children by connecting information from the e-Trailguide to the natural objects nearby as evidenced through their frequency of pointing gestures; and (d) the development of an analytical framework related to joint observation strategies used between family members to support science-related sense making. Design recommendations for the future implementation of e-Trailguides in outdoor settings include the incorporation of place-based observational questions, place-based textual prompts for focusing observations, drawing activities to record observations, and place-based images to support identification of wildlife.

Key words: family learning, engagement, mobile-based learning, outdoor learning, observation, environmental education, informal science learning
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In addition, an earlier version of my dissertation analysis with regards to the four place-based design features (discussed in Chapter 6) was appraised by editors Lucy Avraamidou and Wolff-Michael Roth in preparation for being included as a chapter in their new book, Intersections of Formal and Informal Science.

Personal Acknowledgements

I first decided to pursue my PhD after watching my (now) advisor present on her dissertation research during the Science Education department’s colloquium in the spring of 2009. I had one more year to complete my Master’s in Education in Science Education and knew that I was very interested in “informal learning” based on my time as an intern and graduate assistant at Shaver’s Creek Environmental Center—but I didn’t know how to move forward with that interest. During that colloquium, Heather’s discussion about her research on families’ engagement with science across a variety of contexts intrigued me and after briefly talking with her after the presentation, I investigated the possibility of learning how to do research in this field. Needless to say, I followed that line of interest and began working with Heather in the fall of 2010. During my time as a doctoral student, Heather pushed me to conduct research from the ground up, present at international conferences, and
publish in prestigious journals. I’ve had the honor of working alongside Heather as we together pursued our like interests in family learning, informal education, and environmental education; developed new interests in mobile learning; and created our own research niche around family learning with mobile devices in the outdoors. I owe my professional success to Heather who supported me not only as my advisor, but also my friend.

Thank you to my dissertation committee, Susan Land, Simon Hooper, and Scott McDonald, who each challenged me to think more critically about my topic and supported my research efforts throughout the dissertation process. Thank you to Michele Crowl and Andrea Gregg for their friendship and support that only fellow graduate students can provide to one another!

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I am blessed with academically and professionally gifted family members who have shaped my interests and intellectual maturity. My dad, Bonham Richardson, is a retired professor of cultural geography who, for the majority of my time as a graduate student, greeted me with an email each
morning and is mainly responsible for my insatiable fervor for sports, especially college basketball. My sister, Eliza Marone, has her PhD in geophysics and is currently an associate professor and a lead faculty member for the online Earth Science master’s degree program at Penn State. Eliza has undoubtedly been an inspiration for me ever since I can remember—I always wanted to be just like her when I was a kid (including growing up to be a lifeguard because that was her summer job for a few years). My brother-in-law, Chris Marone, is one of the top seismologists in the world while also being an outstanding father to his five children (Vicki, Dan, Linda, Tino, and Massimo) and husband to my sister. He is someone who everyone likes and wants to be around and someone who always finds time for everyone, no matter how busy he is. My mother-in-law, Lois McClain, has always been my #1 cheerleader throughout my time as a doctoral student—she has provided so much emotional support for me in the years I have known her and I am thankful for her presence in my life.

Words cannot do justice to describe the love and support that my husband, Casey McClain, has provided to me as I muddled through my years as a graduate student. He has always been there for me during the most stressful periods (right before a paper deadline or a conference presentation) and the most fulfilling times (my first first-authored publication and feelings of accomplishment after a conference presentation). Although my line of research has been persistently challenging to succinctly describe, he has been my most faithful advocate and source of encouragement throughout my graduate career. I am forever grateful for Casey’s ability to make me laugh and to feel more confident in myself. I have truly won the spousal jackpot!

Last but not least is the newest addition to our family, Conary Shiring McClain, who was born shortly after I completed my dissertation data collection in the summer of 2014. Whether he knows it or not, Conary joined me (he didn’t have a choice!) on every single nature walk with the 32 families that comprised my data corpus. Being a new mom while working towards finishing my PhD has been a challenge in and of itself, but it has also been a blessing in that it has reminded me what things are really and truly most important in life. I am so lucky to be a mom.
DEDICATION

Linda B. Richardson
May 17, 1947 – September 24, 2007

My dissertation is dedicated to the memory of my mom, Linda B. Richardson, who passed away on September 24, 2007, when I was 22 years old. I often think about what my life would be like if she were still here today and while I know many things would be different (and better), the one consistency from my childhood that would endure is how outwardly proud she always was of my accomplishments. My mom never missed a soccer game in my 10-year career of competitive traveling and school soccer—she diligently arranged her work schedule as a university librarian around my games so that she could always be there to cheer me on (or nervously cover her eyes while I lined up for a penalty shot).

If my mom were here today, she would undoubtedly be celebrating the fact that I’m finally rounding out my time as a student. She once commented that I might end up being a “student for life.” While 26 years is indeed a long time to be a student, I know my mom has been cheering me on throughout my time in graduate school. If I can be half the mom for my son that my mom was for me, then I know I will have truly succeeded in life.
Chapter 1

Introduction

Mobile technology programs that support outdoor-based learning experiences have seen a recent surge in design and research energy (e.g., Boyce, Mishra, Halverson & Thomas, 2014; Cumbo, Paay, Kjeldskov, & Jacobs, 2014; Eliasson, 2013; Land & Zimmerman, 2015; Zimmerman, Land, McClain, Mohney, Choi, & Salman, 2015). Research on this topic area has largely focused on school-based studies (e.g., Chang, Chen & Hsu, 2011; Chen, Kao, Yu & Sheu, 2004; Dunleavy, Dede, & Mitchell, 2008; Jones, Scanlon & Clough, 2013; Rogers et al., 2004; Rogers et al., 2009), while less analytic attention has been paid to how mobile devices facilitate out-of-school learners’ engagements and interactions with science in the natural world. As such, the research and educational design presented in this dissertation study focuses on one common social group of learners that regularly visit informal institutions—families—and how to support their engagement with the natural world during nature walks through the use of an increasingly common 21st century learning tool: a mobile touch-screen device equipped with an electronic trailguide (or fieldguide), which will be referred to as an “e-Trailguide” in this document.

Why study learning with mobile devices in informal institutions?

Youth and parents use digital technologies, including mobile phones, for learning purposes (Barron, Martin, Takeuchi, & Fithian, 2009) across socioeconomic divides (Yardi & Bruckman, 2012). In fact, when Google™ commissioned the “Our Mobile Planet” research study to determine the prevalence of smartphone adoption and usage by consumers around the world in 2013, the results showed that in the United States, over half of Americans owned a smartphone (56.4%) and 83% of smartphone owners said that they did not leave home without their device (Google Inc., May 2013). In 2015, the Pew Research Center updated these statistics to say that
64% of Americans owned a smartphone, which is roughly equal to two-thirds of the population (A. Smith, 2015). Clearly, the trend of smartphone usage is only expected to increase in future years and consequently, being able to use these mobile devices at anytime and anywhere has become the expected norm for not only Americans, but for populations around the world (Google Inc., May 2013).

Aware of the everyday prevalence of mobile devices, museums in a variety of countries have scaled up their media and technology presence so that their patrons can interact with museum content both on and off site using a range of mobile devices (Johnson, Adams Becker, Estrada, & Freeman, 2015). When people visit museums, they often do so because they are interested in the content. With the rise of purposeful mobile technology designs for education, visitors who are particularly drawn towards a certain subject are better able to access supplemental information about that topic. Furthermore, researchers suggest that using one’s personal device to explore a subject more deeply within the space of a museum provides a deeper learning experience (Johnson, Adams, & Witchey, 2011; Klopfer, Squire, & Jenkins, 2002) and sustained engagement with the museum content (Hsi, 2003; Pattison, Ewing, & Frey, 2012; Yoon, Elinich, Wang, Steinmeier, & van Schooneveld, 2012).

In response to this rise of mobile technology use in informal learning settings, research projects focusing on the effect mobile technologies have on learning activities has steadily increased over the past decade. These research settings include science centers (Hsi, 2003; Knipfer, Mayr, Zahn, Schwan, & Hesse, 2009; Pattison et al., 2012), zoos (O’Hara et al., 2007; Perdue, Stoinski, & Maple, 2012; Yocco, Danter, Heimlich, Dunckel, & Myers, 2011), arboretums (Land & Zimmerman, 2015; Zimmerman & Land, 2014; Zimmerman et al., 2015), and nature centers (Boyce, Mishra, Halverson, & Thomas, 2015; McClain & Zimmerman, 2016b). With this variety of projects, a better understanding of how people interact with mobile
technologies in the space of a museum has taken shape, while design recommendations for creating robust mobile programs have been generated and enacted.

**Why study learning with mobile devices in the outdoors?**

Learning about the natural world while immersed in an outdoor space, such as a nature preserve, provides an authentic opportunity for directly experiencing (Dewey, 1903) and observing concrete examples of the topic being explored (Ballantyne & Packer, 2001; Orion & Hofstein, 1994; Smith, 2002). Furthermore, when educational materials are purposely structured for the specific physical environment where learning takes place, learners have been shown to better connect the application of science concepts to real world situations (Giamellaro, 2014; Rivet & Krajcik, 2008). Because of this importance of learning within the authentic setting of the environment, the implementation of mobile technologies has emerged as one means of supporting learners during outdoor experiences. For example, Jones and colleagues (2013) argue that one advantage of using digital devices in outdoor spaces is the ability for learners to access resourceful information in situ to identify what they are seeing in front of them, such as local and migrating birds.

Most commonly, research aimed at understanding how technology impacts the outdoor learning experience will focus on school students during field trips. Previous studies have investigated how mobile technologies can be combined with outdoor learning experiences with nature to improve students’ real-world, scientific skills like observation (Chen, Kao, & Sheu, 2003), data collection (Rogers et al., 2004), social practices of science (Squire & Klopfer, 2007), and understanding the biological function of plants (Chen, Hwang, & Tsai, 2014). These school-based studies have provided a foundation of fruitful research findings and design recommendations for technology-enhanced learning about nature, yet less attention has been given towards understanding how mobile devices influence and facilitate informal learning.
groups’ engagement with the science of the natural world. With a focus on family learning
groups, this research study addresses this gap by presenting a study of 31 family’s experiences
using a place-based designed e-Trailguide to engage with and learn about the natural world
during a nature walk.

Research purpose of this dissertation

The purpose of this study is to leverage a design-based research methodology in order to
evaluate a self-guiding mobile learning tool designed for family groups exploring the diverse
biota located alongside one nature trail at Shaver’s Creek Environmental Center (SCEC) in
central Pennsylvania. This purpose was accomplished through the investigation of a third
implementation of an iBook™-based “e-Trailguide” with 31 groups of family visitors over the
summer of 2014 (May-August). Due to the ever-increasing ubiquity and capability of mobile
devices for learning, there is a need for more research on how these technological tools are used
to support robust learning in a variety of settings. To date, little research has been conducted on
the use of mobile devices and their role in family learning in outdoor settings. While one project
has studied family learning in an arboretum to provide a basis for understanding how families use
mobile devices during a naturalist-led tour (Zimmerman et al., 2015), as of December 2015 (as
vetted through Google Scholar), all other published mobile learning research conducted in
outdoor settings has been limited to school-based programs and field trip studies with youth (e.g.,
Barak & Ziv, 2013; Boyce, Mishra, Halverson, & Thomas, 2014; Chen et al., 2003; Eliasson et
al., 2011; Jones et al., 2013; Rogers et al., 2004; Ruchter, Klar, & Geiger, 2010) or university
students (Rogers, Connelly, Hazlewood, & Tadesco, 2009; Ryokai, Oehlberg, Manoochehri, &
Agogino, 2011). As such, my dissertation study addresses the need to study self-guiding mobile
technologies for families, especially because family groups make up the majority of visitors to
informal learning institutions (Bell, Lewenstein, Shouse, & Feder, 2009), including
environmental education sites (Falk & Heimlich, 2009). Consequently, this study contributes toward a better understanding of how these intergenerational learning groups utilize mobile computers to explore their natural world together.

**Research needed to understand family learning with mobile devices in the outdoors**

The study site, SCEC, is a typical environmental center, with the exception of its university connection, which makes it ideal to study for this project that focused on families’ mobile-based learning experiences in the outdoors. Like most nature centers in the United States, SCEC has a small year-round staff. On the weekends, when the highest number of casual, drop-in visitors come to the center, there is typically only one SCEC staff member on site to cover the front desk, gift shop, and phone-answering responsibilities. During weekends and other busy times, the naturalist staff members are unable to physically guide visitors to interpret the landscape face-to-face. This creates a common problem of practice: how can the SCEC staff ensure that their guests are supported to learn about their natural world in the absence of a naturalist? While this dissertation focuses specifically on SCEC and learning about the northeastern woodland biome with mobile devices, this Center’s dilemma is a typical case of environmental centers, allowing for this study’s findings related to mobile-learning designs to potentially apply to other nature centers worldwide.

This problem of practice of supporting visitors in the absence of an in-person naturalist is addressed through the implementation of a self-guiding technology that can support family visitors to see, hear, and explore the landscape in a similar way that a staff member would facilitate if they were physically guiding learners through an environmental education-based program. However, it is not my intention to replace naturalists or interpreters with mobile technology guides; rather, I contend that the e-Trailguide provides a viable option for facilitating families to learn about the natural world when an in-person tour guide is unavailable.
While most environmentalists are wary of the rapid advancements of mobile devices in our world (cf. Monke, 2005; Shultis, 2001), especially when it comes to engaging people with their environment, the argument put forth in this dissertation acknowledges this technological expansion and demonstrates that mobile devices can be leveraged as beneficial science learning tools for families in outdoor spaces. Through an investigation using a design-based research approach to understand learning and engagement with nature supported by the third iteration of a mobile-based design, my dissertation provides an in-depth exploration into specific design features that support an iPad-based e-Trailguide to act as a learning facilitator for family groups along a nature trail.

**Research questions to understand family learning with an e-Trailguide**

This project provides a foundation for understanding how specific design components within a self-guiding e-Trailguide facilitated engagement with nature and a collaborative learning experience for 31 families on one nature trail at SCEC. My dissertation answers the following three research questions and sub-questions:

1. What specific native Pennsylvania plants and animals did families learn about during their nature walk with the e-Trailguide?

2. What design features (e.g., questions, prompts, drawing activity, place-based images) within the e-Trailguide at one interactively designed Discovery Spot focused on native trees facilitated the three types of technology-mediated engagement with nature (observation, pointing, and tactile investigation) across families?

   a. What differences were there, if any, between patterns of technology-mediated engagement with nature among adults and patterns of technology-mediated engagement among children?
3. When using the e-Trailguide, how did pointing-based joint observation strategies used by parents/grandparents and children support families’ science-related sense making about native trees?

Research question 1 is addressed in Chapter 5, research question 2 is described in Chapter 6, and research question 3 is answered in Chapter 7.

**Sociocultural theories of learning**

This study’s conceptual framework guided the design and analysis of an electronic book (iBook), or e-Trailguide, delivered on a mobile computer intended to support families’ explorations of the native biota along one nature trail to increase learning about and engagement with the local biodiversity. Sociocultural theories of learning comprise this study’s foundation; more specifically, theories related to family science learning, place-based learning, and mobile-based learning are employed. Previous work and theory-building has transpired in relation to how families learn together in informal spaces, how families interact in the setting of an outdoor learning space, how mobile devices can be leveraged as a supportive learning tool for visitors in informal spaces, and how mobile devices can facilitate outdoor learning experiences for students on field trips. However, there is a gap in the field’s understanding regarding how mobile devices can be leveraged as self-guiding mediators for engagement and learning with nature for family groups on a nature trail.

The full conceptual framework is discussed in Chapter 2, but as an overview, pursuing this specialized topic related to family learning with mobile devices in the outdoors required building from previous theoretical frameworks related to:

1. Place-based learning in environmental education;
2. Informal family learning;
3. Mobile-based learning, with a specific focus on how mobile learning supports situated learning and engagement with the learning setting. Taken together, these three avenues of research contributed to the development of the conceptual framework that supported both the design of the e-Trailguide and the analytical lens adopted in this research study.

**Significance of researching family learning with an e-Trailguide**

Environmental education centers and other informal science learning institutions that have a focus on the natural world will find this work to be of interest. From a practical standpoint, implementing this type of self-guiding technology can alleviate staffing pressures at these traditionally low-budget institutions, while it can also ensure that visitors are seeing, hearing, and exploring the landscape comparable to how a staff member would if they were physically guiding a family through an environmental education-based program. Because mobile computers can be more easily and quickly updated with new content, as compared to traditional wayside exhibits, the potential for providing a variety of topic-specific educational programs during different seasons along a nature trail is an attractive solution for nature centers. The flexibility afforded by mobile computer programs to have up-to-the-minute content provides an appealing learning opportunity for a variety of learners, as well.

Science educators may also be encouraged to further implement mobile learning devices into educational activities in order to hone science inquiry skills, including observations and explorations of their local, natural world. In their review of 468 science inquiry activities from middle- and high-school textbooks, Chinn and Malhotra (2002) concluded that “few if any” of the activities captured the cognitive processes of authentic science (p. 204). Mobile computers, however, have the capability to readily engage students with more authentic science inquiry activities because they can be leveraged within and across relevant learning spaces. For example,
at Penn State University’s Lehigh Campus, one biology class utilized iPad minis™ with attached microscopes to explore up-close the biological diversity on their campus (see A. Goodin’s article in *Penn State News*, “At Lehigh Valley campus, mobile technology enables biological discovery,” 2013). In presenting the design of the e-Trailguide, my dissertation study aimed to illustrate the usefulness of mobile devices as scientific learning tools for visitors to informal, outdoor-based environmental education sites through the inclusion of interactive widgets to promote deeper observations of a woodland biome and prompts to facilitate face-to-face scientific discussions between learning group members.

For educational technology researchers, the testing of design principles and theory-building around technology-mediated engagement with nature and family learning processes with a mobile device will be of value. For instance, the enactment of a self-guiding mobile device to support face-to-face collaborative learning between family members was an important design principle in this work. Recommendations from two conceptual pieces (Knipfer et al., 2009; Lyons et al., 2010) related to collaborative learning with mobile devices were thus considered and included in the structure of the e-Trailguide. Knipfer and colleagues (2009) recommended that mobile devices include device-generated questions and prompts to facilitate face-to-face dialogue, while Lyons et al. (2010) suggested that in order to maintain parent-child interactions and engagement in museums when mobile devices are introduced to the learning activity, posing questions and structuring joint tasks are important design features to consider. In reviewing the literature, these design suggestions have not yet been tested. As such, this study aimed to elucidate how these design recommendations played out when family groups used mobile computers to engage with and learn about the natural world together.
Conclusion

This dissertation study evaluated the implementation of a self-guiding digital field guide—an e-Trailguide—and its ability to facilitate the collaborative learning experiences of family groups as they engaged with an outdoor-based nature trail. The intent of this study was not to generalize to all family visitors through design-based research; instead, the goal was to test design principles recommended by previous research studies and to uncover specific design features from the Shaver’s Creek e-Trailguide that other outdoor sites can use, regardless of their biome, to support their family learners to engage with and explore the natural world together, leading to biodiversity knowledge gains. This work, therefore, provides important design recommendations that can be applied to other environmental education institutions that wish to engage their family visitors with nature through the use of mobile devices.
Chapter 2

Theoretical Framework

Sociocultural learning theory provided the lens with which this research topic focused on family learning with mobile devices in the outdoors was examined. A sociocultural view of learning asserts that people make sense of their world with the people and cultural tools within a space where learning takes place (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991; Vygotsky, 1978). In this regard, learning is not a “predetermined system of activity,” but is a process that is constantly shaped and influenced by external factors such as one’s cultural environment and the use of tools to achieve an objective (Vygotsky, 1978, p. 55). As such, understanding learning from a sociocultural perspective requires researchers to examine previous learning experiences, norms, practices, and interests that influence informal learning activities alongside a consideration of all aspects of the learning environment. Within this larger paradigm of sociocultural learning theory, constructs related to this study’s participants (family groups), setting (one outdoor-based nature trail), and the learning tool (an iPad-based e-Trailguide) combined to form the theoretical foundation for this dissertation study.

Overview of three-pronged theoretical framework

Sociocultural learning theories related to place-based learning, family learning, and mobile-based learning to support engagement with nature were central to my research study. Accordingly, by integrating the literature from these different topic areas, a framework was developed to support my research efforts. Table 2-1 illustrates the theoretical frames and concepts that were considered within this conceptual framework; each topic area is discussed in more detail in the following sections.
Table 2-1: Three-pronged conceptual framework.

<table>
<thead>
<tr>
<th>Theoretical frame</th>
<th>References</th>
</tr>
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<tbody>
<tr>
<td>Place-based learning theory</td>
<td>- <em>Learning about the environment while being in the environment</em> (Ardoin, 2006; Brody, 2005; Gruenewald &amp; Smith, 2014; Sobel, 2004; Smith, 2002).</td>
</tr>
</tbody>
</table>
| Informal-based family learning theory | - *Sense making during family science learning moments* (Allen, 2002; Ash, 2003; Ellenbogen, 2002; Povis & Crowley, 2015; Zimmerman, Reeve, & Bell, 2010);  
- *Guided participation and roles available for parents and children during learning activities* (Crowley et al., 2001; Crowley & Galco, 2001; Crowley & Jacobs, 2002; Gleason & Schauble, 2000; Palmquist & Crowley, 2007; Paradise & Rogoff, 2009; Rogoff, 2003; Zimmerman, McClain, & Crowl, 2013; Zimmerman, Perin, & Bell, 2010). |
| Mobile-based learning theory | - *Mobile-based learning is situated* (Dunleavy & Dede, 2014; Rogers et al., 2004; Sharples, 2000; Squire & Klopfer, 2007);  
- *Mobile-based learning facilitates engagement with the learning setting* (Brown et al., 2010; Hsi, 2002; Lyons, 2009; McClain & Zimmerman, 2016b). |

**Place-based learning**

The design of the e-Trailguide was influenced by place-based learning theory, which emphasizes the importance of connecting learners with their local community through participation in activities that take place within the immediate setting of the learner’s natural and social ecosystems (Ardoin, 2006; Gruenewald & Smith, 2014; Smith, 2002; Sobel, 2004). Highly relevant to sociocultural and situated theories of learning, place-based learning is often associated with pedagogies related to environmental education (e.g., Woodhouse & Knapp, 2000) and
community-based science education (e.g., Bang & Medin, 2010). Because learning is situated in and shaped by the social interactions within the disciplinary and physical setting in which a learning activity takes place (Brown et al., 1989; Lave & Wenger, 1991; Vygotsky, 1978), the physical setting has a significant impact and influence on how learners negotiate and come to understand new information (Falk & Dierking, 2000). For instance, learning about the outdoors while physically being in the outdoors allows for a stronger contextualization of the science education content (Ballantyne & Packer, 2002; Giamellaro, 2014; Rivet & Krajcik, 2008). Furthermore, Brody (2005) has written that in order for meaningful learning to take place [in nature], “the individual must have the direct experience of being in nature…it must be direct experience to promote the fullest thinking and feeling. The physical setting is critical” (p. 611). In other words, learning in the physical, natural environment assumes that learning is situated, or context-dependent (Lave & Wenger, 1991). The stimulation of the senses, emotional reaction to physical features and landscapes, and engagement with wild animals, plants, and other biotic and abiotic features of the ecosystem (Myers, Saunders, & Bexell, 2009) all comprise a unique and memorable learning experience that is often difficult to replicate.

It has been observed and argued that experiencing and exploring natural landscapes in its physical context, which books and computers can only describe, may provide a more heightened and memorable sense of wonder, awareness, and motivation for future learning about environmental characteristics and issues (Smith, 2002; Sobel, 1996). Place-based education can provide important learning opportunities and explorations of the local landscape that can later serve as the foundation on which investigations of more distant or abstract phenomena can be constructed (Smith, 2002, p. 588). Furthermore, Ballantyne and Packer (2002) argue that when students are engaged in the environment with the ability to directly experience and observe wildlife, their environmental understandings become more powerful. More recently, the National Research Council (2015) outlined criteria for identifying effective out-of-school STEM programs.
Providing “first-hand experience,” which includes place-based investigations, goes beyond hands-on learning in that students are directly engaged with the relevant context of a learning activity. Including place-based learning theory within my theoretical framework was essential for not only designing the Shaver’s Creek e-Trailguide, but also for situating and analyzing the data from my dissertation study.

**Family learning theory in informal science institutions**

While individual learners do visit informal education institutions, such as museums and zoos, it is more common that people visit these spaces in social groups. In my study, I focus on one common social group, families, which are the central unit of analysis. To date, considerable research efforts have focused on how families learn and engage with science-related sense making together. For this dissertation, I focus on previously established theory related to how families learn together in informal science education spaces, like museums (i.e., Allen, 2002; Ash, 2003; Bell, Bricker, Lee, Reeve, & Zimmerman, 2006; Borun, Chambers, & Cleghorn, 1996; Ellenbogen, Luke, & Dierking, 2004; Povis & Crowley, 2015; Zimmerman, Reeve, & Bell, 2008; Zimmerman, Reeve, & Bell, 2010).

To understand family learning processes, sociocultural theories of learning are an ideal analytical tool. Recognizing a family group as its own culture and learning institution armed with specific agendas, norms, and beliefs, is a critical perspective for informal education researchers to maintain (Ellenbogen et al., 2004). For instance, Borun and colleagues (1996) state that, “families have a culture of shared knowledge, values, and experiences. A family group that visits a museum

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1 While there are several terms that are used in the informal research and environmental education literature to describe the learning that occurs between adults and youth, such as “intergenerational learning” (Duvall & Zint, 2007), where youth and unrelated elders learn and work together, the term “family learning” is used throughout this study to refer to the social learning processes that occur between parents/guardians (or distant relatives like grandparents, aunts, and uncles) and children within a related family group.
can enrich its culture, storing knowledge for later sharing among family members” (p. 135).

Informal institutions are important settings that provide sense-making opportunities related to science and other topics. From the families’ perspective, however, their social interactions are based on their own unique motivations, identities, and prior experiences, and are not necessarily the result of the content in a particular learning space (Ellenbogen et al., 2004). As such, the family culture, or agenda (Ellenbogen et al., 2004; Zimmerman, Perin & Bell, 2010), provides an important lens of analysis in informal education spaces and is therefore, a subsequent component of my dissertation.

The importance of sense making during informal family learning events

The perspective adopted for this study considers sense making to be an integral learning process for family groups participating in informal learning experiences. According to Zimmerman, Reeve, and Bell (2010), sense making involves the “social efforts people undertake to construct an individual and shared understanding of new information” (p. 2). Sense making is a collaborative activity that incorporates individual utterances to be considered and shaped within the larger context of a family learning experience. In informal education, encouraging social learning is essential to the experience. Evidence from one museum research study with middle school-aged students has pointed toward the importance of social interactions in supporting conceptual knowledge gains (Yoon, Elinich, Wang, Steinmeier, & Tucker, 2012). In family groups, dialogue and collaboration is equally important to support parent and child learning. According to Ash, who observed and recorded family groups at a science museum in 2003, families use conversation as a means to “negotiate meaning, get attention, push on reasoning skills, advance language acquisition and tell personal stories over time and context…in order to

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2 The terms “meaning making” and “sense making” are often used interchangeably in the literature. For the purposes of my dissertation, I will use the term “sense making” throughout this document.
achieve common understanding” (p. 154). These conversational processes, which Zimmerman, Reeve, and Bell (2010) call “epistemic resources,” work together to assist families in their collaborative sense making, or the construction of individual and shared understanding of new information.

When engaged in sense making activities, family learning groups employ social processes by mutually bridging meanings (Rogoff, 2003) through conversations, gestures, and remembering shared experiences (Allen, 2002; Ash, 2003; Ash et al., 2007; Ellenbogen et al., 2004; Kiesiel et al., 2013; Zimmerman et al., 2008; Zimmerman et al., 2010). Previously shared experiences and the knowledge gained from those experiences can act as scaffolds and shapers of new knowledge (Bell & Linn, 2002; Bransford et al., 2006) for families (Borun, 2002; McClain & Zimmerman, 2014; Zimmerman, Perin & Bell, 2010; Zimmerman, Reeve, & Bell, 2010). For example, Ellenbogen (2002) argues that when families participate with interactive exhibits, they refer to previously shared experiences as resources to formulate a new conceptualization about that topic.

Related to mobile learning, Rogers and colleagues (2009) defined sense making as “the conversations and interactions that take place between students and their instructors, when moving between observations of the physical world and various digital representations of the underlying phenomena made available via a mobile device” (p. 112). This definition seems apt for my current dissertation study, with the only modification being a focus on family members rather than students and instructors. As such, sense making between family members during a nature walk occurs as they verbally and physically negotiate their understandings about the natural world as they are facilitated by a place-based e-Trailguide.

**Gesturing during sense making.** While verbal communication between family members is a main conduit for which thinking and sense making becomes externalized, gesture is also considered to be a main feature of the communicative process (Roth, 2001). Specifically, Roth
maintains that “deictic gestures” are pointing gestures that are context dependent and are often coupled with verbal cues to support communication efforts between two people. Furthermore, Goodwin (2003) describes pointing as being a situated interactive activity whereby one person’s act of pointing is an attempt at creating a shared focus among the individuals in that same space. In his earlier work, Goodwin (1994) argued that gestures, such as pointing, should not be analyzed alone; they must be considered alongside the pointer’s dialogue, the activity being pursued, and the environment where the activity is taking place. Put simply, “Talk and gesture mutually elaborate on each other within a framework of action” (Goodwin, 1994, p. 614).

Research has supported the notion that learners who gesture are more likely to retain what they have learned (Cook, Mitchell, & Goldin-Meadow, 2008), which suggests that gesturing facilitates learning. With regards to how family groups leverage gestures during learning and sense making activities in informal education spaces, Povis and Crowley (2015) observed 54 parent-child dyads engaging with dioramas and how they established joint attention—defined as “a reciprocal noticing of the same object by the other person in the dyad” (p. 179)—between one another through the manipulation of a flashlight. The physical manipulation of the flashlight, which served the purpose of restricting the field of vision within the diorama, was found to be an important facet for increasing learning talk among the families. Because both verbal and physical interactions are critical components of family learning processes in informal spaces, especially within the setting of this research study, social dialogue and gestures between parents and children were essential sources of data for my dissertation.

Guided participation and the roles of parents and children during family learning events

Founded on Vygotsky’s concept of interaction in the “zone of proximal development” (1978), where novices first learn with the assistance of experts before moving forward independently, Rogoff (2003) developed the concept of “guided participation,” whereby “children
learn as they participate in and are guided by the values and practices of their communities” (p. 284). During guided participation activities, Rogoff argues that parents and children (a) mutually bridge meanings, which involves communicating with one another in order to achieve common understanding and subsequently accomplish activities together, and (b) mutually structure participation, which encourages children to be highly involved in shared endeavors with their parents. In this way, parents are key facilitators of learning for their children and through guided participation practices, children become active learning participants by observing and “pitching in” (Paradise & Rogoff, 2009) during everyday learning activities.

**Roles of parents and children during informal family learning activities.** When families visit informal science institutions, parents have most often been observed taking on the role of teacher, or facilitator, in museums (Crowley et al., 2001; Crowley & Galco, 2001; Gleason & Schauble, 2000; Swartz & Crowley, 2004), aquariums (Rigney & Callanan, 2011), science centers (Zimmerman, Perin, & Bell, 2010; Zimmerman, Reeve, & Bell, 2008), zoos (Patrick & Tunnicliffe, 2013), and nature trails (Zimmerman, McClain, & Crowl, 2013). Even at home, parents act as teachers and collaborators in order to support their children’s learning and interests around technology (Barron, Martin, Takeuchi, & Fithian, 2009). At Shaver’s Creek, parents similarly act as role models for their children by encouraging the use of exploration tools, like hand lenses, to observe plants and animals, while they also foster empathy by demonstrating how to respectfully treat natural objects and organisms (McClain & Zimmerman, 2013).

In these informal learning settings, it is also not uncommon for children to demonstrate their expertise around certain interests (Crowley & Jacobs, 2002; Palmquist & Crowley, 2007). In their work with 28 families, Crowley and Jacobs (2002) described the importance of informal learning spaces, like museums, for developing children’s deep content knowledge on certain topics. These “islands of expertise” are often driven by children’s interests and subsequently become integral pieces of families’ activities, including the development of a parent’s knowledge
on these subjects. At Shaver’s Creek, children often displayed specific content knowledge about the natural world during nature walks with their parents and took on lead roles by orienting the family to certain geographic spots along the nature trail (McClain & Zimmerman, 2014). Because children depend on their parents to support their interests by taking them to museums or checking out library books on that topic, the development of this knowledge is inherently social and mutually constructed between family members. In sum, both parents and children can act as authorities on different topics (Zimmerman, Reeve, & Bell, 2010), which contribute toward their interaction of mutually bridging meanings (Rogoff, 2003). As such, these collaborative learning experiences provide important opportunities for joint inquiry and meaningful learning conversations among families in informal learning settings.

**The role of mobile devices in supporting situated learning and engagement in the outdoors**

This dissertation study is focused on one cultural tool (Brown et al., 1989; Vygotsky, 1978)—a mobile device—in order to understand how technology can mediate learning about and engaging with the natural world. An advantage of mobile-based learning is that an educational activity can straddle between settings so that the learner is not confined to only one location. Given that learning is a situated activity that inherently occurs in the “lived-in world” (Lave, 1991, p. 67), the ability for mobile devices to move seamlessly from one setting to another supports a multifaceted learning experience that is sustained across contexts. For example, Brown and colleagues (2010) contend that, “If learning becomes mobile, location becomes an important context, both in terms of the physical whereabouts of the learner and also the opportunities for learning to become location-sensitive” (p. 2). Furthermore, Sharples (2010) posits that this portability of mobile devices provides opportunities for distributing learning across people, places, and tools, which is an important concept given the social nature of family learning previously discussed.
Mobile devices, like smartphones, are context-aware, meaning that they support learners to interact with digital content while being physically located in a specific learning environment (Dunleavy & Dede, 2014). Because knowledge is ingrained within the setting in which it is used, learning should take place within relevant environments (Dunleavy & Dede, 2014; Lave & Wenger, 1991), a process that mobile devices can facilitate as a pedagogical agent (Rogers et al., 2004; Sharples, 2000; Squire & Klopfer, 2007). For example, in outdoor environments, mobile devices allow users to promptly access resources and content in situ to support identification of natural species (Jones, Scanlon, & Clough, 2013).

While mobile devices allow learning experiences to flow over settings, time, and topics, they also support the social process of learning with others (Sharples, 2000). This can occur through synchronous communication with others physically nearby or asynchronously with others in differing locations (Sharples et al., 2009). Although previous research has observed that mobile devices can make users feel isolated from one another during museum-based learning experiences (Hsi, 2002), other studies have demonstrated the collaborative inquiry that can ensue between students sharing one device in an outdoor setting (Rogers & Price, 2008). Because learning is socially constructed, mobile-based educational endeavors are apt to support what Squire and Klopfer (2007) refer to as social interactivity between learners.

Technology-mediated engagement with the learning setting

Informal learning research often considers learners’ *engagement* as a proxy for science learning. Calabrese Barton and colleagues’ notion of engagement (2004) includes people’s personal involvement in, orientation towards, and socio-historic participation of a learning event. Additionally, Heath and vom Lehn (2008) define engagement in out-of-school settings as the extent to which people engage in “interactivity” with others and with exhibits. Interactivity refers to both tactile investigations and social communication with others and, as the authors argue, is a
critical component of engagement. For the purposes of this dissertation study, these two concepts were blended so that engagement was considered as a combination of people’s orientation, participation, and interactivity towards the outdoors as mediated by a hand-held technology.

With the adoption of mobile devices as tools for learning, the tendency to be “lured by the screen” (Filippini-Fantoni & Bowen, 2009), which has become known among museum practitioners as the “heads-down phenomenon” (Hsi, 2002; Lyons, 2009), increases. Consequently, Pea & Maldonado (2006) suggested that educators and designers should create mobile learning platforms that enable users to remain engaged in the tasks to be accomplished, rather than to focus on the devices themselves. Given these important recommendations, the notion of fostering engagement with the physical learning setting was paramount in the design of the e-Trailguide. Deduced from the literature and based on the definition of engagement previously stated, a framework called “technology-mediated engagement with nature” emerged and developed out of the pilot study with the e-Trailguide (McClain & Zimmerman, 2016b). Within this framework, three types of technology-mediated engagement with nature were identified:

1. heads-up observations (Hsi, 2002; Lyons, 2009);
2. pointing (Goldin-Meadow & Alibali, 2013; Roth, 2001) to plants and animals along the trail; and
3. tactile, or hands-on, investigations of natural objects along the trail (Zimmerman et al., 2015).

These three forms of nature-technology-social engagement were used to evaluate the effectiveness of the design guidelines within the Shaver’s Creek e-Trailguide and are further described as part of the analytical coding scheme in Table 4-5, Chapter 4.

**Technology-mediated engagement with nature through observation.** Observation is arguably the basis for all scientific activity (Norris, 1985), yet the literature attests that developing
disciplined observation skills among children is difficult (Eberbach & Crowley, 2009). It is also a challenging skill for educators to support (Eberbach & Crowley, 2009; Smith & Reiser, 2005). A thorough literature review on children’s scientific observations of the world has typically occurred within school settings (Eberbach & Crowley, 2009); however, informal learning venues provide important opportunities to improve children’s science inquiry skills (Gutwill & Allen, 2009), including the transition from everyday noticings to more disciplined, scientific observations (Allen, 2004). When engaged in informal education settings as a family group, Paradise and Rogoff (2009) argue that, “learning through observing and contributing in family and community life is often based on intense concentration by the observer, negating the common assumption that observation is a passive way of learning,” (p.110). Indeed, observations contribute both towards one’s orientation towards important features of a learning environment, while they also precede one’s future participation in cultural activities (Paradise & Rogoff, 2009).

In this dissertation study, technology-mediated engagement through observation occurred when learners were provoked by the content in the e-Trailguide to look up and out at their surroundings.

**Technology-mediated engagement with nature through pointing.** Pointing, a deictic gesture, is a physical movement that combines with speech in order to orient others towards an object of interest (Goldin-Meadow & Alibali, 2013; C. Goodwin, 2003; Roth, 2001). In education, pointing can play an important role in collaborative learning activities, while it also serves as a mode for externalizing one’s thinking and understanding of a concept (Roth, 2001). During the e-Trailguide’s pilot study with youth summer campers (McClain & Zimmerman, 2016b), pointing emerged as a social sign of interaction with nature as pointing to a natural object was a gesture done with the purpose of directing another learner’s attention towards something specific while on the nature trail. Given the importance of both dialogue and gesture during communication between individuals (Goodwin, 2003), technology-mediated engagement with
nature through pointing was an important type of action to examine across families in my dissertation study.

**Technology-mediated engagement with nature through tactile investigation.** A third type of engagement included tactile investigations that were considered to be important for connecting people with nature and science. In informal settings, high-level sensory interactivity has been sought through the implementation of “hands-on” exhibits (Gutwill & Allen, 2002), which require the use of learners’ mind and body (Allen, 2004). Interactions with exhibits are thought to promote understanding and recall of exhibits’ science content (Allen, 2004, p. S24). While museum designers regularly create exhibits that promote these direct sensory experiences for visitors, on nature trails, hands-on interactivity is more challenging to document and to encourage. For instance, while sensory interactions do occur, there are also plants that learners are discouraged from touching (e.g., poison ivy) and animals that visitors cannot reach or that move too quickly to touch. Nonetheless, when mobile devices are integrated as learning tools into outdoor spaces, tactile learning has been shown to result. In their work at an arboretum with 10 family groups, Zimmerman and colleagues (2015) observed the families as they used mobile devices to facilitate closer inspections of the trees onsite. The scientific images on the mobile devices influenced the parents and children to physically touch parts of the trees, like the bark, to contextualize their understandings and observations.

**Conclusion**

Social interactions play significant roles when environmental education takes place in an outdoor setting. When families are learning about their local, natural world along a nature trail, it is important to support their sense making processes through face-to-face discussions and joint inquiry activities so that parents and children are able to support one another as a collaborative learning unit. Additionally, when conceptualizing the design of the e-Trailguide, it was important
to not only situate the educational material within the local place of the native ecosystem at Shaver’s Creek, but to also enable the families’ engagement with the diverse biota surrounding them on the nature trail. As such, these theoretical concepts manifested into three main design principles for the e-Trailguide, which are further described in Chapter 3.
Chapter 3

Design of the Shaver’s Creek e-Trailguide

To accomplish this research study focused on family learning with mobile devices in the outdoors, I developed the Shaver’s Creek e-Trailguide as a self-guiding mobile learning tool. My intent was that the e-Trailguide would support family groups’ engagement with nature and collaborative learning as they explored the diverse biota along one nature trail affiliated with the environmental center. Using design-based research methods (as described in Chapter 4), the e-Trailguide was developed through two prior research iterations conducted with summer camp children (McClain & Zimmerman, 2016b). The third version of the e-Trailguide is the current focus of this dissertation study. In this Chapter 3, I first describe the design structure of the e-Trailguide followed by a section that explains how design-based research methods were applied to the overall conception and design of the e-Trailguide. The chapter ends with a design description of Discovery Spot #3, Juniper’s Bench—the focus of this study’s qualitative analysis—and the three iterations of design-enact-analyze-revise (Puntambekar & Sandoval, 2009) it endured over the pilot study period and dissertation study period.

Setting of design

The e-Trailguide was designed specifically for the Boardwalk Trail (Figure 3-1). The Boardwalk Trail is ADA (Americans with Disabilities Act) compliant, which means that it is a level trail that can accommodate wheelchairs and strollers. It is approximately .5-miles (1 km) round-trip and leads hikers from a mixed woodlands ecosystem, to a predominantly evergreen and marshy habitat, and back. The short distance of this trail, coupled with the ecosystem diversity, provides a visitor-friendly recommendation and hiking experience for either outdoor-loving or inexperienced visitors. Given that the Boardwalk Trail is short, easily navigable, ADA-
approved, and diverse in terms of the northeastern woodland landscape, the design of the e-Trailguide was designed particularly for this stretch of trail.

Figure 3-1: SCEC property map featuring the Boardwalk Trail (in green and brown).

**Structure of e-Trailguide**

This study occurred within a rural area of hardwood forest, and correspondingly, Internet and cellular phone reception were limited. Consequently, a technology tool that did not require any access to the Internet was required, such as an electronic book. As a result, the Shaver’s Creek e-Trailguide was created using the program iBooks Author™ in order to create an iBook™ usable on two types of Apple Inc.® tablets: iPads™ and iPad minis™. A benefit of the iBooks software is that it increases scalability of the design findings to other nature centers, given that only minor computer programming skills are needed to design and implement an e-Trailguide in the form of an iBook.
The e-Trailguide serves as a self-guiding tool, which means that it is intended to be used in the case that there is no naturalist, docent, or other interpreter present. In keeping with design guidelines for facilitating a place-based learning experience via a mobile device (Zimmerman & Land, 2014), all information and visuals included in the e-Trailguide were locally collected by staff members and friends of Shaver’s Creek. Additionally, the seasonal information included pre-recorded information as suggested by other woodland exploration research (Rogers et al., 2004), including videos, photos, and audio-recordings of wildlife.

**Layout of e-Trailguide**

Within the iBook, users move linearly, forwards and backwards, as if they were reading a real electronic book; each “chapter” coincides with a “Discovery Spot,” or designated waypoint, and associated “On the Move” activity along the Boardwalk Trail. The inclusion of “widgets” allow for deeper interactivity within each chapter, such as drawing, taking photos, entering simple data, and recording fieldnotes.

**Discovery Spots.** Using the e-Trailguide for this study, there were six Discovery Spots that were visited along the Boardwalk Trail. The six Discovery Spots were laid out like six book chapters within the e-Trailguide and a map with the designated Discovery Spots was included at the end of each chapter (Figure 3-2). The map was coordinated with physical benchmarks on the trail, which were laminated green stars placed at each Discovery Spot, such as on a tree or bench, in order to alert the users to each location. At each spot, seasonal information about that portion of the Boardwalk Trail and an associated activity was viewable within the e-Trailguide (see Figure 3-3).
Figure 3-2: SCEC e-Trailguide map with 6 Discovery Spots (marked by green stars).

Figure 3-3: Screenshot of information and place-based question at Discovery Spot #1 in e-Trailguide.
**On the Move activities.** In addition to the fixed Discovery Spots, the e-Trailguide included five “On the Move” activities for families to engage with *in between* each Discovery Spot. For example, one On the Move activity featured a scavenger hunt that showed images of seasonal plants and animals that typically seen along a particular stretch of the trail. The learners were encouraged to search for these organisms and check off (via a checklist widget) what they found (see Figure 3-4). A second On the Move activity encouraged families to “Stay very quiet” in order to use their auditory and visual senses to listen for and observe plants and animals as they walked (see Figure 3-5). These types of activities, or challenges, were designed to encourage deeper observations of the surrounding landscape as family groups moved from one Discovery Spot to the next.

![Figure 3-4: On the Move scavenger hunt activity directions (left) and checklist widget (right).](image-url)
Applying design-based research methods to the implementation of an e-Trailguide

The following section outlines the components of design-based research that were applied to both the design of the e-Trailguide as an educational tool—theory-driven design principles—and the structure of this dissertation study, which were iterative feedback cycles to evaluate and improve the e-Trailguide. Further discussion regarding the design-based research methodology is included in Chapter 4.

Theory-driven design principles in designed-based research

In design-based research, theory is identified in the development of a design before that design is enacted within the educational setting it is meant to improve. Collins, Joseph, and Bielaczyc (2004) state that educational designs are “based on theoretical principles derived from
prior research” (p. 18). Such prior theoretical work provides a certain perspective or lens in which the researcher approaches and observes his or her research design in action.

The theories employed in the design of the Shaver’s Creek e-Trailguide combined elements of sociocultural theories of learning, which were previously described in Chapter 2. Prior work in other related areas and an in depth literature review supported the manifestation of the principles upheld when designing the e-Trailguide. According to Herrington, Herrington, and Mantei (2009), “design principles refer to characteristics of a planned learning design (what it should look like), or its procedure (how it should be developed) [van den Akker, 1999]” (p.130). In adopting this definition, the three main design principles stated below were based on my conceptual framework (see Chapter 2) and were considered to be the most influential for supporting family learning about their natural environment during a nature walk with an e-Trailguide:

1. *e-Trailguide’s educational material should be place-based, or grounded in the immediate, local setting.*
2. *e-Trailguide should support a face-to-face collaborative learning experience for visiting families.*
3. *e-Trailguide should facilitate engagement with the natural world.*

Table 3-1 outlines and describes these key design principles that were gleaned from the literature and subsequently incorporated into the development of the Shaver’s Creek e-Trailguide; each principle is further discussed in relation to prior empirical research in the following sections. Additionally, linked to these design principles were learning objectives (described in a later section) that were inherent in the design process.
Table 3-1: Three key design principles incorporated into the development of the Shaver’s Creek e-Trailguide.

<table>
<thead>
<tr>
<th>Design principle</th>
<th>Design guidelines deduced from the literature</th>
<th>Strategies and resources incorporated into e-Trailguide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile-based educational material is place-based (grounded in the immediate, local setting).</td>
<td>Deliver “custom” information (Lyons et al., 2010) in order to create a place-based learning experience (Ardoin, 2006; Gruenewald &amp; Smith, 2014; Smith, 2002; Sobel, 2004).</td>
<td>The e-Trailguide considers design guidelines for place-based learning via mobile computers (Zimmerman &amp; Land, 2014) and provides information about the native trees, animals, plants, and aquatic systems seen along the nature trail, thereby grounding the mobile learning material in the immediate, physical setting that families are immersed within (Giamellaro, 2014; Rivet &amp; Krajcik, 2008).</td>
</tr>
<tr>
<td>Technology-use supports a face-to-face collaborative learning experience for families.</td>
<td>Parent-child interactions are enhanced (not diminished) to promote family learning through face-to-face dialogue (Knipfer et al., 2009; Lyons et al., 2010).</td>
<td>In order to promote parent-child interactions, the e-Trailguide includes prompts and questions to encourage family discussion (Knipfer et al., 2009; Lyons et al., 2010), provides explanations about unusual features of the trail to spark family conversation, and provides challenge activities (i.e., scavenger hunts, observational drawings) for families to jointly pursue.</td>
</tr>
<tr>
<td>Mobile device facilitates engagement with the natural world.</td>
<td>Mobile devices should not take away from directly experiencing nature (Eliasson et al., 2011; Jones et al., 2013; Ruchter et al., 2010), but should enhance the experience by fostering engagement with the natural world through observation, pointing, and tactile investigation. (McClain &amp; Zimmerman, 2016b).</td>
<td>The activities embedded in the e-Trailguide aim to facilitate deeper observations and engagement with the natural world (McClain &amp; Zimmerman, 2016b). The incorporation of place-based questions, place-based prompts, a variety of widgets (sketchpad, notepad, checklist) and activities, and place-based images for identifying local biota were included to engage families with their surroundings, explore the biota along the trail, and record their observations.</td>
</tr>
</tbody>
</table>
Design principle 1: Mobile-based educational material is place-based. This first design principle was founded on theories of place-based learning as previously described in Chapter 2. To support a place-based learning experience (Gruenewald & Smith, 2014; Smith 2002; Sobel, 2002) in the design of the e-Trailguide, previous design guidelines for facilitating place-based learning via mobile computers were considered (Zimmerman & Land, 2014). These guidelines include organizing the mobile content to connect with the local ecosystem, using images to amplify learners’ observations of biota within their community, and providing opportunities to develop artifacts of local species through photographs or other means of data collection. Building from this work, the Shaver’s Creek e-Trailguide’s content was grounded within the setting of the northeastern woodland landscape so that the deepening of knowledge gains regarding the local biodiversity were supported. Because a primary objective in the design of the e-Trailguide was to improve the knowledge gain outcomes for families with regard to the northeastern woodland biodiversity, the e-Trailguide included biological content that was grounded in the local space where families were exploring. Additionally, the e-Trailguide was designed to focus family members’ thinking about specific biological concepts (including biodiversity, habitats, and ecological relationships) and biota (such as mushrooms, trees, and insects) by explicitly linking images and text to natural objects found easily on the trail.

Design principle 2: Technology use supports a face-to-face collaborative learning experience for families. This second design principle is based on theories related to family learning, which were described in Chapter 2. Because previous work has demonstrated the importance of collaboration as a knowledge building scaffold in informal learning spaces (Yoon, Elinich, Wang, Steinmeier, & Tucker, 2012), this e-trailguide was carefully designed in order to not only provide essential educational content, but to also support the learning of that content by facilitating discussions between family members through questions and dialogue prompts.
Prior research has shown that parent-child interactions play a critical role in helping to shape children’s ways of thinking about the world (Lyons et al., 2010, p. 87), while they are also a primary motivation of families who seek out informal learning outings (Falk & Dierking, 2000; Yocco et al., 2011). For instance, family groups visiting Shaver’s Creek on a leisurely weekend often anticipate both an enjoyable afternoon and an opportunity to learn about the natural world together. With this in mind, it was necessary for the design of and content within the e-Trailguide to not only provide information to the individual holding the mobile device, but to also support visitor-to-visitor collaborative learning among all present family members.

In 2009, Knipfer and colleagues analyzed the literature pertaining to media applications at science museums aimed at facilitating visitor-to-visitor knowledge communication. Their work pointed toward the importance of knowledge dialogue between visitors as they engaged with exhibits and recommended the inclusion of advanced media technologies (like mobile devices) to facilitate face-to-face dialogue through a medley of methods, including device-generated questions and prompts. In a similar literature review, Lyons et al. (2010) analyzed articles relevant to the intersection of parent-child interaction and human-mobile interaction in order to theorize about the role of mobile devices during parent-child learning in informal venues. Based on their analysis, Lyons and colleagues suggested that in order to maintain parent-child interactions when mobile devices are being used in museum spaces, posing questions and structuring joint tasks are important design features to include. Taking into consideration both of these conceptual pieces, simple activities and challenges that engaged both youth and parents were included in the e-Trailguide. For example, one “On the Move” activity in the e-Trailguide challenged families to complete a scavenger hunt where they explored a specific section of the trail in order to find and check off organisms on the list (see Figure 3-4). This task required families to work together to observe their surroundings and point out to one another when a certain organism was found. Additionally, conversational prompts and questions that engaged
families in a discussion or dialogue with one another (Knipfer, et al., 2009; Lyons, et al., 2010) was a simple technique incorporated into the e-Trailguide’s design. Because these design suggestions have not yet been tested, this research study aimed to elucidate how these mobile-based design recommendations influenced joint family learning and observations about trees at one Discovery Spot on a nature trail.

**Design principle 3: Mobile device facilitates engagement with the natural world.**

This last design principle was developed based on theories surrounding mobile-based learning and the importance of engagement with the learning setting, as described in Chapter 2. The e-Trailguide was intentionally designed to not only provide science information about the local ecosystem, but to also enable families’ engagement with nature. In museums, engaging visitors through hands-on exhibits and multi-sensory experiences is a regular objective (Gutwill & Allen, 2002). High levels of engagement and interaction with an exhibit often leads to a prolonging in the amount of time one spends with that educational content (Sanford, 2010). Conversely, some researchers argue that the more time one spends with an exhibit, the more meaningful their engagement (Humphrey & Gutwill, 2005; Yoon, Elinich, Wang, Steinmeier, & Tucker, 2012) and the higher the potential for conceptual gains (Borun et al., 1996). Determining the types of engagement among the family groups in my study was equally important because the objective was to facilitate joint explorations and observations of the natural world.

Based on the literature surrounding the topic of engagement, including design components that facilitated engagement with nature was a leading goal during the development of the e-Trailguide. As such, observational activities were purposefully grounded at specific junctures along the nature trail to focus families’ observations on specific parts of the ecosystem. Interactive tools, called widgets, were also incorporated in order to encourage the creation of observational records through both drawing and taking notes. Including opportunities to observe and draw during the nature walk was an important component within the e-Trailguide experience.
Fox and Lee (2013) argue that drawing can be a meaningful sense-making activity for children and is influential for honing young children’s observation skills. In their work with 42 kindergarten students observing live animals, the authors reported that the children who drew their observations (versus those who did not draw) scored higher on descriptions of the animals. Lastly, I developed specific On the Move activities in order to promote pointing and tactile investigations along the nature trail.

**Learning objectives**

Alongside the aforementioned design principles, three related learning objectives drove the creation of the e-Trailguide and were inherently tied into the iterative design process. These learning objectives aimed to:

1. Improve the local biodiversity knowledge and awareness of all family members as shown in the families’ talk and post-hike interview responses,
2. Facilitate a collaborative learning experience between family members as demonstrated through the families’ conversations and joint observation strategies, and,
3. Foster people’s engagement with the natural world as shown through families’ instances of technology-mediated engagement with nature.

First, because previous work with family groups at SCEC indicated that identification of a plant or animal was an enticing shared endeavor for families, but often more challenging than the families expected (Zimmerman & McClain, 2014), a main objective of the e-Trailguide was to support families’ familiarity and identification of the biological diversity found along the Boardwalk Trail. To support this, finite identification keys with place-based images of local plants and animals were incorporated into the e-Trailguide’s content. Evidence for the success of

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1 For a description of the full set of Discovery Spots and On the Move activities within the e-Trailguide, their learning objectives, and observed learner outcomes at each of these locations on the trail, refer to Appendix A.
this learning objective was evaluated through the participant families’ self-reported new learnings as expressed during the post-hike interviews.

Second, parent-child interactions in informal learning spaces have been recognized as critical in the development of youth’s scientific understandings of the world (Crowley & Callanan, 1998; Lyons et al., 2010) and the support of adults’ learning opportunities (Palmquist & Crowley, 2007). Consequently, using the e-Trailguide as a conduit for face-to-face conversations and joint observational activity between parents and children on the Boardwalk Trail was an essential learning objective. While mobile applications are typically designed for a single user (Lyons et al., 2010), the e-Trailguide intentionally incorporated design features such as collaborative drawing tasks and place-based questions and prompts to support social interactions between family members. The families’ conversations and joint observation strategies used during their time with the e-Trailguide were referred to as indicators of success for this learning objective.

Lastly, the e-Trailguide aimed to support novice families’ engagement with nature. This learning objective was motivated by the concern that mobile devices can detract rather than promote interactions with the physical environment for learners (Eliasson, 2013; Hsi, 2003; Lyons, 2009). To foster engagement with the natural world, the e-Trailguide included place-based observational questions, place-based textual prompts for focusing observation, and drawing activities to record observations (McClain & Zimmerman, 2016a). The effectiveness of this learning objective was observed by applying the technology-mediated engagement with nature framework to the data (McClain & Zimmerman, 2016b).

**Iterative cycles in design-based research**

The process of iteratively implementing an educational design is critical for creating an effective learning tool. Each iteration is a feedback cycle (Bannan-Ritland, 2003) that helps to “sharpen aims [and] deepen contextual insights” (McKenney, Nieveen, & van den Akker, 2006,
p. 77-78), while it also develops better supports for learning (Joseph, 2004). Cycles of design implementation in an educational setting result in long periods of data collection; however, because improving learning outcomes is a main goal of design-based research (Edelson, 2002), it is important for researchers to observe, evaluate, and refine the design for each new cycle so that the design’s practical application fits the setting it is set out to improve.

The current study builds off of the first two cycles of implementation, which occurred in summer 2013 with 83 youth campers aged 8-10 years old (McClain & Zimmerman, 2016b). Improvements in the design of the e-Trailguide were incorporated into the current, third design of the e-Trailguide program. The original intention of the e-Trailguide was to be used as a mobile learning tool by families visiting Shaver’s Creek; as such, the current project recruited family groups to participate with the third cycle of implementation. These types of iterative cycles of design-enact-analyze-revise (Puntambekar & Sandoval, 2009) are emblematic of a design-based research study and were critical in the creation of the e-Trailguide.

**Overall design and re-design of e-Trailguide in iterations 1 and 2.** The first two cycles of implementation and re-design occurred during a pilot study during the summer of 2013 with 83 summer campers as “testers” of the e-Trailguide (McClain & Zimmerman, 2016b). The video data from iteration 1 revealed that the participant children spent a large amount of their time on the hiking trail looking at the screen in order to read the information presented. Because the e-Trailguide was designed to foster engagement with the natural world, rather than just reading, revising the design of the e-Trailguide was an important first area of revision. As such, the second version of the e-Trailguide (see Table 3-2) included a 32% reduction in text, two videos, 97 graphics, and four interactive widgets. Additionally, in iteration 2, the conversational prompts and questions were re-worded to better direct the users to engage with the On the Move activities.
Table 3-2: Mobile material design and revisions, showing the differences in the two pilot study iterations.

<table>
<thead>
<tr>
<th>Iteration</th>
<th>Subjects</th>
<th>Design iterations of e-Trailguide described</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iteration 1:</td>
<td>42 children, aged 8 - 11</td>
<td>• Text included about 56 words per chapter&lt;br&gt;• 1 video&lt;br&gt;• 81 graphics&lt;br&gt;• 2 interactive widgets (1 sketchpad widget, 1 checklist widget)</td>
</tr>
<tr>
<td>8 sessions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iteration 2:</td>
<td>41 children, aged 8 - 11</td>
<td>• Text included about 38 words per chapter&lt;br&gt;• 2 videos&lt;br&gt;• 97 graphics&lt;br&gt;• 4 interactive widgets (2 sketchpad widgets, 1 checklist widget, 1 notebook widget)</td>
</tr>
<tr>
<td>7 sessions</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Overall outcomes from iterations 1 and 2.** The overall limitations of the design of the e-Trailguide were fully realized during these first two iterations, and were subsequently addressed in the current (third) version of the design. These earlier limitations of the e-Trailguide were varied and provided important feedback. Two major outcomes from the first two iterations emerged through my own observations and in reviewing the video records:

1) Counselors were necessary to engage campers in the e-Trailguide’s activities; the e-Trailguide was not “self-guiding” as it was designed to be, and

2) There was a noticeable breakdown in the e-Trailguide’s waypoint ability.

In addressing this first outcome, despite the purposeful design of the e-Trailguide to encourage conversation and collaboration between campers using the e-Trailguide through the incorporation of prompts, questions, and joint On the Move activities, counselors with each group played a critical role in encouraging campers to articulate their thoughts and engage with the activities outlined in the e-Trailguide. Although the counselors were instructed to let the campers
explore at their own pace, it soon became obvious that the counselors needed to step in to regulate and ensure the campers were paying attention to the activity.

There were no differences between iterations 1 and 2 when it came to the need for a facilitator (the counselor) for each group of campers. The excerpt below illustrates one interaction that took place during a data collection session within the second iteration of the pilot study. In this vignette, the campers and the counselor, Ursa, have arrived at Discovery Spot #1 and everyone sits down on the ground to read through the information in the e-Trailguide. Ursa sits next to two girls sharing an iPad, Ava and Caroline (pseudonyms), and encourages them to talk about the information captured in the e-Trailguide’s text:

Ursa: So what- what does it say on Discovery Spot one?
Ava: ((holding iPad and reading the e-Trailguide)) “When do you think this picture- this picture was taken? It looks very different as you walk down the trail today.”
Ursa: Ooh. So, what do you think? ((Ava and Caroline both look at screen without saying anything))
Ursa: What do the trees look like? ((Ava and Caroline look up at trees around them))
Ava: Was this taken in winter or something?
Ursa: Ooh.
Caroline: Or fall?
Ursa: Or fall. Why do you think that?
Caroline: Because all the trees are dead. Or—not dead—not, not leafy.

In the example above, Ava and Caroline were both looking at the iPad screen, presumably reading to themselves. Ursa encouraged one of them to read the text out loud when she asked, “So what does it say on Discovery Spot one?” After Ava read the conversational prompt, Ursa further encouraged them to talk about their ideas by asking, “So, what do you think?” Ava and Caroline both look at the screen for a few moments and Ursa further guides them by asking, “What do the trees look like?” which resulted in both girls looking up at the trees around the area where they were sitting. Both Ava and Caroline shared different ideas about when the picture in
the e-Trailguide may have been taken and Ursa encourages Caroline to articulate why she thinks it could have been taken in the fall. After Caroline explains her reasoning (“Because all the trees [in the picture] are dead, not leafy”), Ursa acknowledges her thoughts and then suggests they move onto the next page of the e-Trailguide. The interaction between Ursa, Ava, and Caroline was typical of the amount of encouragement and facilitation counselors gave to their campers throughout all of the data collection sessions.

Second, the video analysis of both iterations 1 and 2 revealed that the e-Trailguide did not act as a sufficient stand-alone guide along the trail. In both iterations, the campers ignored the included maps and often relied on each other or their counselor to tell them when to stop at a Discovery Spot. Additionally, a number of Discovery Spots were bypassed altogether. During the third week of data collection (iteration 2), Discovery Spot #6 was skipped by all seven of the camper groups. A mobile device that pings the learner would be helpful for this type of self-guiding program, but the lack of wireless capabilities along the trail due to Shaver’s Creek’s remote location prevents that level of guidance. Consequently, one revision made during the third iteration of enactment was the addition of physical markers in the form of laminated green stars to signal the participant families when they had arrived at a Discovery Spot. Additional revisions were incorporated into the third iteration of the e-Trailguide as a result of iterations 1 and 2 and are described in the next section.

**Overall re-design of e-Trailguide in iteration 3.** This third iteration of the e-Trailguide was implemented with 31 family groups as the participant learners. Based on the analysis of the first two iterations with youth summer campers, important design improvements were implemented into this current version of the e-Trailguide. These refinements included:

- posting physical markers at each Discovery Spot on the Boardwalk Trail in the form of a laminated green star (e.g. on a bench or tree);
• including two new in-book photo widgets (specifically at On the Move #1 and Discovery Spot #3);
• omitting unnecessary features that were unrelated to the content at given Discovery Spots (e.g., a video of a shrew at Discovery Spot #1, a spot that provided content about arching trees);
• incorporating larger fonts, bold fonts, and articulated directions to better highlight each prompt or question aimed at enabling face-to-face family interactions;
• providing species “keys”, or identification guides, through location-specific images (specifically at Discovery Spot #3); and
• including explanations for natural phenomena that were frequently brought up in conversation between summer campers during iterations 1 and 2 (e.g., providing information about where the lake’s water level will be when the lake returns).

Since this was the third implementation, but the only one that involved family groups, it is highly likely that additional re-designs and enactments will occur beyond this project in order to ensure that the e-Trailguide best supports families’ engagement along the Boardwalk Trail. Because “there is always room for improvements in the design and subsequent evaluations,” these iterative cycles are critical to design-based research and improving educational practice (Anderson & Shattuck, 2012, p. 17). Therefore, future edits to the e-Trailguide, due changes to the local environment, for example, are expected.

**Study focus to understand engagement with nature: Discovery Spot #3**

The design principles and learning objectives previously discussed were intentionally incorporated into the e-Trailguide to foster learners’ engagements with the natural world and in doing so, support their learning processes about the local biodiversity. Prior to my pilot study (McClain & Zimmerman, 2016b), there had not been any studies that specifically documented the
engagement patterns between the learner and the natural phenomena when a mobile tool is incorporated into the learning activity. As such, both my pilot study and dissertation work provide a needed description of what it means to be engaged with one's surroundings in an outdoor setting when mobile technologies are present. To best understand the types of engagements with nature that were supported by the e-Trailguide, I focused on one Discovery Spot—Juniper’s Bench—to deeply analyze.

In the e-Trailguide, each Discovery Spot and On the Move content section includes a variety of activities to engage the learners: questions, prompts, widgets, challenges, quizzes, and joint activities. The third Discovery Spot (Juniper’s Bench) included the most activity variety of all the other Discovery Spots. Additionally, the content at Juniper’s Bench went through the most substantial design changes from iteration 1 to iteration 3. The original version of this Discovery Spot presented a one-way informational spread focused on deciduous and evergreen trees through text and images. Observations of the summer camp participants who used this earlier version of the e-Trailguide revealed a considerable amount of heads-down time at Discovery Spot #3. Given these results, I re-designed Discovery Spot #3 to have less text in iteration 2 and to further promote engagement with nature through prompts, questions, and activities in iteration 3. These design changes were necessary for achieving my intended learning objectives to support family engagement and learning about the local biodiversity. The following three sections describe the content of Discovery Spot #3 as it was designed in all three iterations and how it was modified in iterations 2 and 3.

**Iteration 1: Design description of Juniper’s Bench**

In the first design iteration of the e-Trailguide’s Discovery Spot #3, I included textual information and visuals pertaining to deciduous trees and evergreen trees with a particular focus on white pines and leaves of deciduous trees. The intention behind this learning design was to
provide tree-based content related to the native trees surrounding Juniper’s Bench. When I first began designing this Discovery Spot in the fall and winter of 2012 (when the trees were bare of leaves), I noted that white pines were abundant in the area and chose to provide content focused on this species of tree. During the first iteration with summer campers, this content choice revealed to be a major flaw: the white pines were barely visible during the summer months when the leaves of deciduous trees were in full bloom. Alongside this drawback, the amount of informational text about trees at Discovery Spot #3 required the campers to spend the majority of their time with their heads down to read from the device.

In each of the three iterations, the introductory page to Juniper’s Bench was the one page of content that remained the same (Figure 3-6). Upon first arriving to Juniper’s Bench, this first page asks simple questions such as, “What do you hear? What do you see?” These “warm up” questions encouraged the summer campers in iterations 1 and 2 and the children and parents in iteration 3 to first familiarize themselves with this area of the nature trail before moving on to the subsequent pages that featured specific content and tasks focused on native trees.
During iteration 1, the second page of content at Juniper’s Bench began with a prompt to “Look up!” that was intended to encourage observation and identification of white pine trees in the area (Figure 3-7). A photo browser widget featured three different images to show the different parts of a white pine such as the five-clustered needles, the long pine cones, and distinctive bark. As previously described, the white pines (and other evergreen trees in the area) were difficult to locate during the summer months due to the crowded leaf cover of the deciduous trees in the area.
Figure 3-7: Information on white pines at Juniper’s Bench in e-Trailguide (iteration 1).

Next, the e-Trailguide provided an overview on deciduous trees and evergreen trees that was meant to provide place-based content related to the trees near to Juniper’s Bench (Figure 3-8). Primarily text-directed information, this page lacked any place-based prompts to encourage observations of the physical surroundings; instead, learners were prompted to compare two pictures featured within the e-Trailguide, thereby focusing their attention on the screen rather than the natural objects nearby.
Figure 3-8: Information on deciduous trees and evergreen trees at Juniper’s Bench in e-Trailguide (iteration 1).

The last page of content at Juniper’s Bench focused on text-based and visual information focused on deciduous leaves to support observations of deciduous trees proximal to Juniper’s Bench (Figure 3-9). A “fun fact” compared deciduous leaves from trees with deciduous teeth in humans in an attempt to make a relevant connection to the learner. Five photos of different deciduous leaves from different season of the year were featured in the photo browser widget to provide a visual example of the stages of a deciduous leaf.
Iteration 2: Design description of Juniper’s Bench

When reviewing the video-records from the first iteration, it became apparent that the summer campers participating in the study spent the majority of their time on the Boardwalk Trail reading information from the e-Trailguide. In an effort to reduce the amount of heads-down time with the mobile device and increase heads-up engagements with the surrounding natural world, the overall amount of text was trimmed down throughout the e-Trailguide. In addition, joint activities and widget tasks were incorporated to enhance the collaborative learning goal of supporting opportunities to observe and engage with nature. For instance, one widget—the sketchpad for drawing at Discovery Spot #5 (Loon’s Lookout)—was popular among the children in iteration 1. From the analysis (McClain & Zimmerman, 2016b), the campers in iteration 1 spent the most amount of time at Discovery Spot #5 as they recorded their observations of the landscape through this drawing activity. Given this outcome, I posited that this particular
technology feature was linked with high observational engagement. For this reason, an additional sketchpad widget was added to the content at Discovery Spot #3 (Juniper’s Bench) in the second iteration of the e-Trailguide.

As in the first iteration, the introductory page and content remained the same (Figure 3-6). The second page of content shifted from the defunct white pine information featured in the first iteration to a brief overview on deciduous trees and evergreen trees, and one example photograph of each (Figure 3-10). The brief information about the differences between deciduous and evergreen trees was included to support learners’ understandings of basic tree biology as they lingered in this area that was surrounded by both types of trees. The shortening of text was a purposeful decision made in an effort to shorten the amount of time learners spent reading from the e-Trailguide.

Figure 3-10: Information on deciduous trees and evergreen trees at Juniper’s Bench in e-Trailguide (iteration 2).
The final page of content at Juniper’s Bench during iteration 2 (Figure 3-11) featured a prompt in the form of a place-based observational question (McClain & Zimmerman, 2016a):

“Look up! How many different kinds of trees do you see around you?” This question was added in order to facilitate real-world observations of the trees proximate to Juniper’s Bench. A second feature of this page was the inclusion of the sketchpad widget, which provided an opportunity for the campers to more closely observe their surroundings by drawing “the trees and leaves” around them.

Figure 3-11: Drawing activity at Juniper’s Bench in e-Trailguide (iteration 2).
**Iteration 3: Design description of Juniper’s Bench**

During the third iteration of the e-Trailguide that the 31 participant families used during their hikes, the overall information about trees remained the same from iteration 2. However, iteration 3 included new place-based prompts and questions in order to encourage deeper observations of the trees encompassing Juniper’s Bench. A second addition to the third iteration of this Discovery Spot was a new page of content featuring locally-collected images of deciduous tree leaves and evergreen tree needles; these images were provided to further the drawing activity by supporting the families in their identification of tree species nearby.

As before, the introductory page of Discovery Spot #3 was unchanged from the first iteration (Figure 3-6). Next, the brief informational overview on deciduous trees and evergreen trees from iteration 2 remained the same. However, to contextualize this information through observations of nearby trees, both a place-based observational question and a place-based textual prompt (McClain & Zimmerman, 2016a) were added to the content on this page (Figure 3-12). To support observations of deciduous trees and their leaves, the e-Trailguide asks, “Do you see any deciduous leaves on the ground around you?” Then, to shift their observation to evergreen trees in the area, the e-Trailguide prompts, “To see the evergreen trees in this area, look closely beyond the leafy, deciduous trees!” A mixture of brief informational content and place-based prompts revealed to be a successful technique for promoting the families’ engagements with the natural world (McClain & Zimmerman, 2016a).
Figure 3-12: Information and observational prompts pertaining to deciduous trees and evergreen trees at Juniper’s Bench in e-Trailguide (iteration 3).

On the following page (Figure 3-13), families were asked a series of place-based questions meant to hone their observation skills of the native trees in that area. For the drawing activity, the prompting text was better articulated from iteration 2 by asking groups to work together to find a particular tree that interested them, draw that tree, and label their tree as either deciduous or evergreen. These drawing activity directions specifically prompted families to “work together” in order to promote a collaborative learning experience at Juniper’s Bench. Additionally, the directions challenged the families to label their drawn tree as either deciduous or evergreen, thereby demonstrating their comprehension of the previous page’s content on types of trees.
After they completed the drawing of a tree, the next page identified and displayed six species of tree leaves found in the area by Juniper’s Bench (Figure 3-14). This information was incorporated into the third iteration of Discovery Spot #3 as a follow up to the drawing activity in order for the families to identify the tree they had drawn. Because cartoon drawings, which are often shown in paper-based fieldguides, can impede families’ successful identification of wildlife (Zimmerman & McClain, 2014), the provided leaf photos in the e-Trailguide at Discovery Spot #3 were taken directly from the trees surrounding Juniper’s Bench so that the identification activity would be more easily accomplished. If a family could not identify their tree, they were given the option to take a photo of their tree using the in-book photo widget. This option was provided with the idea that families could refer back to the photo for future identification efforts.
Summary of three design iterations of Juniper’s Bench

Revising the content at Juniper’s Bench was an essential undertaking that involved observing how the campers in iterations 1 and 2 used the e-Trailguide and how the mobile device did (or did not) support the campers’ engagement with the natural world. Reducing the amount of text and incorporating prompts, questions, and widget-based activities in iterations 2 and 3 were important design modifications that better facilitated heads up observations of the physical surroundings. As a summary of the design-enact-analyze-revise (Puntambekar & Sandoval, 2009) process of the content at Discovery Spot #3, Table 3-3 outlines each of the three iteration’s design elements, limitations of the design, and revisions that were incorporated into the design.
Table 3-3: Design elements, limitations, and revisions of content at Juniper’s Bench during iterations 1 through 3.

<table>
<thead>
<tr>
<th>Iteration</th>
<th>Design elements</th>
<th>Limitations of design elements</th>
<th>Revisions made to content and design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iteration 1</td>
<td>• Introductory page with “warm up” questions to familiarize learners with sights and sounds around Juniper’s Bench (Figure 3-6).&lt;br&gt;• Textual information on white pines and photo gallery of white pine images (Figure 3-7).&lt;br&gt;• Textual and visual information describes differences between deciduous and evergreen trees (Figure 3-8).&lt;br&gt;• Textual information on tree leaves and photo gallery of leaves from varying trees (Figure 3-9).</td>
<td>• White pines challenging to see in the summertime when leaves of other trees are full.&lt;br&gt;• Large amount of informational text with no connection to nearby trees.&lt;br&gt;• Large amount of informational text with no connection to leaves in area.</td>
<td>• Deletion of white pine content page and tree leaf content page.&lt;br&gt;• Simplified text pertaining to deciduous and evergreen trees (Figure 3-10).&lt;br&gt;• Addition of prompt on third page of content to encourage observation of tree diversity around Juniper’s Bench (Figure 3-11).&lt;br&gt;• Addition of sketchpad widget; provided opportunity to “Draw the trees and leaves that you see” (Figure 3-11).</td>
</tr>
<tr>
<td>Iteration 2</td>
<td>• Introductory page with “warm up” questions to familiarize learners with sights and sounds around Juniper’s Bench (Figure 3-6).&lt;br&gt;• Brief textual and visual information pertaining to deciduous trees and evergreen trees (Figure 3-10).&lt;br&gt;• Place-based observational question to facilitate observation of trees around Juniper’s Bench (Figure 3-11).&lt;br&gt;• Tree-based drawing activity via sketchpad widget (Figure 3-11).</td>
<td>• Deciduous tree and evergreen tree information is stand-alone; it does not connect learners to real world trees in area.&lt;br&gt;• Vague prompt for drawing activity.&lt;br&gt;• Drawing activity lacks clear objective; no “closure” to activity.</td>
<td></td>
</tr>
</tbody>
</table>
Iteration 3
31 family groups (n = 105 individuals)

• Introductory page with "warm-up" questions to familiarize learners with sights and sounds around Juniper's Bench (Figure 3-6).

• Brief textual and visual information pertaining to deciduous trees and evergreen trees; place-based textual prompt and place-based observational question associated with deciduous trees and evergreen trees (Figure 3-12).

• Place-based observational questions to facilitate observations of variety of trees by Juniper's Bench (Figure 3-13).

• Tree-based drawing activity via sketchpad widget (Figure 3-13).

• Place-based images to aid in identification of tree that family previously drew (Figure 3-14). In-book photo widget included if tree could not be identified with provided images (Figure 3-14).

• In-book photo widget included if tree could not be identified using the provided images (Figure 3-14).

• Articulated instructions to encourage joint activity among family members to choose and draw one tree during drawing activity (Figure 3-14).

• Place-based images of tree leaves to support identification of tree species around Juniper's Bench (Figure 3-13).

• Articulated instructions to encourage place-based observational question added to deciduous tree and evergreen tree content (Figure 3-12).
Due to the significant revisions made to the content at Juniper’s Bench, I focused my qualitative analysis on this particular Discovery Spot in order to deeply explore how the e-Trailguide enabled certain patterns of engagement with nature and joint observation between children and families.

**Conclusion**

The Shaver’s Creek e-Trailguide was designed to guide families to learn about and engage with the natural world during a short hike via the implementation of design-based research methods. Three theory-driven design principles for the e-Trailguide were incorporated into the mobile program in order to a) create a place-based program that would support learning about the local biodiversity, b) provide an opportunity to engage with the natural world as mediated by a mobile technology, and c) facilitate a collaborative learning experience to promote family interactions about the natural world. Through a pilot study with youth summer campers, two design iterations were enacted that resulted in a decrease in the amount of text and an increase in the number of observation-based prompts and interactive widgets. Overall, these first two iterations revealed that the youth summer campers did not adhere to the “self-guiding” design of the e-Trailguide and required a facilitator (their counselor) in order to interact with the e-Trailguide’s prompts, questions, and widgets. Additionally, the map embedded within the e-Trailguide did not appear to be a useful mode for keeping the summer campers “on track” while they were on the trail. This resulted in the campers skipping over some Discovery Spots altogether. Analysis of the video records from both iterations 1 and 2 resulted in several necessary revisions to the e-Trailguide, particularly with regards to Discovery Spot #3, Juniper’s Bench, which have contributed to the current, third iteration of the e-Trailguide centered on in this dissertation study.
Chapter 4

Data Collection Methods and Data Analysis

Design-based research (DBR) is the methodological perspective that guides this research study. In the early 1990s, Ann Brown (1992) and Allan Collins (1992) first proposed that educational research on learning processes and design interventions be performed in an actual educational environment, such as a classroom, rather than the confines of a laboratory. This methodology, which was originally called “design experiments,” would be one necessary means by which learning could be studied in situ, thereby providing richness and reality to theories of learning and recommendations for educational practice (Brown, 1992). Carrying out research within the setting where learning occurs, rather than a laboratory, can not only speak directly to the problems of educational practice, but can develop sharable learning theories to be used by educational designers, teachers, and policymakers (Design-based Research Collective, 2003). Design-based researchers aim for two goals during their design development, implementation, and evaluation: 1) to generate and develop theories of learning and 2) to realistically improve learning processes and educational outcomes in specified learning settings.

While the initial move from laboratory to real-world classrooms may have been the first identifiable trait of DBR as a methodology (Brown, 1992; Collins, 1992), researchers in the subsequent decades have identified additional, critical methodological traits. Procedurally speaking, the design-based research methodology has associated key components that help to separate it from other methodologies that have been applied in the educational research field. These most recognized features of DBR include:

- situating the design and data collection within the educational setting that is meant to be improved;
- the enactment of a theoretical, research-driven design;
• procedural iterative cycles of implementation, evaluation, and refinement; and,
• applying mixed methods in order to collect thorough data.

These four characteristics of the design-based research methodology thus provided the foundation upon which to frame the research study presented in this dissertation.

Research setting: Shaver’s Creek Environmental Center

Originally, design-based research studies were embedded within “real world” classroom settings (A. Brown, 1992; Edelson, 2002; Joseph, 2004); however, this study focused on informal learning audiences engaged with an outdoor-based nature trail at a nature center. The study setting, Shaver’s Creek Environmental Center (SCEC), is very highly tied to learning outcomes on behalf of its visitors. More specifically, SCEC aims to connect individuals with their local ecosystem by providing knowledge, values, and skills through a variety of outdoor-based, experiential programs.

SCEC is generally regarded as Penn State University’s Nature Center and receives over 100,000 visitors annually. The property is host to over 20 injured and non-releasable birds of prey, or raptors, which are visible to the public on a daily basis, all year round. In addition, the main building is occupied by Pennsylvania-native amphibians and reptiles alongside environmental-themed, interactive exhibits designed and developed by Penn State undergraduate students and interns. SCEC retains both permanent and seasonal staff members who teach university courses, care for the onsite wildlife, lead public programs, and host school field trips.

SCEC is located within the Stone Valley Forest in Petersburg, Pennsylvania and has many miles of hiking trails that begin on SCEC’s property and wind through the local forest and wetland ecosystems. Visitors to SCEC commonly traverse these well-maintained and marked trails. The most frequently recommended hiking trail by staff at SCEC is the “Boardwalk Trail,” which was the focus of this study (see Chapter 3).
Family group visitors at Shaver’s Creek

Of the annual 100,000 visitors that Shaver’s Creek hosts, the majority of the casual weekend visitors arrive as family units. At SCEC, families are characteristically attracted to the live animals onsite, while they also frequently attend weekend public programs hosted by a staff naturalist. Prior work with families at SCEC has provided important insights for the design of the e-Trailguide and the current research study. When observing and assessing how families utilized physical “exploration tools” (e.g., field guides, binoculars, magnifying glass) during nature walks at SCEC, family members struggled when manipulating magnifiers to observe their surroundings (Zimmerman, McClain, & Crowl, 2013) and when using field guides as a tool for identifying an organism encountered during the walks (Zimmerman & McClain, 2014). The broadness of the field guides (e.g., “Eastern Birds of North America”) often provided families with too many choices when attempting to identify a species, while the line drawn sketches of the plants and animals in the field guides were difficult to compare to the real-world organisms along the trail (Zimmerman & McClain, 2014). Oftentimes, when these types of challenges arose, families would abandon an activity or simply move on in order to maintain a positive learning experience and social harmony between family members (Zimmerman, McClain, & Crowl, 2013). As such, these obstacles may be hindering the potential learning opportunities for families in this natural setting; my dissertation project sought to address these problems with a new technology designed to facilitate and support families’ investigations of the local biota.

A close examination of the discourse of families has shown that facilitation from text, such as exhibit labels found in museums, enriches families’ conversations (Zimmerman, Reeve, & Bell, 2008); however, prior work with families on trails without signs suggests that they heavily rely on their prior knowledge and experiences to connect with and make sense of what they observe in nature (McClain & Zimmerman, 2014). Implications from these studies at SCEC and in other museums indicate that families need guidance when it comes to exploring the
dynamic space of a nature trail and when using tools like binoculars and field guides. The current study thus aimed to enhance the facilitation of families’ learning experiences as they explored their local ecosystem through location-specific information and images found in the e-Trailguide.

**Research participants**

Thirty-two families (n = 108 individuals) were recruited to participate in my dissertation study at Shaver’s Creek. One family was not included in the final analysis due to the child being above the age range (15 years old) for acceptable child participants. As a result, 31 families (n = 105 individuals) comprised my dissertation research project and analysis. Table 4-1 provides a detailed breakdown of the 31 family groups that participated.

A recruitment email sent out through the SCEC member listserv was the primary means of contacting interested families (see Appendix B). One specification for groups that participated in this study included families with children between the ages of 6 and 13 as of summer 2014. Families with children in this age group were purposely sampled because the e-Trailguide was designed for children in the elementary through middle school range. Additionally, this study was restricted to English-speaking families due to my own language limitations. At least one parent and one child (between the ages of 6 and 13) were necessary to participate. Because this study was interested in family learning and interactions, additional family members were also welcomed into the study, such as siblings or grandparents, regardless of their age. As long as at least one child fit the age parameters noted above, anyone in the family was welcome to participate. The families that participated in this study spanned suburban and rural communities.

As per Penn State Office of Research Protections and IRB regulations (this study is approved and recorded under Protocol ID #42937), each family member was consented and assented into this study. Parents/guardians provided consent for themselves and their children (minors under the age of 18), while youth in each family provided verbal assent as required by
IRB for any youth under the age of 14. Both consent and assent were obtained onsite at SCEC before any data collection occurred.

Table 4-1: Thirty-one consented family groups participating in e-Trailguide research study at Shaver’s Creek Environmental Center.

<table>
<thead>
<tr>
<th>31 families</th>
<th>Adults</th>
<th>Children</th>
<th>Other notes of interest</th>
</tr>
</thead>
</table>
| 105 total individual participants | 47 individual adults were analyzed:  
- 29 mothers  
- 14 fathers  
- 3 grandmothers  
- 1 grandfather | 58 total individual children:  
- 26 girls  
- 32 boys | 1 pair of cousins (two boys; 10 and 4) |
| | 51 children within study’s age range (between ages 6 and 13):  
- 24 girls  
- 27 boys | | 4 friends of children in study (not related to family):  
- 3 girls  
- 1 boy |

Participant families’ demographics

Prior to their visit to SCEC, each family was asked to complete an online survey through the secure Qualtrics program (http://www.qualtrics.com). This survey was designed to provide an overview of the participant families’ backgrounds, their experiences in the outdoors and at Shaver’s Creek, and their familiarity with technology in their everyday lives. While each family was requested to complete this survey prior to their visit to Shaver’s Creek to use the e-Trailguide, not completing the survey did not preclude families from participating in the study; as such, the survey received a 94% response rate with 29 out of 31 completed.

Parents and guardians. Participating adults totaled to 47 individuals. Mothers most often attended the project hike at Shaver’s Creek with their children. Twenty-nine mothers participated in this study, while 14 fathers participated. Two sets of grandparents (one grandmother and her granddaughter and a grandmother and grandfather with their two grandsons) participated, as well. There were 15 sessions where a mother was the sole adult participating with
their child or children and 14 sessions that included both the mother and father. There were no sessions where only a father participated with his child or children.

Occupations varied among the parents and guardians in the participant families. The 29 adults who completed the online survey self-identified themselves and their spouses by declaring their job titles, which spanned across different employment sectors including professional house cleaner, professor, stay-at-home parent, commercial banker, business manager, nurse, freelance writer, self-employed, police officer, and minister. This range of jobs is reflective of the regional community in which Shaver’s Creek is located.

**Children.** There were 58 total children who participated in this study, 51 of which were in the requested age range of 6 to 13 years. The average age of the 51 children participants was 8.6 years. The gender breakdown of the 51 age-appropriate children was relatively even with 27 boys and 24 girls. There were considerably more families that participated with siblings as compared to families with only one child in attendance: twenty-two families with multiple children participated, while eight families came to Shaver’s Creek with only one child in attendance. One family included two boys who were cousins.

According to the 29 completed surveys, the majority of age-appropriate children who participated in this study attended a public school. Seven children attended a non-public school (private or charter), three were home-schooled, and one child attended a faith-based (Christian) school (see Figure 4-1).
Families’ leisure time in the outdoors

To better understand these families’ leisure experiences, several survey questions focused on family outdoor activities. Regarding their familiarity with Shaver’s Creek, two families had never been to Shaver’s Creek, while three families said they had not been to Shaver’s Creek in over a year. The majority of families (76%) responded that they visited Shaver’s Creek less than once a month in the past year, and one family visited Shaver’s Creek 2-3 times per month in the past year, which was the most frequent visiting quantity.

The survey responses also suggested that the families participating in this study were comfortable spending time in the outdoors on a regular basis. In selecting from a series of multiple-choice options, two families said they spent time outside together 2-3 times per month (7%), while three families spent time together outside once a week (10%). On a more daily basis, 11 families (38%) said they spent 2-3 days per week in the outdoors, while 13 families (45%) said they spent time outside everyday.
When asked in an open-ended response to describe the types of outdoor activities they participated in as a family, answers included: “Dad goes biking with the kids regularly when it is nice,” “Mom takes kids to parks, on walks around the neighborhood and on simple hikes,” “With her father, she goes with him to look through her telescope on clear evenings,” and “Kid LOVES bugs and is out in backyard or climbing a tree!” Commonalities across these responses are shown in Figure 4-2 with hiking, swimming, walking, and biking being the most commonly cited family outdoor activities.

![Family outdoor activities](image)

**Figure 4-2**: Survey results: Family outdoor activities.

**Families’ use of technology**

The survey also gauged the families’ ownership and use of technology in their everyday lives. First, families were asked how many computer devices they owned—this could include
desktop computers, laptop computers, mobile phones, tablets, videogame consoles, and handheld video games. Out of the 29 families that completed the online survey:

- One family owned 1-2 technological devices (3%),
- 4 families owned 3-4 technological devices (14%),
- 5 families owned 5-6 technological devices (17%), and
- 19 families owned 7 or more technological devices (66%).

In addition, all participating families except for one explicitly noted in an open-ended response that they owned a smartphone (mobile device).

The majority of children in this study interacted with technology on a daily basis in their homes (72%), while 36% interacted with technology on a daily basis at school. When asked what types of activities their children engage with on both computers and mobile devices, the parents responded that most often, their children used technology to play a recreational game, complete homework, play educational games, or take photos (Figure 4-3).

![Children's technology-based activities](image)

**Figure 4-3:** Survey results: Children’s technology-based activities.
Families’ experience with nature-based apps and using technology in the outdoors

The majority of families (23 families) indicated they had never used a nature-based app or e-fieldguide before (79%), while the remaining six families (21%) said they had experience using apps and e-fieldguides. Through open-ended responses, those six families shared that the apps helped them to identify birds (using Peterson’s Bird Guide and Audubon Birds), identify leaves (using Leaf Snap), learn about planets, participate in geocaching, and identify unknown species.

Lastly, families were asked if they had ever used technology in an outdoor setting. Twenty families (69%) selected “Yes,” while the remaining nine families (31%) selected “No.” Those who selected “Yes” shared the types of activities where they used technology in the outdoors via an open-ended question. Common responses were tallied and compiled into the following categories:

- Two families (10%) used technology in an outdoor setting to help them identify something in nature like a bird, insect, or tree,
- Four families (20%) used technology in an outdoor setting to look at constellations using a night sky app,
- Five families (25%) used technology in an outdoor setting to take photos and videos, and
- Nine families (45%) used technology in an outdoor setting to navigate and find directions through the use of maps and GPS,

The survey results revealed that over half of the participant families had experience using technology in an outdoor setting; these included maps and GPS programs to help with directions and technology for taking photos while outside. When specifically asked, families said that they had little experience using nature-based apps and e-fieldguides in general and even less so in an outdoor setting.
Based on the survey responses, the participating families were generally familiar with Shaver’s Creek, comfortable in outdoor settings, active with outdoor-based activities, and surrounded by different types of technology in their homes and at school. Although both parents and children were frequent technology users, they had less experience using technology in an outdoor setting, especially for nature-based explorations. Given these insights, the 31 families who participated in this research study experienced a novel activity when they used the Shaver’s Creek e-Trailguide during a nature walk on the Boardwalk Trail.

**Families’ overall experience using the e-Trailguide at Shaver’s Creek**

The recruitment email that was sent to families stated that, “To participate, your family must be available for 1-2 hours…” (see Appendix B). Although this was an estimate as to the amount of time families would be spending onsite at Shaver’s Creek, each family was made aware on the day of their participation that they could spend as little or as much time as they wanted with the e-Trailguide on the nature trail. In short, the families were in control of their participation in terms of the amount of time they wanted to put towards the experience and in what manner they wanted to engage with the e-Trailguide.

**Time spent on the Boardwalk Trail with the e-Trailguide**

The total amount of video footage recorded for all of the 31 families participating in this study added up to just over 40 hours: videos of the family hikes added up to almost 34 hours and the interview data totaled to about seven hours. The average time that families spent on the nature trail using the e-Trailguide was a little over one hour long with the longest family hike being 1 hour and 46 minutes long (Family #25) and the shortest hike being 44 minutes long (Family #18).

The amount of time that the families spent at each Discovery Spot and each On the Move activity was also quantified (Table 4-2).
Table 4-2: Times spent at each Discovery Spot and On the Move activity along the trail.

<table>
<thead>
<tr>
<th>Location on trail</th>
<th>Average time spent at location, in minutes</th>
<th>Shortest time spent at location, in minutes</th>
<th>Longest time spent at location, in minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discovery Spot #1</td>
<td>5:02</td>
<td>1:36 (Family 12)</td>
<td>6:11 (Family 32)</td>
</tr>
<tr>
<td>On the Move activity #1</td>
<td>0:54</td>
<td>0:37 (Family 31)</td>
<td>2:45 (Family 16)</td>
</tr>
<tr>
<td>Discovery Spot #2</td>
<td>4:23</td>
<td>0:49 (Family 12)</td>
<td>6:17 (Family 32)</td>
</tr>
<tr>
<td>On the Move activity #2</td>
<td>8:30</td>
<td>1:27 (Family 31)</td>
<td>10:07 (Family 1)</td>
</tr>
<tr>
<td>Discovery Spot #3</td>
<td>10:20</td>
<td>2:20 (Family 12)</td>
<td>19:39 (Family 26)</td>
</tr>
<tr>
<td>On the Move activity #3</td>
<td>6:50</td>
<td>1:27 (Family 12)</td>
<td>8:23 (Family 1)</td>
</tr>
<tr>
<td>Discovery Spot #4</td>
<td>2:20</td>
<td>0:13 (Family 1)</td>
<td>4:27 (Family 32)</td>
</tr>
<tr>
<td>On the Move activity #4</td>
<td>5:04</td>
<td>2:11 (Family 12)</td>
<td>11:57 (Family 29)</td>
</tr>
<tr>
<td>Discovery Spot #5</td>
<td>7:25</td>
<td>2:07 (Family 11)</td>
<td>14:29 (Family 29)</td>
</tr>
<tr>
<td>On the Move activity #5</td>
<td>2:50</td>
<td>0:30 (Family 4)</td>
<td>11:38 (Family 25)</td>
</tr>
<tr>
<td>Discovery Spot #6</td>
<td>4:27</td>
<td>0:42 (Family 5)</td>
<td>5:49 (Family 16)</td>
</tr>
</tbody>
</table>

*Note:* Times are written as minutes: seconds.

When looking at Table 4-2, several points of interest appear. Discovery Spot #3 (Juniper’s Bench)—which prompted the families to draw a tree they observed and then to identify that tree based on the leaf photographs shown in the e-Trailguide—was where the families spent the most amount of time on average (10 minutes and 20 seconds) during their nature walk experience. One family (Family 26) spent close to 20 minutes at this spot alone. Second to that was Discovery Spot #5, which also had a drawing activity; families spent an average of 7 minutes and 25 seconds at this spot. Even though both of these spots had a drawing task, the difference in time
can be ascribed to the realities of working in an outdoor environment during the summer season. While Discovery Spot #3 was in a cool, shady spot, Discovery Spot #5 was located on the boardwalk and had no shade cover, which presumably led many families to more quickly complete the drawing task at Discovery Spot #5.

On average, families spent the longest amount of time engaging with On the Move activity #2 (8 minutes and 30 seconds), where families were prompted to match various colored blocks shown in the e-Trailguide to objects in nature. It should be noted, however, that although families were highly engaged with this activity, this was also the longest stretch for walking along the trail. Secondly, families took part in On the Move activity #3 for an average of almost 7 minutes (see Chapter 3, Figure 3-5). This was more surprising as this stretch of trail was very short, yet families spent a considerable amount of time on this activity, which asked families to stay very quiet and to use their hearing and vision to observe the plants and animals around them as they walked to the next Discovery Spot. Once they arrived at the next Discovery Spot, they could share with each other the various things they heard and saw during their “quiet walk.”

Families spent the least amount of time at Discovery Spot #4, which is not surprising as this spot had minimal content in the e-Trailguide: families were asked to look at the shagbark hickory tree next to the bench and determine whether it was evergreen, deciduous, or conifer by completing a quiz (this acted as a follow up to Discovery Spot #3 where information about deciduous and evergreen trees was shared in the e-Trailguide). Likewise, On the Move activity #1—which prompted families to count how many arching trees they could see in the surrounding landscape as they walked to the next Discovery Spot—was a short experience, time-wise. Although the families worked together to count the arching trees while they walked and then came to a group consensus when they reached the next Discovery Spot, this activity did not require much collaboration or time in order to finish.
Taken together, families spent an average of 5 minutes and 39 seconds engaging with Discovery Spots along the hiking trail and an average of 4 minutes and 49 seconds engaging with On the Move activities. Given that there were six Discovery Spots and five On the Move activities, it is reasonable to assume that both types of activities were, on average, equally pursued during the families’ hikes with the e-Trailguide.

Collecting data through mixed methods in a design-based research study

Collins, Joseph, and Bielaczyc (2004) purport that examining the many elements of an educational design intervention requires both qualitative and quantitative observations. Within their proposed “Guidelines for Carrying out Design Research,” the three authors recognize the importance of applying qualitative methods of collecting data when attending to “interactions of learners with elements of the environment” (p. 35). For example, in order to capture the effectiveness of a design intervention as it plays out within the personal, social, and community interactions, ethnographic descriptions provide a practical method. While DBR studies often generate an overwhelming amount of data (Dede, 2004), it is also true that purely quantitative studies of learning would be insufficient for understanding the reasoning involved in learning (Kolodner, 2001). Therefore, utilizing both qualitative and quantitative methods in design-based research studies is a critical component of DBR.

Previous and informing data has been collected on this designated hiking trail at SCEC and has required such mixed methods. Video-based and audio recordings, surveys, and open-ended interviews have all been leveraged as fruitful methods for collecting data during previous research exploits at SCEC (e.g., McClain & Zimmerman, 2014; Zimmerman & McClain, 2014; Zimmerman, McClain, & Crowl, 2013). Video-based research has been a powerful tool for capturing the richness of both verbal and non-verbal actions of participants in this educational setting, while utilizing surveys has provided a broader set of information. Since these previous
data collection periods have been the basis for informing the design of the e-Trailguide, primacy was given to qualitative data as a means for analyzing the engagement levels and social interactions of family groups. Since I was also interested in evaluating the e-Trailguide and the potential biodiversity knowledge gains such a mobile program could cultivate, I also leveraged post-hike interviews as an important source of data that could be categorized and subsequently quantified. Table 4-3 displays the data collection methods used in this design-based research study.
Table 4-3: Mixed methods used to observe and evaluate an e-Trailguide used by families.

<table>
<thead>
<tr>
<th>Research question</th>
<th>Data collection</th>
<th>Data analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) What specific native Pennsylvania plants and animals did families learn about during their nature walk with the e-Trailguide?</td>
<td>• Post-walk interviews (reflection on the experience)</td>
<td>• Thematic analysis and quantification of post-walk interviews (reflection on experience, etc.)</td>
</tr>
<tr>
<td>2) What design features (e.g., questions, prompts, drawing activity, place-based images) within the e-Trailguide at one interactively designed Discovery Spot focused on native trees facilitated the three types of technology-mediated engagement with nature (observation, pointing, and tactile investigation) across families? a. What differences were there, if any, between patterns of technology-mediated engagement with nature among adults and patterns of technology-mediated engagement among children?</td>
<td>• Video-records • Fieldnotes</td>
<td>• Analysis and coding of videos and fieldnotes using Studiocode (technology-mediated engagement with nature and design features supporting engagement [McClain &amp; Zimmerman, 2016b]) at Discovery Spot #3.</td>
</tr>
<tr>
<td>3) When using the e-Trailguide, how did pointing-based joint observation strategies used by parents/grandparents and children support families’ science-related sense making about native trees?</td>
<td>• Video records • Fieldnotes • Transcriptions of video records</td>
<td>• Full transcription of videos from Discovery Spot #3; thematic analysis and identification of emergent themes with regards to joint observation and the role of pointing between family members.</td>
</tr>
</tbody>
</table>
Quantitative data collection supporting the study of learners’ content knowledge

One of the main goals of this research study was to closely observe and analyze the learning and interactional processes that were at play when families participated in a nature walk with the use of a mobile device containing an e-Trailguide program. However, it was also important to understand the knowledge change among individuals included in this study. Because this e-Trailguide provided rich content in the form of text, videos, and pictures pertaining to the local biodiversity in the immediate area, assessing knowledge gains was a major interest for the staff at SCEC who had supplied the information and visuals.

Post-walk interviews. Interviews with each of the family groups after their hike with the e-Trailguide provided an integral piece of data for my study (see Appendix B). Including the post-walk interviews was important for understanding the families’ content knowledge gains on an open-ended basis. These semi-structured interviews (Glesne, 2011) were 13 minutes on average and gleaned families’ reflections on their e-Trailguide experience, new concepts about the local biodiversity that they learned, and their nature-based sightings on the trail. Not only did these interviews give me an opportunity to clarify any assumptions behind observations attained during the actual e-Trailguide experience and to more completely understand the families’ intentions behind their activities on the trail, but they also allowed me to better understand any new learnings about Pennsylvania biodiversity that were gleaned from the experience with the e-Trailguide.

Qualitative data collection to understand families’ engagement with the natural world and social learning processes with each other

Microethnography (Spradley, 1980), using video-based methods (Allen, 2002; Ash et al., 2007; Derry et al., 2010), was the dominant qualitative method used in order to elucidate how family groups engaged with and talked about the natural world with an e-Trailguide. Overall,
ethnography aims to investigate and describe people through observations, fieldnotes, and
interpretation (Wolcott, 1999). Microethnography is a form of ethnography that uniquely
analyzes shorter time frames of learners’ engagement with cultural tools, allowing for a deeper
investigation into verbal, social, and physical interactions among and between individuals. It was
ideal for this research study focused on learning interactions between family members where
dialogic exchanges, patterns of engagement, and moments of joint observation were the focus.
Furthermore, documenting and analyzing discourse between parents and youth is an important
data source for understanding family learning and sense-making processes in informal learning
settings. Social dialogue between family members allows both parent and child to articulate their
individual understandings, while also permitting them to support each other as a collaborative
learning group (M.H. Goodwin, 2007; Knipfer et al., 2009; Lyons et al., 2010; Vygotsky, 1978).
In short, the application of an ethnographic methodology in this study was apt for closely
observing and describing the learning behaviors of all participating family groups as they
engaged with a nature walk using a mobile device.

Video-based techniques both from the learning sciences field (Derry et al., 2010) and
museum research field (Allen, 2002; Ash et al., 2007) were used in order to capture both verbal
and non-verbal interactions between family members during the nature walk. Video records are
advantageous to an ethnographic-based research study because they support detailed analysis of
the subjects and setting of focus, while they can also be analyzed repeatedly (Derry et al., 2010;
Glesne, 2011). In addition, video analysis may reveal insights that were not immediately obvious
during the actual period of data collection. In relation to my dissertation, video records provide a
particularly useful method for capturing the various aspects of learning as it occurs in a social
setting (Jordan & Henderson, 1995), specifically adult-child interactions as they occur in informal
learning settings (Allen, 2002; Ash et al., 2007; Derry et al., 2010).
**Video records, photographs, and fieldnotes.** Video recordings were pertinent in order to analyze general patterns and more nuanced details of the participant families’ engagement with nature as it was mediated through the e-Trailguide. Each data collection session with each family group was video recorded in its entirety. The children in each of these families were asked to wear a wireless microphone in order to record the dialogue of the family; in the event that a child preferred not to wear a microphone, an adult wore one. Children were chosen to be microphoned because they tend to have softer voices and because the adult participants tended to stay in close proximity to their children on the trail, their voices were readily picked up through the microphone. The audio from the microphones was captured by the video camera, which was monitored through headphones, in order to ensure clarity and continuity of the dialogue (Allen, 2002).

While analysis from video recording has many advantages, namely the capturing of subtle and detailed interactions between participants, one limitation to video-based techniques is the potential loss of social and physical settings’ context due to the limited video-camera range (Glesne, 2011); for this reason, detailed fieldnotes (Emerson, Fretz, & Shaw, 1995) were recorded immediately after each session while they were still recent (totaling to 31 sets of fieldnotes). Photographs taken during each session supplemented the video records, resulting in almost 2,500 photographs of the families. Additionally, 250 screenshot images were collected from the iPads after each family completed their participant time onsite at Shaver’s Creek. These screenshots were artifacts from the families’ experience using the e-Trailguide on the Boardwalk Trail and included their sketchpad widget drawings, photos taken with the in-book photo widget, and fieldnotes taken with the notepad widget.

In working with 31 families for over an hour per family, a large amount of data was collected in the form of video records and photographs (see Table 4-4). With close to 33 hours of total hiking time recorded on video, a portion of this video data—the time families spent at
Discovery Spot #3 (Juniper’s Bench)—became the focus of this study’s analysis. The total amount of video recorded of families at Discovery Spot #3 was about 5 hours.

Table 4-4: Total video and photo data collected with participant families.

<table>
<thead>
<tr>
<th>Video data</th>
<th>Collected photographs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hiking time:</strong></td>
<td><strong>Photos of families on the trail:</strong> 2,426</td>
</tr>
<tr>
<td>33 hours, 2 minutes, 52 seconds</td>
<td></td>
</tr>
<tr>
<td><strong>Interview time:</strong></td>
<td><strong>Screenshots of widgets (e.g., drawing activity,</strong></td>
</tr>
<tr>
<td>6 hours, 54 minutes, 39 seconds</td>
<td><strong>note-taking widget, photo widget) on iPads:</strong> 230</td>
</tr>
</tbody>
</table>

**Data analysis procedures**

Due to the implementation of a design-based research approach in this study, which combines qualitative and quantitative data collection protocols, the analytical procedures were correspondingly diverse. Analytical procedures for the quantitative data and the qualitative data are described in the following two sections.

**Analysis of post-hike interviews to study families’ content knowledge change**

I analyzed the post-hike interview responses in order to provide a descriptive portrayal of the families’ content knowledge gains related to the local biodiversity and new learnings about Pennsylvania wildlife. Because structured tests may not adequately describe the full account of families’ new understandings (Hoepfl, 1997), especially during an informal learning experience (Bell et al., 2009), I analyzed, thematically coded (Glesne, 2011), and quantified emergent themes that arose from the families’ post-hike interview responses that I recorded both on video and on
paper. Particular focus was given towards interview questions that resulted in family members’ responses that related to conceptual knowledge gains about the local flora and fauna.

After carefully reviewing all interview transcripts, I selected to analyze the post-hike interviews with a particular focus on three interview questions that related to new understandings about Pennsylvania species. The main question that probed the families’ content knowledge—“Was there something new you learned about Pennsylvania plants or animals? What?”—was the primary source of responses pertaining to understandings of local biodiversity gleaned from the interviews. However, I also analyzed and coded responses to two additional interview questions: a) “What was your favorite part of using the e-Trailguide on this hike today?” and b) “What was the coolest thing you saw while out on the trail?” because these two questions often elicited responses from family members where they specified new concepts or content they had learned during the hike. For these two interview questions, I only coded responses where a family member explicitly stated they had learned something new. Such statements as, “I didn’t realize that...” or “I had never really thought about that before...” or “I was surprised to see...” were identified and subsequently included in the analysis because I interpreted these statements as segues into sharing new concepts or content knowledge about local flora and fauna. Statements like 8-year old Owen’s interview response, “The coolest thing I saw on the trail was Shaver’s Creek [the physical creek] because it was hot and I wanted to jump in it!” were excluded because while they reflected on physical aspects of the landscape or wildlife observed during their nature walk, they did not reveal new conceptual understandings about these phenomena. Given these coding parameters, each participant family member’s response to these questions was coded and categorized.
Analysis of qualitative data to understand families’ engagement with the natural world and social learning processes with each other

Rich qualitative data was collected for this research study (see Table 4-4). For this dissertation project, the qualitative analysis focused on exploring the families’ engagement with nature as it was mediated by the e-Trailguide at Discovery Spot #3, Juniper’s Bench. This particular Discovery Spot was chosen as a focus of analysis due to its interactive design components and its significant revision undertakings during the three study iterations (see Chapter 3).

Coding for technology-mediated engagement with nature. To observe and determine the different types of technology-mediated engagement with nature, the video-records from Discovery Spot #3 were fully analyzed for each participant family. The videos were coded through the use of the video-analysis software, Studiocode™, which allowed me to take iterative passes through the data and pinpoint certain moments that aligned with my video codes, which are subsequently described.

Each video was coded using a pre-conceived coding framework related to the families’ interactions and engagement with the natural world as mediated through the e-Trailguide. Coding was conducted using the three types of technology-mediated engagement with nature (McClain & Zimmerman, 2016b), which were defined by the literature and refined based on iterative passes through the data. These codes were originally developed through the pilot study and subsequently applied to the current study’s analysis (see Chapter 2 for more detail). The three primary codes for technology-mediated engagement with nature included: 1) observation, 2) pointing, and 3) tactile investigation.

The coding framework, which was established from the pilot study (McClain & Zimmerman, 2016b), is summarized in Table 4-5, which includes the types of technology-mediated engagement with nature that were coded for within the videos, as well as a general
description of each type of engagement. I observed and coded each individual family member (for children, only those above 6 years old were coded) in order to get a sense of the differences in engagement between parents and children, if any. As such, these three forms of nature-technology-social engagement were used as one measurement to assess the effectiveness of the design guidelines within the e-Trailguide, while they also allowed me to identify specific design features within the e-Trailguide that especially promoted the families’ engagement-with-nature moments.

Table 4-5: Types of technology-mediated engagement with nature using an e-Trailguide (McClain & Zimmerman, 2016b).

<table>
<thead>
<tr>
<th>Types of technology-mediated engagement with nature</th>
<th>General description of engagement patterns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observation</td>
<td>“Heads up” observations indicated that learners were responding to the content in the e-Trailguide by looking out into the landscape or at a natural object closely.</td>
</tr>
<tr>
<td>Pointing</td>
<td>Pointing indicated that learners were socially and actively connecting a concept introduced in the e-Trailguide to the surrounding area or natural object located along the nature trail.</td>
</tr>
<tr>
<td>Tactile investigation</td>
<td>Tactile investigation of a natural object along the trail indicated that learners were using a hands-on approach to investigate a biological specimen introduced in the e-Trailguide.</td>
</tr>
</tbody>
</table>

During the coding process, the codes in Table 4-5 were only applied to learners’ gestures that were in direct response to information from the e-Trailguide, such as heads up motions immediately following screen gaze, pointing gestures in response to content from e-Trailguide, or physically touching a natural object to contextualize content from e-Trailguide. While there were numerous instances of looking around and pointing at objects while the families walked along the
nature trail, I only coded for these engagement moments when they looked at or pointed at a
natural object or the landscape in response to a prompt from the e-Trailguide content.

**Coding parent-child interactions.** Each family’s verbal dialogue and physical gestures
associated with their nature hike using the e-Trailguide at Discovery Spot #3 was captured
through full transcriptions produced from the video-records. In focusing on the transcripts and
video records, conversational segments\(^4\) relating to this study’s theoretical interests in family
learning processes (dialogue) and engagement with nature (gesture) were identified through
thematic analysis (Glesne, 2011). Applying a thematic analytical approach to the transcripts
allowed me to identify emergent themes within the data and compare those themes across family
groups. Once these themes were developed and categorized, relevant conversational episodes
from each transcript were re-analyzed through line-by-line coding.

Through this thematic analysis, the social act of pointing surfaced as a ubiquitous type of
engagement with nature and engagement with one another across all 31 participant families.
Given this outcome, the process of line-by-line coding centered on conversational segments that
included a family member physically pointing to a natural object in the vicinity. For example,
there were many conversational exchanges pertaining to a family group’s observations about a
tree nearby; however, because my study was interested in patterns of engagement with nature, I
only coded observation-focused conversations that included a pointing gesture. After establishing
my coding framework, I was able to deduce patterns and relationships related to joint observation
of natural objects and how parents and children coupled their dialogue with pointing as a means
to focus others’ attention on an object of interest.

\(^4\) Because this study aimed to better understand the role of device-mediated parent-child
interactions, conversational episodes were coded as the unit of analysis, rather than individual
utterances.
Methodological strengths and weaknesses of this dissertation study

A major limitation of this study was that analyses focused on engagement patterns among the family groups was confined to one of the Discovery Spots along the Boardwalk Trail. Given that the participant families visited six Discovery Spots during their time with the e-Trailguide at Shaver’s Creek, the findings reported on in this dissertation have not yet been cross-checked with the families’ engagement patterns during the rest of their nature walk experience. While this certainly limits this study’s ability to generalize beyond the design features incorporated into the e-Trailguide at Juniper’s Bench, these findings do provide a necessary starting point for understanding how mobile devices influence family learning activities in an outdoor setting.

During their participation at Shaver’s Creek with the e-Trailguide, the families were aware of the video camera and my presence as the researcher onsite. While the cameras may have influenced the families’ behavior, the study took place on a publicly accessible nature trail with other visitors to the center. Given this circumstance, the video cameras likely had as much influence on the families as did the other visitors at Shaver’s Creek. In addition, my in situ observations of the families during each of their participation periods and later analyses of the video-records indicated that the families acted within the norms of their everyday interactions with each other; the children regularly requested snacks and water breaks, parents reprimanded children’s behaviors, and siblings squabbled. Although there is a certain amount of biases in using this video-recording technique, capturing the families’ naturally occurring conversations and moment-by-moment interactions with the e-Trailguide and each other provided a rich set of data that other methods could not.
Conclusion

Leveraging a design-based research methodology was advantageous for deeply analyzing how 31 participant families (105 individuals) utilized the third iteration of an e-Trailguide during a nature hike. By combining quantitative and qualitative data collection and analysis techniques, a more thorough understanding of the families’ engagement and learning experiences while using the e-Trailguide developed. Quantitative data in the form of coded and quantified post-hike interviews, allowed me to assess the families’ overall content knowledge gains related to the local biodiversity. Video-based techniques uncovered more nuanced engagement and learning patterns between family members as they participated with the interactive content at one Discovery Spot along the trail. In short, applying a design-based research methodology to this dissertation study was beneficial for examining both across and within the families’ experience with the e-Trailguide.
Chapter 5

Families’ Content Knowledge Gains About Local Biodiversity After Using the e-Trailguide

One of my main learning objectives when designing the e-Trailguide was to improve the local biodiversity knowledge and awareness of all family members. To support this local biodiversity learning objective, I referred to research literature that highlighted the importance of grounding environmental education material in the immediate local setting (Ardoin, 2006; Giamellaro, 2013; Rivet & Krajcik, 2008; Smith, 2002; Sobel, 2004), which led to one of the e-Trailguide’s main design principles: the mobile content should be place-based (Zimmerman & Land, 2014). Consequently, I designed the e-Trailguide to include finite identification keys with place-based images of local plants and animals to support the coordination of device-based visuals with real-world observations. To assess how this place-based design work contributed to the learners’ knowledge of Pennsylvania biodiversity, I examined the 31 post-hike interviews conducted with each participant family. Specifically, I thematically coded these interviews to understand what native Pennsylvania plants and animals the families learned about during their nature walk with the e-Trailguide. As a result of this analysis of the post-hike interviews, I found that families developed a diverse collection of new understandings related to Pennsylvania plants and animals, including why trees take on an arching condition, plant and tree identification skills, and recognizing the difference between damselflies and dragonflies.
Families’ new knowledge about Pennsylvania plants and animals as elucidated through interview responses

The post-hike interviews illuminated a broad perspective of the families’ knowledge of native and non-native species that resulted from using the e-Trailguide. These interviews allowed the family members to share new knowledge about local plant and animal species, while it also gave parents and children an opportunity to reflect on their new understandings related to unique characteristics of the local biota that they observed while on the Boardwalk Trail as mediated by the e-Trailguide.

Specific wildlife content learned during the hike with the e-Trailguide

Overall, I found that families gleaned a variety of new understandings related to the local wildlife of plants and animals as a result of their e-Trailguide experience. This finding came from a total of 168 post-hike interview responses that were coded and categorized into 21 distinct categories (Figure 5-1), which were all directly connected with the content delivered from the e-Trailguide.
The concept of arching trees was the most common interview response related to families’ new knowledge about Pennsylvania wildlife. Coding the interview transcripts revealed that adults and children most often shared a new understanding with relation to why trees take on an arching behavior in nature (32 individual responses). This was a prominent theme across both adults’ and children’s interview responses as something new they learned about plant life in central Pennsylvania. The content at Discovery Spot #1 relating to arching trees was incorporated because previously observed families involved in research at Shaver’s Creek (e.g., McClain & Zimmerman, 2014; Zimmerman & McClain, 2014; Zimmerman, McClain, & Crowl, 2013) verbalized an interest in this anomaly in the landscape along the Boardwalk Trail.
As such, a main learning outcome at this Discovery Spot was for families to understand both the natural and man-made processes that occurred in previous years to cause the trees in the area to bend over and remain bent over the trail (see Appendix A). In addition, On the Move activity #1 challenged the families to observe and record the number of arching trees seen along the stretch of trail between Discovery Spot #1 and Discovery Spot #2. I posit that this unique circumstance of tree behavior and the e-Trailguide’s direct connection to this observable feature in the landscape via a brainstorming activity and a subsequent explanation as to what caused the trees to arch was something that sparked an interest among the families, leading the adults and children to share this new conceptual understanding during their post-hike interviews.

Figure 5-2: Introductory page at Discovery Spot #1 displaying image of arching tree over the Boardwalk Trail.
Families identified poison ivy and skunk cabbage as two newly learned plant species. A second piece of wildlife knowledge that was frequently cited as being a new fact that families learned about was generally classified as “plant identification” (18 interview responses) and primarily included interview responses describing new observations of plant species along the Boardwalk Trail, such as skunk cabbage and poison ivy. Families especially discussed poison ivy because it was highlighted and identified in the e-Trailguide’s introductory content as a plant species to avoid during the families’ hikes (Figure 5-3). Parents were particularly vocal (and appreciative) of being able to identify poison ivy so that they could help their children to avoid stepping into patches of poison ivy adjacent to the trail.

Alongside being able to recognize poison ivy, I posit that skunk cabbage was identified as a newly learned plant during the post-hike interviews because it was ubiquitous along the stretch of trail by the boardwalk. This self-reported new fact learned about skunk cabbage supported the utility of the e-Trailguide experience in imparting new knowledge about local species. Additionally, starting around May, skunk cabbage can become extremely large and subsequently prominent in wetland ecosystems, like the area by the boardwalk at Shaver’s Creek. Due to the large amount of skunk cabbages in this area during the summertime, I included skunk cabbage in the image list of place-based species to find during On the Move activity #4 (Figure 5-4). I included other plant identification keys within this On the Move activity, including jewelweed and wild black raspberry; however, the recognizable parts of these two plants, such as the bright orange flowers on the jewelweed and the fruit on the wild black raspberry bushes, were only noticeable towards the end of July and into early August. Given that this study took place between the months of May and August, only the families who participated towards the end of the study period would have been able to regularly observe these two species of flowering plants. Because poison ivy and skunk cabbage were two species of plants that were easily visible throughout the entire study period, I posit that they were specifically named as examples of new
plant knowledge more frequently among the families during their interviews. This further suggests that families were actively coordinating the place-based information from the e-Trailguide to their real-world observations along the nature trail.

Figure 5-3: Introductory material in e-Trailguide featuring a visual warning about poison ivy.
Figure 5-4: On the Move activity #4 featuring a list of plant and animal species to find along the boardwalk, including skunk cabbage (that I circled in red).

Families identified damselflies as a newly learned animal species. A third common category of content knowledge that families said they learned about was the difference between damselflies and dragonflies (14 interview responses). The identification of damselflies supported the efficacy of the content in the e-Trailguide for supporting new knowledge gains, particularly because the ebony jewelwing damselfly, which is a native animal species of Pennsylvania, was featured within the insect-related content during On the Move activity #5. More specifically, during their interview responses, both adults and children would share that they learned about the differences between the two insect species of dragonfly and damselfly. For example, when I interviewed the Roderick family, the dad shared that he had not previously known about damselflies, which encouraged the mom and both daughters to agree with this new learning. The mom went on to say that, “We have a creek on our property and we have damselflies, not
dragonflies. But we’ve been calling them dragonflies.” Given that insects are fleeting and not always visible on any given day, not every participant family was able to observe a damselfly and dragonfly during their hike, which may explain why this interview response was less common than the statements related to arching trees and plant identification. However, the content in the e-Trailguide pertaining to these two insect species was evidently salient enough that families recalled them during their post-hike interviews.

**Figure 5-5**: Screenshot of On the Move activity #5 featuring information about dragonflies and damselflies.

**Interview responses pertaining to new knowledge about plant species versus animal species**

An interesting outcome of the interviews with the families was that new content knowledge pertaining to plant and tree species were vocalized more often than animal species. In her dissertation work that observed parents and children during nature walks, Marin (2013)
observed that these dyads verbally attended to living organisms seen during their walks more often than any other category topic (i.e., non-living natural kinds, land and atmosphere). In looking more deeply at this category of “living organisms,” Marin found that animals, large and small, were discussed more often than plants, which is in accordance with previous research findings suggesting that children typically prefer to learn about animals over plants (cf. Sanders, 2007). My analysis of the post-hike interviews with the participant families in my dissertation study revealed the opposite trend: plants and trees were more commonly reflected on when compared to animal species. Given that the content in the e-Trailguide was relatively balanced with regards to information, activities, and visuals about plants and animals, did parents and children reflect most often on plants and trees in their interviews because they came into the study knowing very little about plants and trees and thus indicated them as new areas of learning after using the e-Trailguide? Or, were families truly more interested in the plants and trees they observed along the nature trail as compared to the animal species? Further analyses of in-the-moment talk between parents and children on the nature trail may provide a clearer understanding with regards to what the families attuned to—plants or animals—during their in situ experience with the e-Trailguide.

**Discussion of post-hike interviews and the importance of incorporating place-based educational material into outdoor-based, mobile programs**

The adults’ and children’s open-ended statements regarding their new learnings about local plants and animals provided a means for me, as the designer, to better understand what content within the e-Trailguide was salient and resonated with the families. My analysis revealed that place-based e-Trailguide content pertaining to aspects of the environment that were also regularly observable to the family groups throughout the data collection period, such as the arching trees and plants like the skunk cabbage and poison ivy, were more likely to be recalled
during the post-hike interviews than were plant and animal species that were not always visible or were only visible during a portion of the data collection period. This finding is important because it warrants the inclusion of place-based information and visuals that are seasonally current within mobile device programs in order to support learners’ observations and learning outcomes related to local biota.

**Methodological considerations for assessing family groups’ new learnings after their educational experience with an e-Trailguide**

My methodology for assessing families’ content knowledge changes after using an e-Trailguide aligns with the National Research Council’s supposition that when evaluating informal education experiences, researchers need to be aware of the “idiosyncratic nature of learning” (2015, p. 34), which accounts for new understandings that are not exclusively aligned with predetermined outcomes, such as content-specific tests. As such, I suggest that future work with families using mobile devices in the outdoors give primacy to assessments that are open-ended and self-reporting in order to extract relevant reflections about the learners’ experience, which can then be considered during design revisions. For example, I posit that the post-hike interviews with each family group provided a “safe” outlet for sharing about their experience, as compared to a more structured pre- and post-test (Bell et al., 2009). By conducting these post-hike interviews in a conversational tone and often in a relaxed, quiet area where the families could eat their lunch or snacks, I believe that the families felt comfortable sharing their learning experiences from the nature walk with me, the researcher. Given this “nonthreatening” method of assessment, families were given space to provide “unexpected and emergent outcomes” (Bell et al., 2009, p. 63) with regards to their new content knowledge facts pertaining to the local wildlife of central Pennsylvania. My work suggests that assessing educational designs with family groups in outdoor-based, informal learning spaces will glean unanticipated yet beneficial information
pertaining to the effectiveness of the mobile program’s design and related learning outcomes when open-ended interviews are conducted.

**Conclusion**

Through an analysis of the post-hike interview responses focused on the participant families’ new content knowledge gains, the efficacy of the e-Trailguide in providing local biodiversity knowledge and awareness for its learners was illuminated. Since a main learning objective when designing the e-Trailguide was to improve families’ local biodiversity knowledge and awareness through the incorporation of place-based content, I argue that this goal was achieved based on a main piece of evidence: the breadth of the families’ self-reported new understandings as expressed during the interviews. Conducting the post-hike interviews provided a beneficial piece of data as they elucidated the families’ new understandings about local wildlife, which consequently emphasizes one of the e-Trailguide’s main design principles that mobile educational material should incorporate seasonally-relevant place-based content.
Chapter 6

Family Engagement with the Natural World When Mediated by Place-based Design Features in the e-Trailguide

Directly observing plants and animals up close is an important pedagogical technique for effectively engaging learners with environmental topics in order to influence their knowledge, attitudes, and behavioral intentions regarding environmental decisions (Ballantyne, Fien, & Packer, 2001; Ballantyne & Packer, 2002). Observation is also a fundamental practice of science where learners hone their attention on certain features in the “sea of stimulus surrounding them” (Allen, 2002, p. 21) and enhance their everyday noticings by focusing on particular aspects within disciplinary contexts (Eberbach & Crowley, 2009). Consequently, one of the major design principles for the e-Trailguide was to facilitate learners’ engagement with the natural world (McClain & Zimmerman, 2016b; Zimmerman et al., 2015) via sensory exploration (e.g., observation, pointing, and tactile investigation) and opportunities to record observations through the use of drawing tools. Given this engagement objective, I systematically analyzed the video records of family interactions to illuminate how the e-Trailguide mediated family groups’ engagement with the natural world during a nature walk. The analysis of the qualitative data in this chapter relied on the application of the framework of technology-mediated engagement with nature, which was developed in my pilot study (McClain & Zimmerman, 2016b), in order to deduce the patterns of engagement among the participant families during their time on the nature trail. Previous studies have provided important design guidelines for supporting learners’ heads-up engagement (Eliasson et al., 2011; Hsi, 2002), which motivated my development of the e-Trailguide. The analysis of the participant families, which is described in this chapter of my dissertation study, adds four place-based design features aimed at engaging learners with nature
and more specifically, how these specific features facilitated families’ observations, pointing gestures, and physical investigations of the local flora and fauna.

**Four place-based design features facilitated families’ engagement with nature**

To accomplish this dissertation study’s qualitative analysis using the framework of technology-mediated engagement with nature (McClain & Zimmerman, 2016b), I coded the data for three forms of engagement (i.e., heads-up observations, pointing, and tactile exploration).

When I compared the excerpts that were coded as fostering families’ engagement with nature, four distinct *place-based design features* within the e-Trailguide’s content at Juniper’s Bench were found to enhance the learners’ engagement with nature as evidenced through the frequency of instances of observation, pointing, and tactile investigation seen across families. These four features include:

1. Place-based observational questions, such as written text in the e-Trailguide that states, “Do you see any deciduous leaves on the ground around you?” and

2. Place-based textual prompts for focusing observations, such as written text in the e-Trailguide that states, “To see the evergreen trees in this area, look closely beyond the leafy deciduous trees.”

3. Place-based drawing activities to record observations, such as using the *sketchpad widget* in the e-Trailguide to draw a picture of a tree nearby.

4. Place-based images to support identification of wildlife, such as *photographs of tree leaves* that assisted in tree identification.

To demonstrate how each of these four place-based design features in the e-Trailguide influenced the families’ engagement with nature, I provide transcript excerpts from the families’ experiences.

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5 An earlier version of this analysis with regards to the four place-based design features was presented in Avraamidou and Roth’s (Eds.) *Intersections of Formal and Informal Science* (McClain & Zimmerman, 2016a).
with the e-Trailguide in the following sections. Each place-based design feature is described with regards to how it influenced the three different types of technology-mediated engagement with nature—observations, pointing, and tactile investigations—across the families. In each exemplar, learners’ gestures are represented within double parentheses [(( ))]. *Italicized font* indicates that a learner is reading from the e-Trailguide. Double slash marks [/] indicates overlapping talk. **Bold font** is used to indicate how the interactions were interpreted using my analytical coding scheme.

**Learners’ observations of nature supported by all four place-based design features**

Overall, my analysis that connected the three types of technology-mediated engagement with nature and the design features in the e-Trailguide revealed that observation was the most common type of engagement across the families who participated in the dissertation study. Across all designed features, heads-up observations occurred on average, five times per minute, per individual (1,618 instances per 5 hours). This finding of high amounts of heads up observations aligns with the findings from the pilot study (McClain & Zimmerman, 2016b) and is important given the design strategies that were incorporated into the development of the e-Trailguide to support engagement with the outdoor learning setting and not just the mobile computer. Families’ sense making on the trails occurred when family members were facilitated by the content in the e-Trailguide to look away from the screen and look up to observe the natural surroundings, which is an outcome that the first finding demonstrates. Given that the goal of the e-Trailguide was to support families to observe plants and animals, rather than spending time on the iPad’s screen, this finding indicates the overall success of the design features within the e-Trailguide to support family learning and observation in the outdoors.

With regards to learners’ heads-up observational engagements as mediated by the four place-based design features, three subfindings emerged:
1. Place-based questions and textual prompts equally fostered adults’ and children’s heads-up observations of nature.

2. The tree drawing activity especially encouraged children’s observations of trees and other plants.

3. The place-based images used to identify native trees facilitated close-up observations and direct comparisons of the images on the e-Trailguide to natural specimens, which were key aspects of the families’ sense-making activities.

**Place-based questions and textual prompts facilitated observations of surroundings**

A first subfinding from the qualitative analysis revealed the utility of the e-Trailguide’s place-based questions and textual prompts in creating observational opportunities for family groups on a nature trail. While prior work on outdoor-based mobile device programs has only provided very general guidelines with regards to how mobile programs can be designed to engage learners with their surroundings when in the outdoors, such as “design for physical interaction with the environment in the design of the activities” (Eliasson et al., 2011, p. 12), my work found that particular design features, such as place-based observational questions and textual prompts for focusing observations, both promoted technology-mediated nature-based observations.

I noted that questions pertaining specifically to the area in which the families were located along the trail facilitated their observations of the natural biota immediately surrounding them, as exemplified in the following example with Kendra (12 years old), Whitney (9 years old), their mom and their dad:

1) Kendra: *Deciduous trees versus evergreen trees. Deciduous trees have big leaves that fall off the tree every fall then come back in the spring. Do you see any deciduous leaves on the ground around you?*

2) ((Kendra, Whitney, mom, and dad **look down at ground**))

3) Whitney: What's a dec--/
4) Kendra: //Yes, there's one (looking at ground and points down)
5) Mom: ((laughs)) Yes, you're right. There's one (looking at ground and points with toe at leaf))
6) Whitney: There's one, there's one, there's one (looking at ground and points at several leaves on ground))

The simple question, “Do you see any deciduous leaves on the ground around you?” provoked each of the family members to look at the ground where they were standing (line 2). While looking at the ground, Kendra first pointed out a leaf nearby, saying, “Yes, there’s one,” (line 4) which was confirmed by her mom who also gestured toward a leaf on the ground by pointing at it with the toe of her shoe (line 5). Whitney followed the actions of her sister and mom as she looked at the ground and repeatedly pointed at three different leaves nearby while saying, “There’s one, there’s one, there’s one” (line 6). In this example, the place-based question prompted the family of four to shift their attention to the ground in order to answer the question. Actively looking at the ground for deciduous leaves and pointing in response to the question stated in the e-Trailguide signified the family’s connection between the mobile-based content to the physical environment of the nature trail.

A second example demonstrates the utility of place-based textual prompts in also facilitating the families’ observations of the natural surroundings. One mom and her 6-year old son, Graham, were seated on the bench at Discovery Spot #3 and the mom read aloud from the e-Trailguide which prompted the family to seek out evergreen trees close by:

1) Mom: To see the evergreen trees in this area, look closely beyond the leafy deciduous trees.
2) ((Graham and mom look around the area))
3) Graham: ((turns around and looks behind the bench then looks forward again))
   Hmm. This is hard.
4) Mom: ((looks up and around)) This is a harder one.
5) Graham: ((looking straight ahead)) Ohh! I see one! ((smiles))
6) Mom: (looks in the direction where Graham is looking) Where?
7) Graham: There ((points at tree)). See out there? See that little thing peeking out?
8) Mom: ((leans in closer to Graham to look towards where he is pointing)) Ohh, I think I do see!

This prompt, which aims to connect the information about evergreen trees in the e-Trailguide to observations of the physical setting, stated where to look to see evergreen trees, as read by Graham’s mom in line 1. Immediately following this cue, both Graham and his mom began to look around from their spot on the bench (lines 2-4). After several moments of seeking to find an evergreen tree, Graham focused his attention on one spot in the landscape and announced, “Ohh! I see one!” (line 5), which resulted in his mom averting her attention in the direction where Graham was looking and asking her son, “Where?” (line 6). When Graham gave verbal directions and pointed towards the tree he had found (line 7), his mom leaned in closer to him to coordinate her observations with his, and confirmed that she also saw the tree (line 8). Similar to what was seen when families were cued by the place-based questions, as in the section above, place-based textual prompts for focusing observations were equally effective for fostering families’ observational coordination between the content in the e-Trailguide to the natural features within the landscape. Overall, these findings advance prior suggestions that question-posing strategies may support family interactions during mobile learning activities (Knipfer et al., 2009; Lyons et al., 2010) by demonstrating that both questions and textual prompts, when they are place-based, or anchored to features viewable in the physical learning setting, foster adults’ and children’s heads-up observations of nature.

**Drawing activity especially encouraged children’s observations of nature**

My second subfinding from the qualitative analysis of the video data is that the e-Trailguide’s drawing activity especially encouraged children’s observations of trees and other
plants. This is important because creating observational records of real-world observations has been identified as an important means for enhancing children’s scientific observation skills (Eberbach & Crowley, 2009; Fox & Lee, 2013). For instance, Fox and Lee (2013) argue that when children are given opportunities to draw what they are observing around them, their analytical skills, such as spatial visualizations, increase and their ability to describe factual information based on their scientific observation improves. In this way, the drawing task moved the children participating in my study beyond just noticing their surroundings to more deeply observing particular aspects of the environment.

To illustrate how the drawing activity resulted in numerous instances of heads up observations of plants among children in my dissertation study, consider the following example of Clara (11 years old) and her brother Zak (9 years old). Clara and Zak participated with their mother on the trail. Clara took the lead with the drawing activity in the e-Trailguide. After she read the instructions for drawing a tree, she appointed herself to be the lead drawer. As she drew, Clara sat on the ground in front of her chosen tree and was soon joined by her brother (Figure 6-1). This example shows how the drawing activity facilitated observations of the native trees proximal to Juniper’s Bench for both Zak and Clara:

1) (Clara looks up at tree and Zak sits down on ground next to her))
2) Clara: (looks down at iPad and draws) Then it goes like vooop (moves finger along iPad screen to draw a branch)
3) (Clara looks up at tree)
4) Clara: (looks down at iPad to draw) This.
5) (Clara looks up at tree)
6) Clara: (looks down at iPad to draw) And then over here... (looks up at tree)
7) Zak: Which one's that? (looks at trees in front of them)
8) Clara: (looks down at iPad to draw) Well, you can guess when I'm done (laughs), see if I'm good at it.
In this example, Clara was in a constant state of looking up at the tree she was drawing (lines 1, 3, 5, 6) and then looking back down at the iPad screen to draw certain features of the tree (lines 2, 4, 6, 8). She talked to herself—loudly enough so that her brother could hear her—as she drew parts of the tree, like the branches (line 2: “Then it goes like vooop”), and seemed to follow a pattern of looking up to observe details of the tree before adding a new element to her drawing. When Zak asked her, “Which one’s that?” and looked at the stand of trees in front of them, Clara told him that he “can guess” once she had finished the drawing. Clara suggested that she would be able to measure how “good” she was at drawing the tree if her brother could guess the correct tree when she was done. In this example, Clara was heavily involved in the drawing task, with Zak as an observer of the activity. Clara worked on the drawing task for about 3 minutes and 40 seconds—within this time period, she looked up at the tree 36 times. This high frequency of heads up observations in a short time frame bolsters the ability of the drawing activity, as one design feature in the e-Trailguide, to support numerous instances of heads up observations among the children as they coordinated their tree sketches with a real tree in the natural setting.
Figure 6-1: Clara and Zak sit on the ground together as Clara observes and draws a tree in the e-Trailguide.

Clara and Zak were only two examples of how many of the participant children engaged in science observations when mediated by the drawing task in the e-Trailguide. Overall at Juniper’s Bench, there were 874 instances of engagement through observation among the children and 744 instances of engagement through observation among parents (Table 6-1). I posit that this trend resulted because children were the primary drawers using the sketchpad widget at Juniper’s Bench. In their review of the literature related to children and scientific observation, Eberbach & Crowley (2009) argue that in out-of-school settings, children often relinquish the responsibility of recording observational data to parents; Gleason and Schauble’s (2000) research in a children’s museum in the Midwest United States documenting parent-child interactions during an experiment-based activity also supported this notion. However, with the e-Trailguide at Juniper’s Bench, children were the primary recorders of observation through their use of the sketchpad widget. In fact, in all 31 families, children put themselves in charge of drawing a tree when presented with the opportunity, sometimes allowing parents to briefly add to the picture. As a result, the children’s moments of observation increased dramatically as they focused on that
particular tree and capturing its details in the drawing. When the data was analyzed more closely with regards to the types of engagement with nature occurring around the drawing task alone, there were 367 instances of observation among children and 289 among the adults. As such, this design feature of the sketchpad widget and associated drawing activity accounted for the largest discrepancy in instances of observation between parents and children. Overall, the sketchpad widget was one design feature in the e-Trailguide that was particularly successful for engaging children with observing native trees within the natural setting and subsequently representing their observations of the trees through a drawing activity.

Table 6-1: Instances of technology-mediated engagement with nature through observation across 31 family groups.

<table>
<thead>
<tr>
<th></th>
<th>Instances of technology-mediated observations of nature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adults</td>
<td>744 (46%)</td>
</tr>
<tr>
<td>Children</td>
<td>874 (54%)</td>
</tr>
<tr>
<td>Total</td>
<td>1,618</td>
</tr>
</tbody>
</table>

Place-based images to support identification of biota encouraged families’ close-up observations of trees

A third subfinding of the qualitative data was that close-up observations and direct comparisons of the images in the e-Trailguide to natural specimens were key aspects of the families’ sense-making endeavors. Motivated by the learning objective to provide biodiversity content for families who used the e-Trailguide and in response to prior research with families at Shaver’s Creek, which suggested that families needed a more manageable system for identifying local wildlife (Zimmerman & McClain, 2014), I included place-based images of tree leaves as a follow-up to the tree drawing task. Incorporating these place-based images within the third iteration of the e-Trailguide’s content at Juniper’s Bench resulted in families participating in a
heightened level of observation where they would often go right up to a low-hanging tree branch to compare the images on the iPad to the actual tree leaf. This finding about close-up observations was important because it most often went hand-in-hand with parent-child learning talk related to the identification of a tree species based on the physical characteristics of the tree’s leaves.

A typical example of how this happened occurred in one family of four that included a mother, father, and two brothers, Jeremiah (age 8) and Samuel (age 6), were standing beneath a tree that Jeremiah had previously drawn and actively trying to identify the tree species. The mother was holding the iPad at a level so that everyone in the family could see the tree leaf images throughout the activity:

1) Mom: ((looking at iPad)) So which of these…? ((points to image on iPad screen)) Does it look like that?
2) Samuel: ((looking at iPad)) Yeah! Yeah.
3) Jeremiah: ((looks at image on iPad then looks up at tree)) No. It's fat- fatter.
4) Samuel: ((looks at tree)) Yeah, fat.
5) Jeremiah: ((looking at iPad)) The one next to it. Yeah, that one. Has to be that one. ((looks at tree))
6) Mom: ((looks up from iPad screen to look at tree)) Well, but ((looks down at iPad screen and points to image on screen)), this is one leaf per stem.
7) Jeremiah: ((looks at iPad then looks up to tree)) Ohhh.
8) Mom: ((looks at iPad and points to image on screen)) And look- look at this one again.
9) Jeremiah: ((looks at image on iPad then looks up to tree)) Yeah.
10) Mom: ((points at image on iPad screen while looking up at tree)) This is multiple leaves per stem.
11) Dad: ((looks at tree)) Yeah it's a white ash ((looks down at iPad)).
12) Jeremiah: ((looks at tree)) Yeah it's a white ash ((looks down at iPad)).

In this transcript excerpt, the mom prompted the rest of the family members to look at the images of the tree leaves displayed in the e-Trailguide and asked, “Does it look like that?” (line 1). Although Samuel immediately responded with a “Yeah!” (line 2), Jeremiah looked at the tree leaf
image shown on the iPad, then up to the tree and observed that the leaf on tree he had drawn was “fatter” than the leaf image shown in the e-Trailguide (line 3). Jeremiah then suggested, while looking at the images in the e-Trailguide, that, “it has to be that one” (line 4). His mom responded by looking up at the tree then down to the images on the iPad screen and referred to one tree leaf image as having “one leaf per stem” (line 6). In line 7, Jeremiah looked again at the tree and comprehended his mom’s observation (“Ohhh”). The mom then pointed to another image on the iPad screen and encouraged the family members to “look at this one again” (line 8) because it had “multiple leaves per stem” like the leaves on the tree they were looking at (line 10). Both the dad and Jeremiah looked up at the tree and agreed with the mom’s observation, announcing that they had identified their tree as being a white ash (lines 11-12). In summary, this tree identification activity, as mediated by the place-based images included in the e-Trailguide, provided an opportunity for multiple families, in addition to Jeremiah and his parents, to engage with deep levels of observation. Across the families, rich sense-making dialogue accompanied close-up observations of trees as families worked together to name the tree species in the area.

Learners’ pointing gestures to natural objects supported by all four place-based design features

A second finding from my video analysis revealed that a second form of technology-mediated engagement with nature, pointing, acted as a social means for families to make sense of what they saw on the trails. Pointing, or intentionally gesturing to plants and animals along the trail) occurred at a relatively high rate of twice per minute, per individual (474 instances per 5 hours), second in comparison to the 1,618 instances of observation. This pattern indicates that family members were frequently engaging each other with the natural setting by actively using pointing gestures to coordinate the questions, prompts, drawing activities, and place-based photos for identification from the e-Trailguide to their physical surroundings. While less frequent than
moments of observation, pointing was an important interaction between adults and children that signaled a social type of engagement whereby the person who pointed did so in order to orient someone else’s observations to a natural object nearby (McClain & Zimmerman, 2016b). I posit that pointing indicated a heightened level of engagement with nature as it demonstrated that families were actively observing and describing to each other where something was located. A more detailed analysis related to the role of pointing to achieve joint observation between family members is provided in Chapter 7.

With regards to learners’ engagement with nature through pointing gestures as facilitated by the four place-based design features, four findings emerged:

1. Overall, adults pointed to natural objects more often than children while at Juniper’s Bench.
2. Place-based questions and textual prompts provoked parents and children to point out certain features of the landscape as a mode of response to the prompts.
3. The tree drawing activity prompted parents to point most often during their time at Juniper’s Bench.
4. The place-based images used to identify native trees encouraged parents and children to engage with joint sense making by communicating their ideas both verbally and through corroborating pointing gestures.

**Adults pointed to natural objects more often than children**

A compelling subfinding about pointing was that the parents and guardians participating in this research study pointed to natural objects more often than children. For example, the adults had a combined total of 277 instances of pointing at Juniper’s Bench, while the children had a combined total of 197 instances of pointing (Table 6-2). I attributed this trend to the prevalence of parents/guardians to adopt a teacher-like role during the families’ time on the nature trail, which
has been similarly observed among family groups in other informal learning settings like museums (Crowley et al., 2001; Crowley & Galco, 2001; Gleason & Schauble, 2000; Swartz & Crowley, 2004; Zimmerman, Reeve, & Bell, 2008). Similar to the pilot study where counselors emerged as being critical role-players in connecting the e-Trailguide’s content to the local nature trail for the campers (refer to Chapter 3), the adults in this family-based study assumed similar roles. The parents actively assisted in their children’s learning by pointing out a tree or leaf to bridge the e-Trailguide’s information about trees to the real world around them.

Table 6-2: Instances of technology-mediated engagement with nature through pointing across 31 family groups.

<table>
<thead>
<tr>
<th></th>
<th>Instances of technology-mediated pointing to nature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adults</td>
<td>277 (58%)</td>
</tr>
<tr>
<td>Children</td>
<td>197 (42%)</td>
</tr>
<tr>
<td>Total</td>
<td>474</td>
</tr>
</tbody>
</table>

Place-based questions and textual prompts elicited families’ pointing gestures to trees

Place-based questions and textual prompts were not only useful for engaging families to look up and observe their surroundings, but an important subfinding from my analysis was that these two design features provoked parents and children to point out certain features of the landscape as a mode of response to the prompts. As discussed in the previous section, parents often leveraged pointing to assist their children in coordinating the information contained in the e-Trailguide with real-world observations. For example, the question, “Deciduous trees have big leaves that fall off the tree every fall and then come back in the spring. Do you see any deciduous leaves on the ground around you?” provided an opportunity for family members to first turn their attention to the ground to find a leaf, which invariably led to someone (or sometimes multiple
people simultaneously) pointing to a leaf and verbalizing their affirmative response to the prompt. In one example of how this place-based observational question facilitated a parent-led learning moment involving pointing, Maureen and her daughter, Nancy (age 6), were sitting on the bench at Discovery Spot #3 and Maureen had just read the question from the e-Trailguide out loud:

1) Maureen: ((points to trail)) We saw some over there ((Nancy looks to where her mom is pointing)), right where we were doing our colors [for On the Move activity #3], there were some on the ground…that had fallen.
2) Nancy: Mm hmm.
3) Maureen: ((points to the ground)) What about those there? Those green leaves that fell off the tree ((points again)).
4) Nancy: ((looking to where Mom is pointing)) Yeah, look at that.
5) Maureen: ((looks back at iPad screen)) So that's from a deciduous tree.

After reading the place-based observational question related to deciduous leaves, Maureen first pointed back to the nature trail that they had just come down (Figure 6-2) and reminded Nancy that, “We saw some over there,” referring to leaves that they had together investigated during their previous color-matching On the Move activity (line 1). Maureen then redirected Nancy’s attention to the area nearest them by pointing to leaves on the ground next to the bench they were sitting on and asked her, “What about those there?” She then described what exactly she was looking at by pointing for a second time and saying, “Those green leaves that fell off the tree” (line 3). Nancy affirmed her mother’s observation in line 4 when she looked at the leaves to which her mother was pointing and responded, “Yeah, look at that.” Maureen concluded the activity by reiterating that those leaves were “from a deciduous tree” (line 5), which she had previously read about in the e-Trailguide. For Maureen, pointing was an important means of communicating to her daughter as it aided her in connecting the e-Trailguide’s content about deciduous trees with the real leaves on the ground at Juniper’s Bench. Maureen took on a teacher
role with her daughter during this learning moment, as evidenced through her pointing and associated verbal cues.

Figure 6-2: In response to a place-based question in the e-Trailguide, a mom, Maureen, points to a spot on the trail to help orient her daughter’s attention to deciduous leaves that had fallen.

While parents most often exhibited instances of pointing as a means for directing their children’s attention to the natural space surrounding them, there was no discernible pattern between parents with younger kids versus parents with older kids at Juniper’s Bench. Parents with an 11-year old were just as likely to leverage the act of pointing in order to connect information from the e-Trailguide to a nearby natural species, as were the parents of a 6-year old. For example, the exchange between Nancy and Maureen featured above was characteristic of the parent-child dynamics observed among all of the 31 participating family groups. Overall, pointing coupled with dialogue provided important sense-making moves, especially for parents, in order to bridge content from the e-Trailguide to associated natural features within the learning setting.
Drawing activity resulted in the highest amount of pointing for adults

A fine-grained video analysis where I examined each video excerpt multiple times found that the tree drawing activity engaged parents to point most often during their visit. To illustrate this finding, I provide a transcript excerpt from a family of six: a mother, father, two sisters, Alexa (age 9) and Olivia (age 7), and two brothers, Hugh (age 5) and Christian (less than 1 year old). The children, with the exception of baby Christian, each contributed to the drawing. While each child took their turn drawing, the mother often engaged the other children by pointing out and discussing relevant features of their chosen tree. The following exchange between the mom and the older daughter, Alexa, took place as Olivia, the younger daughter was adding to the family’s tree drawing:

1) Mom: ((points to tree)) What kind of bark does it have? Is it smooth? Or rough? Remember?
2) Alexa: ((looks at tree)) Rough.
3) Mom: We've talked about that in school, right?
4) Alexa: Rough and smooth bark.
5) Mom: And then ((points at tree)), are the branches symmetrical or asymmetrical?
6) Alexa: ((looks at tree)) Uhh, symme- symmetrical?
7) Mom: They do look symmetrical don't they?

In this episode, one child was drawing a tree the family had chosen, thus providing the mother with an opportunity to engage another of her children in observing specific features of that particular tree. In line 1, the mom first pointed to the tree to focus Alexa’s attention and asked, “What kind of bark does it have?” Alexa observed the tree and answered that the tree’s bark was “rough” (line 2). Her mom reminded Alexa in line 3 that they had “talked about that in school” (meaning their home-school lessons of which these children attended). The mom next pointed out a second feature of the tree and quizzed Alexa by asking “are the branches symmetrical or asymmetrical?” (line 5), which prompted Alexa to look at the tree again. Alexa suggested that the
branches were symmetrical (line 6). This exchange between Alexa and her mother was typical of the parent-child interactions during the drawing activity that resulted in engagement with nature through pointing and was a particularly salient pattern among the parents in this study.

While the children tallied the most instances of heads up observations during this drawing activity (as discussed in an earlier section), I posit that because the parents were not the primary drawers during this activity, they had more opportunities to point out features of trees. As is a common pattern during family learning moments in informal education spaces (Crowley et al., 2001; Crowley & Galco, 2001; Gleason & Schauble, 2000; Patrick & Tunnicliffe, 2013; Rigney & Callanan, 2011; Swartz & Crowley, 2004; Zimmerman, McClain, & Crowl, 2013; Zimmerman, Perin, & Bell, 2010; Zimmerman, Reeve, & Bell, 2008), parents took on a teacher-like or naturalist-like role during their time on the nature trail where they made suggestions to their children about what to include in the drawings. In summary, parents did not always directly contribute to the tree sketches by physically drawing on the iPad, but they did participate in the family’s sense making moments by pointing out particular features of the trees for their children to record in their drawings.

**Pointing aided families’ efforts to identify trees as mediated by the place-based images**

In order to complete the tree identification task at the end of the content at Discovery Spot #3, parents and children worked together by communicating their ideas both verbally and through corroborating pointing gestures. This subfinding of the role of joint sense making is important because Eberbach and Crowley (2009) argue that in order for children to learn to observe scientifically, they need to participate in shared practices, especially shared conversation. In my iterative analysis of the families’ video records, a pattern emerged where children not only participated in these shared conversations through dialogue, but they also leveraged pointing to support their assertions about a tree species. Pointing was used to connect learners’ observations
about nature to the statement they made. In one such example with the Roderick family, the youngest daughter, Whitney, had just completed her drawing of a tree at Juniper’s Bench and her older sister, Kendra, sat down on the bench next to Whitney to read the next activity’s directions: *Now that you’ve drawn your tree, can you identify what kind it is by looking at the leaves?* These instructions prompted all four family members to subsequently huddle around where Whitney and Kendra were sitting in order to view the tree leaf images displayed in the e-Trailguide. The following collaborative exchange took place as the family worked together to identify Whitney’s tree:

1) Whitney: ((looking at iPad)) It's not, I don't think it's American basswood.  
2) Mom: ((looks up and points to tree)) Oh, I think it's American basswood ((looks down at images on iPad))  
3) Kendra: ((turns body on bench and points behind)) I think the one behind us is American basswood.  
4) Mom: ((turns and looks to wear Kendra pointed)) Oh yeah, I think you're right.  
5) Kendra: ((looks down at iPad)) And then the one she drew is sugar maple.  
6) Mom: ((looks down at iPad)) Oh, okay!  
7) Whitney: ((Looks up and points to tree)) No, it has circle leaves, Kendra, it doesn't have a sugar maple/  
8) Kendra: ///((looks up and points to tree)) Oh, you drew that one! That would be... ((looks down at iPad))  
9) Mom: ((looks up at tree then down to images on iPad)) That's either the oak or the basswood  
10) Kendra: ((looking at iPad)) I think it's basswood.

While these problem-solving exchanges regularly occurred in all families, this transcript excerpt was especially rich with engagement moments that were mediated by the content displayed in the e-Trailguide. Together, the family referred to the tree leaf images in the e-Trailguide to first determine if the tree that Whitney drew was an American basswood. Whitney did not think the tree was an American basswood (line 1), but her mother looked up and pointed at the tree...
contending that it was an American basswood (line 2). As a point of comparison, Kendra turned her body and pointed to a tree located behind the bench that she suggested was an American basswood (line 3). The mom followed Kendra’s pointing gesture to observe the tree behind the bench and affirmed Kendra’s observation (line 4). In line 5, Kendra referred to the tree leaf images displayed in the e-Trailguide to propose that Whitney’s tree was a sugar maple. This statement compelled Whitney to point up at her tree and argue that her tree was not a sugar maple because “it has circle leaves” (line 7). Through Whitney’s pointing gesture, Kendra was able to align her observations with the correct tree, as evidenced in line 8, when she pointed at the tree and conceded, “Oh, you drew that one!” The mom looked up at Whitney’s tree then down to the images displayed on the iPad screen and suggested, “That’s either the oak or the basswood” (line 9), to which Kendra replied, while also observing the tree leaf images, “I think it’s the basswood” (line 10). During the conversational exchanges between Kendra, Whitney, and their mother, pointing was leveraged in order to support observational claims, as evidenced by Kendra in line 3, and to re-orient family members to certain physical characteristics of the tree, as evidenced by Whitney in line 7. Overall, this vignette provides an example of how families were supported by the place-based images in the e-Trailguide to more closely observe the trees that surrounded them and participate in collaborative sense making, as evidenced through their verbal assertions and corroborating pointing gestures.

**Learners’ tactile investigations with plants supported by two of the place-based design features**

The third major finding from my video analysis pertaining to technology-mediated engagement with nature revealed that engaging with nature via tactile investigations were the least common type of engagement across the families in my dissertation study. Instances of tactile investigation occurred about one instance per 31 minutes (93 instances per 5 hours) and only
accounted for 4% of all types of technology-mediated engagement with nature (Table 6-3). I attribute this subdued level of tactile investigations to the fact that the content at Juniper’s Bench did not have explicit instructions or guidance about engaging with a hands-on activity. Given this lack of direct prompting, it is not unexpected that there would be low instances of tactile investigations. Nevertheless, the families did physically engage with trees and other plant specimens at Juniper’s Bench, although these occurrences were significantly less frequent when compared to how often they engaged with heads-up observations and pointing gestures. This suggests that with articulated directions, families’ instances of tactile investigations have the potential to increase in number and is therefore worth further exploration.

Regarding the role of the four place-based design features in prompting learners’ moments of tactile investigation with natural objects, three findings emerged:

1. Overall, only two of the four place-based design features—the drawing activity and the tree identification activity—facilitated tactile investigations of plants.
2. The tree drawing activity resulted in the most instances of adults’ tactile investigations.
3. The place-based images used to identify native trees prompted children to engage with tactile investigations most often.

**Tactile investigations supported by the drawing activity and the tree identification task**

A first subfinding related to tactile investigations at Juniper’s Bench revealed that these hands-on learning moments most often coincided with the later drawing activity and the tree identification task, while they rarely, if ever, occurred as a result of the place-based observational questions or place-based textual prompts for focusing observations, which were presented earlier at Discovery Spot #3. This suggests that the more time families spend with an outdoor activity, the more likely they are to engage more deeply with natural objects via hands-on exploration.
This conjecture aligns with previous museum research arguing that longer “dwell time” results in more meaningful engagement with exhibits (Humphrey & Gutwill, 2005; Yoon et al., 2012). In fact, during my pilot study (McClain & Zimmerman, 2016b), the three types of engagement—observation, pointing, and tactile investigation—occurred hierarchically in a stepwise pattern across the summer campers. If engagement with nature through tactile investigation was achieved by a summer camper, they tended to follow a specific order of engagement starting with heads up observations, then pointing, and lastly engaging with an object through a hands-on investigation. In my dissertation study, the family learning groups seemed to follow a similar stepwise pattern of engagement with nature that progressed from observation to pointing to tactile investigation.

Table 6-3: Instances of technology-mediated engagement with nature through tactile investigation across 31 family groups.

<table>
<thead>
<tr>
<th></th>
<th>Instances of technology-mediated tactile investigations with nature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adults</td>
<td>51 (55%)</td>
</tr>
<tr>
<td>Children</td>
<td>42 (45%)</td>
</tr>
<tr>
<td>Total</td>
<td>93</td>
</tr>
</tbody>
</table>

**Drawing activity resulted in highest amount of tactile investigations for adults**

A second subfinding was that the most instances of adults’ tactile investigations occurred as a result of the families engaging with the e-Trailguide’s drawing activity. Similar to what was found with regards to high amounts of pointing among parents during the drawing activity because the children were most often the lead drawers, parents also had more opportunities to engage with tactile investigations during this particular activity. Specifically, there were 23 instances of tactile investigations among adults and 5 among the children during the drawing activity. As with the adults’ instances of pointing while the children drew, adults also engaged with tactile explorations of trees in order to target a child’s attention to certain features of a tree to
be incorporated into the child’s drawing. For instance, while Alice (age 7) drew a picture of a sugar maple, her mom walked over to the tree and physically placed her hand on a part of the tree in order to call Alice’s attention to the unique feature:

1) Mom: Hey, Alice ((touches tree and looks back at Alice)), one thing I've noticed about the tree- it has a big gash on it right here ((finger touches and moves upwards along gash on side of tree)).
2) ((Alice looks up from drawing at tree))
3) Duncan: From what?
4) Mom: I don't know ((touches gash on tree))…maybe something damaged it when it was younger.

In line 1, the mom in this example directed her comment about a gash in the tree to Alice, who was in the midst of drawing the tree, yet the only response Alice provided was an upwards glance from the iPad to the tree (line 2). However, her younger brother, Duncan (age 4), stood next to his mom and proceeded to inquire what caused the gash in the tree (line 3) which prompted the mom to touch the gash in the tree again and concede that she did not know, but that “maybe something damaged it when it was younger” (line 4). Although Alice did not directly acknowledge her mother’s comment and associated physical investigation of the gash on the tree, Alice’s final drawing did incorporate the gash, as evidenced by her final drawing and her father’s later description of the picture, “She’s got the lichen on the left side and the scar [gash] and the blue blaze.” In her drawing (Figure 6-3), which features an upright tree with branches curving down to the right, the dark brown gash is visible just below the bluish-gray blaze that is painted on the tree as a trail marker. This episode documented one way in which the drawing activity fostered a moment of tactile investigation for a mother who wanted to focus her daughter’s attention to a certain part of the tree she was drawing. As a result, Alice’s final drawing included the gash that her mother had called attention to through tactile investigation. In summary, parents’ tactile investigations were one means of engaging with their children during the drawing activity in
order to focus the child’s attention on a specific feature of a tree so that it could be further
captured within the family’s drawing.

Figure 6-3: Alice’s drawing of a sugar maple that included a “gash” in dark brown (that I
indicated with a red arrow) that her mother had called attention to through tactile investigation.
Place-based images to support identification of biota prompted children to most often engage with tactile investigation

The video analysis revealed that children engaged with tactile investigations most often during the tree identification task. The video analysis revealed that children engaged with tactile investigations most often during the tree identification task. During this activity, there were 15 instances of tactile investigations among the children and 9 among the adults in the study. The following episode features the McAllister family—a father and mother, their son, Eddie (11 years old), and their daughter, Nicole (6 years old), as an example of this learning interaction. The family had just completed their group drawing of a tree. Eddie took over the iPad after they finished their drawing and read the following prompt: *Now that you've drawn your tree can you identify what kind it is by looking at the leaves?* All four family members participated in the tree identification activity and in particular, Eddie and his mother both engaged with tactile investigation of the tree’s leaves in order to more closely compare the actual leaves to the leaf image displayed in the e-Trailguide. This excerpt is illustrated below:

1) Mom: ((showing Nicole the photos in the e-Trailguide)) These are the choices, okay?
2) Nicole: ((looking at iPad)) I think it's that ((points at image displayed in the e-Trailguide))
3) Mom: This one? ((points at image displayed in the e-Trailguide))
4) Eddie: ((reaches up to grab the branch of tree and pulls it down so family can see the leaves more closely)) It's this- this one.
5) Nicole: I think it's that one ((pointing at iPad screen))
6) Mom: ((looks up at maple tree and points to it)) You think this tree- when you look at these leaves ((reaches out to take hold of the branch that Eddie has pulled down towards them)), look at that shape, okay?
7) ((Nicole looks at tree))
8) Nicole: Okay ((reaches for iPad)) Daddy, I wanna see ((looks at iPad)).
9) Eddie: This is the one that we attempted to draw. Yeah, I'm pretty sure it's a sugar maple.
10) Mom: ((still holding onto branch)) It's like the- it's like the type of leaf that's on the Canadian flag.

11) Dad: Oh ((points at iPad)) you can take a picture.

12) Mom: ((let go of branch then reaches back up to branch to pull it closer)) You wanna take a picture of the leaves, Nicole? We can hold it for you.

13) Eddie: ((holding onto branch)) Here, I can hold it down.

14) Mom: ((lets go of branch)) Okay.

The mother, Sandy, and the son, Eddie, both engaged with a tactile investigation of the tree they had previously drawn as a family (Figure 6-4). While Nicole was attempting to match one of the photos from the e-Trailguide with the leaves from the tree their family had drawn (line 2), Eddie assisted her in observing the tree’s leaves more closely by reaching up and pulling the branch down closer to her (line 4). In line 5, the mom looked at and pointed to the tree’s leaves while explaining to Nicole how to compare the images in the e-Trailguide to the real leaves. She interrupted her dialogue to pull the branch closer to Nicole and instructed her to “look at that shape.” Eddie suggested that they had drawn a sugar maple (line 9), but his dad noticed that there was an option to take a photo through the e-Trailguide (line 11). In line 12, the mom offered to hold the branch down towards Nicole so that she could take a picture. Eddie told his mom that he could hold the branch down for his sister (line 13) and the mom acquiesced (line 14). As previously discussed, the content at Juniper’s Bench did not have specific instructions with regards to hands-on activities; however, this family, along with others in the study, manipulated a variety of natural objects, like tree branches and leaves in order to more deeply observe or examine the specimens at this spot along the trail. In the example with the McAllister family, the act of manipulating the physical setting was a guided participation process (Rogoff, 2003) whereby Sandy and Eddie supported Nicole’s observations of the tree’s leaves. This facilitation process coincides with previous family learning research at Shaver’s Creek without mobile
technologies (Zimmerman & McClain, 2015), where a grandmother and mother actively “rearranged” plants along the trail to support the children’s observations of flower buds.

Figure 6-4: Eddie (red shirt) and mother, Sandy (green shirt), from the McAllister family, both engage with nature through tactile investigation while using the place-based photos in the e-Trailguide to identify the tree they had drawn.

As demonstrated by the excerpt with the McAllister family, I found that the place-based tree leaf photos featured at Discovery Spot #3 supported families to make tactile investigations of leaves in order to complete the tree identification task. Because prior work at Shaver’s Creek illuminated the frustration that can stem from being unable to identify wildlife on the trail while using the cartoon drawings shown in many paper-based field guides (Zimmerman & McClain, 2014) and because a major design principle aimed to facilitate families’ engagement with the natural world, the leaf photographs included in the e-Trailguide at Discovery Spot #3 were collected from the actual trees at that spot. Overall, I found that the place-based images were
helpful references especially because families could hold the iPad with the displayed image directly next to a real leaf to make a direct comparison. Additionally, I posit that these place-based images supported families to successfully identify the tree species as evidenced by the fact that about half of the families that participated went beyond simply identifying the tree they had drawn, as the e-Trailguide instructed, in order to seek out all six of the tree species displayed in the images.

Discussion of families’ technology-mediated engagement with nature as facilitated by the four place-based design features

In developing the e-Trailguide, a primary goal was to facilitate engagement with the natural world (McClain & Zimmerman, 2016b; Zimmerman et al., 2015), thereby preventing an entirely heads-down experience (Hsi, 2002; Lyons, 2009). The qualitative analysis presented in this chapter demonstrated how four specific design features within the e-Trailguide supported this goal by facilitating 31 families to engage with nature as evidenced through their high frequencies of observations and pointing, and their infrequent, yet contributive acts of tactile investigation. Using an in-depth microanalysis at one Discovery Spot, Juniper’s Bench, key constructs about learning and engagement were refined that can advance the field’s understanding of how mobile devices can facilitate learning in informal education spaces.

In each of the previously shared data excerpts, specific place-based design features within the e-Trailguide were catalysts for the families’ engagement moments: (a) place-based observational questions, (b) place-based textual prompts for focusing observations, (c) place-based drawing activities for recording observations, and (d) place-based images to support identification of wildlife. Prior research focusing on how to facilitate place-based learning in outdoor environments using mobile computers has recommended organizing the mobile content to connect with the local ecosystem, using images to amplify learners’ observations of biota.
within their community, and providing opportunities to develop artifacts of local species through photographs or other means of data collection (Zimmerman & Land, 2014). Building from this work, my analysis provides evidence for how four design features can promote engagement with nature. Simple place-based questions and textual prompts facilitated families’ engagements with nature through heads up observations of the landscape and pointing gestures to natural objects of interest, while a place-based drawing activity and place-based images used for identification were both effective methods for enabling all three types of technology-mediated engagement with nature, including tactile investigation.

**Conclusion**

In setting out to answer one of my dissertation research questions related to engagement patterns among family groups as a result of using the e-Trailguide and specific design features within the e-Trailguide that prompted these engagements, three significant findings were developed. First, four specific place-based design features emerged as effective facilitators of engagement for families using the e-Trailguide: (a) place-based observational questions, (b) place-based textual prompts for focusing observations, (c) drawing activities to record observations, and (d) place-based images to support identification of wildlife. Second, while all four of these place-based design features successfully enabled the families to observe and point to features within the natural setting, the families’ tactile investigations were supported by the drawing activity and when referring to the place-based images during the tree identification task.

While using the e-Trailguide at Juniper’s Bench, observing and pointing to natural species were common forms of engagement among parents and children, while hands-on explorations were less common. A third finding from my video analysis revealed that overall, the children in this study tended to more frequently look up from the iPad to the area surrounding them, but it was more common to observe adults pointing to a natural object in order to connect
e-Trailguide content to the real world. Although moments of tactile investigations were low overall across both the parents and children in this study, this method of exploration still provided an important means of sense making for the families as they physically connected with plants and trees near Juniper’s Bench.
Chapter 7

Pointing-based Joint Observation Strategies Used Among Family Groups with an e-Trailguide to Support Science-Related Sense Making

In the previous Chapter 6, my qualitative analysis focused on how learners engaged with the elements of the e-Trailguide as a way to investigate the particular design features that facilitated families’ observations, pointing gestures, and tactile investigations with nature. In this chapter, I turn to an in-depth qualitative analysis that focuses on parent-child interactions and how they leveraged pointing and associated verbal cues to establish joint observation of natural objects during their time at one specific spot—Discovery Spot #3—on the trail. As stated in Chapter 3, I made the decision to focus on this spot because I found from the overview analysis that this particular spot was rich with social interactions that took on several forms when directing other family members’ attention towards specific features of the landscape to support collaborative sense making. This was a significant finding because one of the design principles when developing the e-Trailguide was to support a face-to-face collaborative learning experience for visiting families (Hsi, 2002; Knipfer, et al., 2009; Lyons et al., 2010; Yoon, et al., 2012). As such, the emergence of the analytical framework on families’ joint observations described in this Chapter 7 provides evidence for the design features within the e-Trailguide at Discovery Spot #3 (as discussed in Chapter 6) to facilitate parent-child interactions and collaborative sense making during the families’ experience on the nature trail.
**Six-pronged analytical framework to understand families’ pointing-based joint observation strategies**

The result of my analysis of the families’ dialogue (i.e. multiple turns of talk and gesture) is the emergence of a new six-pronged analytical framework to understand families’ joint observations and the important role of pointing in achieving those joint observations. Each of the six aspects of the framework represents key sense-making moves that involved verbal cues and associated pointing gestures between family members to coordinate observations and further support collaborative learning moments on the nature trail. I present this framework for joint observation with evidence from my dissertation data in order to illuminate how the e-Trailguide mediated collaborative parent-child interactions during the families’ experience at Juniper’s Bench. Through an iterative analysis of the transcripts and video records, six distinct sense-making patterns related to family pointing-based joint observations emerged (Table 7-1). These joint observation strategies were categorized as:

- Device-prompted claim
- Conceptual knowledge claim
- Orientation
- Confirmation
- Seeking verification
- Inquiry

Table 7-1 provides an overview of each joint observation strategy, how it was analyzed using the transcripts and video records, and an example from the data corpus. In the following sections of this chapter, a detailed description of each joint observation strategy is presented with additional details on how the joint observation strategy supported families’ sense-making moments on the nature trail. As in Chapter 6, learners’ gestures are represented within double parentheses [(( ))]. *Italicized font* indicates that a learner is reading from the e-Trailguide. Double slash marks [//]
indicates overlapping talk. **Bold font** is used to indicate how the interactions were interpreted using my analytical coding scheme.
Table 7-1: Six categories of joint observation strategies used by family members to support science-related sense-making actions.

<table>
<thead>
<tr>
<th>Joint observation strategy</th>
<th>Sense-making action that occurred when verbal dialogue was coupled with pointing</th>
<th>Exemplar dialogue excerpts from data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device-prompted claim</td>
<td>1. Response to e-Trailguide prompt, question, or activity.</td>
<td>1. Kendra: <em>Do you see any deciduous leaves on the ground around you? Yes, there's one</em> ((points to ground)).</td>
</tr>
<tr>
<td></td>
<td>2. Claim made about identification of natural object in relation to e-Trailguide prompt, question, or activity.</td>
<td>2. Jimmy: <em>The white pine...</em> ((points)). That- I think that's right there. Mom: That's what I was wondering.</td>
</tr>
<tr>
<td></td>
<td>3. Coordinates images from e-Trailguide with real world phenomena.</td>
<td>3. Dad: <em>That one</em> ((points to images on iPad screen)) is that one right there ((turns around and points at tree behind him)).</td>
</tr>
<tr>
<td>Conceptual knowledge claim</td>
<td>1. Shares conceptual knowledge about a natural object (i.e., tree species’ name) that extends beyond the content in the e-Trailguide.</td>
<td>1. Mom: <em>That’s a maple right there</em> ((points to tree)) Kendra: That’s what I thought. Mom: ((still pointing)) Those leaves fall off in the fall. They turn a pretty color and fall off.</td>
</tr>
<tr>
<td></td>
<td>2. Life connection between natural objects and previous experience.</td>
<td>2. Mom: And then what's this kind [of tree]? ((points up)) Dad: This right here? ((points)) Mom: ((still pointing)) This looks more like a lilly pad- a lilly pad leaf.</td>
</tr>
<tr>
<td></td>
<td>3. Shares conceptual knowledge about a natural object different from topic area of e-Trailguide tree content.</td>
<td>3. Mom: ((points)) There’s a catbird right there.</td>
</tr>
<tr>
<td>Orientation</td>
<td>1. Gives instruction to other family member about where to look to see a particular natural object.</td>
<td>1. Mom: “You gotta look up” ((points up at evergreen tree)).</td>
</tr>
<tr>
<td></td>
<td>3. Describes natural object as a means for assisting their observation.</td>
<td>3. Samuel: What? Mom: Straight up ((points)). With the little cones on it ((still pointing)). Samuel: Oh yeah, yeah.</td>
</tr>
<tr>
<td>Session</td>
<td>1.</td>
<td>2.</td>
</tr>
<tr>
<td>---------------</td>
<td>-------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| Seeking       | 1. Seeks verification of natural object being jointly observed.    | 1. Mom: *Now that you've drawn your tree, can you identify what kind it is by looking at the leaves?* Okay, so you were drawing this one right here? ((points at tree))
Owen: ((looks up at tree)) Mm hmm.                                               |
|               | 2. Asks other family member whether or not they can see a specific natural object. | 2. Mom: *Can you see [the tree] up high?* ((points))
Dad: There's one all the way up there. See it?
Jarrett: Yes I can! |
| Confirmation  | 1. Affirms joint observation of a natural object.                  | 1. Dad: ((points)) I found one.
Mom: Where?
Dad: ((still pointing)) Right back there.
Mom: *Oh yeah! ((points)) Good job! I didn’t see that at first.*                |
|               | 2. Original observer confirms that other family member is observing the same object. | 2. Dad: ((pointing)) Is it that the one you're doing?
Mom: *((points)) the one right here, yeah.*                                    |
| Inquiry       | 1. Asks a question about a natural object being observed.          | 1. Mom: ((pointing straight up)) Look at all the little buds on it. There are some that are green and some that are brown.
Molly: For pine needles?
Mom: *((still pointing)) Or pine cones? Do you think that's what they're for?*
|               | 2. Seeks assistance in identifying species of natural object.      | 2. Dad: *So that’s a white oak, right there? ((points to tree behind bench))
Mom: No. That’s that basswood.*                                                |
|               | 3. Prompts for knowledge sharing from other family members.       | 3. Mom: *What do we call ((points to forest beside bench)) this like, trees that are sort of in the middle? ((Points straight up)) What do we call the really tall trees?*
Declan: Old ones?
Mom: *Or it's the- canopy? Right?*                                             |

*Note.* Since conversational episodes were coded (not individual utterances), dialogue that occurred before and after the *coded dialogue*, which is in **bold font** for ease of interpretation, was included, when necessary, in the coding framework in order to demonstrate how the data was analyzed.
Device-prompted claim

A device-prompted claim was a sense-making process that occurred when one family member put forth an idea (i.e., a knowledge claim) about a natural object that was in direct response to a prompt, question, or activity from the e-Trailguide. Developing claims are important in science learning as explained by Toulmin (1958) in the development of science argumentation theory. Toulmin described a “claim” as a conclusion whose merits are to be evaluated via conversation. Family members frequently made claims about natural objects they observed as facilitated by content featured in the e-Trailguide. Often, the person making the claim used a pointing gesture to connect their observations on the trial to the claim they made about what they saw. Verbalizing a claim about a natural object and pointing to that object regularly resulted in joint observation so that other family members could evaluate the claim.

Device-prompted claims could be as simple as responding to a question from the e-Trailguide, such as, “Do you see any deciduous leaves on the ground around you?”, and a family member verbalizing, “Yes, there’s one” while pointing directly down to the leaves lying on the ground. In this example, a verbal claim was corroborated by pointing to the leaves in question, thereby supporting the family member’s response to the e-Trailguide’s prompt. After joint observation of the object had been achieved, the original claim was usually evaluated by a family member. Both confirmatory and disputing responses were given by family members with regard to one’s device-prompted claim. Out of the 31 families who participated in this research study, 30 out of 31 families employed the joint observational strategy of a device-prompted claim at least once during their time at Juniper’s Bench.

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6 In my study, I adopt this definition of a claim, which is also found in the National Research Council’s report of science learning out-of-school (Bell et al., 2009).
To demonstrate how device-prompted claims contributed to the families’ sense-making activities, Karl (age 7), his mom, and his dad sought to find evergreen trees after being prompted by the e-Trailguide:

1) Mom: *Evergreen trees stay green all year round. To see the evergreen trees in this area, look closely beyond the leafy deciduous trees* ((looks up and around)). Do you see any evergreen trees here anywhere?

2) Karl: *(turns in a circle and points behind bench)* Right there.

3) ((Mom and Dad look to where Karl is pointing))

4) Mom: Yeah, good job.

5) Dad: Yeah

6) Mom: Yeah, you gotta look up, huh?

7) Karl: Mm-hmm.

When prompted by the e-Trailguide—and his mom as the reader—as to whether or not he could find any evergreen trees nearby (line 1), Karl looked around and made a claim that he had found one: “Right there” (line 2). This claim was supported by Karl who pointed to the tree he was observing (Figure 7-1) so that his mom and dad could coordinate their observations of the evergreen (line 3). Once they had achieved joint observation of the evergreen tree that Karl had found, both his mom and dad evaluated and confirmed that he had indeed found the correct type of tree (lines 4-5).
Figure 7-1: Karl supports his device-prompted claim that he had found an evergreen tree by pointing to an evergreen tree for his parents to see.

At other times, a family member would reference the e-Trailguide as further evidence for a device-prompted claim. During a family’s engagement with the tree identification activity on the last page of Discovery Spot #3, individuals often coordinated the featured images with actual trees in the area by pointing to both the device then the tree being observed. In one such learning moment, a grandmother and her granddaughter, Keira (6 years old), were viewing the tree leaf images in the e-Trailguide and the grandmother claimed that she had matched one of the images with a nearby tree:

1) Grandmother: What about this tree right here? ((Points at tree)) What do you think that one is?
2) Keira: Hmm.
3) Grandmother: Which of these leaves does it look like? Does it look like this one ((points at iPad)) or this one ((points at iPad))? I think this one would be right here- this one ((points at iPad)) is right there ((points at tree)).
4) Keira: Yeah! Oops. And I think white pine would be over there ((points at tree)).
In line 1, the grandmother pointed to a tree in front of where she and Keira were standing and prompted Keira by asking, “What do you think that is?” Keira was unsure (“Hmm”) and the grandmother pointed to two choices of images in the e-Trailguide (line 3): “Does it look like this one or this one?” Through her dual point at two separate spatial frameworks (Goodwin, 2003)—the iPad showing an image from the e-Trailguide (“I think this one…”) and the physical tree in front of them (“…is right here”)—the grandmother put forward her device-prompted claim about the identification of the tree. During this learning experience, Keira was challenged with “the task of coordinating multiple visual fields” (Goodwin, 2003, p. 224) in order to successfully take part in the activity of identifying a tree. In both of the examples, the gesture of pointing corroborated a family member’s claim about an observation they made in response to a prompt by the e-Trailguide. Pointing not only supported one’s claim, but also assisted the other learners to simultaneously attend to, and eventually evaluate, the original claim.

**Conceptual knowledge claim**

*Conceptual knowledge claims* were important sense-making moments for families as they extended learning beyond the content of the e-Trailguide, while they also contributed to the overall knowledge-building among the family groups. I continue to use the same definition of “claim” as above (Bell et al., 2009; Toulmin, 1958) but the difference here is that the conceptual knowledge claims were not in direct response to the e-Trailguide’s prompts, as were the device-prompted claims. For example, the e-Trailguide content at Discovery Spot #3 centered on native trees and specific tree species at Shaver’s Creek, and while this content often prompted family members to engage with and observe the trees nearby, there were times when a family member pointed out and put forth a knowledge claim about a different natural object, such as a plant or bird, that was unrelated to the e-Trailguide content. Other times, family members shared their
understandings about trees that elaborated on the content presented in the e-Trailguide. In these moments, family members shared their conceptual knowledge (Allen, 2002), or previous knowledge, about something they observed. This knowledge could either be explicitly sourced to a prior experience (Allen, 2002; McClain & Zimmerman, 2014), such as, “In our backyard…” or it could be unsourced knowledge, such as, “This right here is poison ivy.”

One family that included a grandmother, a mother, a daughter (11 years old) and son (8 years old) were prompted to look for evergreen trees: *Evergreen trees stay green all year round.* That's why they're called evergreen trees. Instead of leaves, they have needles that stay on the branches all year. To see the evergreen trees in this area look closely beyond the deciduous trees. The grandmother pointed upwards to indicate that she had found one, followed by the mom who expanded upon the e-Trailguide’s information about evergreen trees:

1) Grandmother: ((points up)) There's one.
2) ((Family members look up to where she is pointing))
3) Mom: ((points up to tree)) But larch, I think, is a deciduous//
4) Grandmother: //That's larch. It’s…
5) Mom: ((still pointing)) It's an evergreen.
6) Grandmother: It's an evergreen, that's//
7) Mom: //((still pointing)) it's needle-leafed but it's deciduous.
8) Grandmother: Yes.
9) Mom: There’s two of them I think…larch and something else.

While the e-Trailguide provides information about evergreen trees that states, “*Evergreen trees stay green all year round. That's why they're called evergreen trees. Instead of leaves, they have needles that stay on the branches all year,*” it does not provide details regarding “special case” trees, such as trees that have needles and are also deciduous7. In the learning moment outlined

7 Larches and tamarack trees are considered to be “deciduous conifer” trees, which bear cones and lose their needles every fall season. Additionally, there are “broad-leaved evergreen” trees and shrubs, such as evergreen magnolias and rhododendrons.
above, the grandmother pointed overhead of where the family was standing and verbalized a
device-prompted claim that she had found an evergreen tree: “There’s one” (line 1). The mother
also pointed up at the tree and advanced the grandmother’s observation by suggesting that, “larch,
I think, is a deciduous” (line 3). In line 4, the grandmother acknowledged that the tree they were
observing was a larch and they both aimed to articulate the tree’s uniqueness in lines 5 and 6 until
the mother repeated her assertion that the larch tree is “needle-leafed but it’s deciduous” (line 7)
to which the grandmother agreed (line 8). Lastly, in line 9, the mom suggested that there were
two types of trees that have this unique characteristic, “larch and something else.” The e-
Trailguide’s brief information about evergreen trees and the prompt to find one by looking
*Beyond the leafy deciduous trees* resulted in the family’s joint observation of a tree they classified
as an evergreen. However, the grandmother and mother identified the tree species as a larch and
used the opportunity to elaborate on the information presented in the e-Trailguide by explaining
that the tree they were pointing at was actually a unique needle-leafed deciduous tree.

Consequently, this example shows that opportunities to transfer (Linn, 2006) and apply biological
understandings from previous experiences to the current activity setting are particularly supported
by the learning space of the outdoors.

**Orientation**

*Orienting* other family members to observe a feature of the landscape at Juniper’s Bench
was an important first step before parent-child learning talk could proceed. This particular joint
observation strategy emerged as an important means for further instructing or describing the
“target of the point” (Goodwin, 2003, p. 221), especially when a family member asked the
pointer, “Where?” or “Which one?” with regards to the object being observed. Relatedly, this
orienting strategy has been recently emphasized from a research study in a natural history
museum. While observing 54 groups of parents and children at static dioramas, Povis and
Crowley (2015) noted that establishing joint attention through the use of a flashlight was a productive part of parent-child interaction and increased the likelihood of a family engaging with deeper learning talk. In my outdoor-based study, families leveraged the act of pointing and verbal instruction to establish joint observation between family members. In one such instance, one mom and her twin daughters, Maggie and Molly (both 9 years old), referred to the place-based images on the last page of content at Discovery Spot #3 in order to identify the tree that Maggie had previously drawn:

1) Molly: I think it might be the American hornbeam...?
2) Mom: Okay, well it would matter which tree you're looking at. ((Points up to a tree))
   This is not the tree Maggie drew. ((Points to different tree)) This is the tree.
3) Molly: Ohh.
4) Mom: Okay?
5) Molly: Which one? This one? ((Points at tree))
6) Mom: This one- with oval leaves ((Points at tree))
7) Molly: Ohh.

In their efforts to identify the tree that Maggie had drawn, Molly first suggested that it could be an American hornbeam (line 1). Her mom then surmised in line 2 that Molly was not looking at “Maggie’s tree”: “This is not the tree that Maggie drew,” and subsequently oriented Molly to the correct tree by pointing to a different tree and saying, “This is the tree.” In line 5, Molly sought verification that she was looking at the correct tree: she pointed upward and asked, “Which one? This one?” which led her mom to further orient her to the tree by pointing and describing the tree’s leaves as being “oval” (line 6). Molly responded with an acknowledging “Ohh” (line 7), which signified that she had achieved joint observation of the tree that Maggie had drawn.

In addition to describing the target of one’s observation through pointing and giving verbal directions, orienting sometimes acted as a means for justifying one’s original device-prompted claim about an observation. As previously described, when making a claim about a
natural object, pointing was an important piece of the evidence for the person making the claim. However, if someone made a verbal claim that was not corroborated with a pointing gesture, they were often asked to justify their claim from another family member. For instance, Samuel (age 6) made a verbal claim that he had seen deciduous leaves by the bench, but did not support his initial claim:

1) Mom: Do you see any deciduous leaves on the ground around you?
2) Samuel: Yes.
3) Mom: Where?
4) Samuel: Right there (points), right there (points), right there (points), right there (points).

After Samuel claimed “Yes” to the e-Trailguide’s question about deciduous leaves (line 2), Samuel’s mom asked him to justify his response by asking “Where?” in line 3. Samuel leveraged a pointing gesture as evidence to support his original, verbal-only claim as he pointed and oriented his mom to jointly observe several leaves on the ground and said, “Right there, right there…” (line 4). In both of these cases, orienting served an important purpose for ensuring that other family members shared in the observational activity as the original observer intended. For Molly and her mom, pointing and verbally describing where the tree was located (“This is the tree”) then describing physical attributes of the tree (“with the oval leaves”) oriented Molly to jointly observe the same tree that her mother and her sister, Maggie, were trying to identify. For Samuel, the joint observation strategy of orienting his mother to the trees on the ground, “Right there ((points))…” was used to justify his original, verbal-only claim that he had found deciduous leaves on the ground as the e-Trailguide had prompted.
Seeking verification

Determining joint observation of a natural object between family members was a necessary sense-making move to support further collaboration during e-Trailguide tasks. Seen most often during the drawing task activity and the tree species identification activity, seeking verification occurred when one family member pointed to an object and asked other family members whether they were viewing the relevant object currently under discussion. Previous research at Shaver’s Creek that observed families on a nature trail without mobile devices (Zimmerman & McClain, 2015) documented a similar guided participation pattern (Rogoff, 2003) where a mother and grandmother frequently “checked in” with the family’s four-year old son using verbal clues such as “Do you see?” to assist his observation of plants along the trail. When mobile devices were introduced to family groups during nature walks, this process of “checking in,” or seeking verification through verbal cues and pointing, was a recurrent type of joint observation strategy used between parents and children. For one 7-year old girl, Brianne, seeking verification from her mother and twin brother, Brad (also age 7), was an important first step before they could begin their drawing task. During this episode, the family of three was determining which tree by Juniper’s Bench they wanted to draw:

1) Brianne: Let's dooo…that one ((points)). That has the big gap in it- next to the//
2) Mom: //the one with the big gap in it?//
3) Brianne: //next to the one with the purple spot.
4) Mom: ((looking at trees)) The purple spot?
5) Brianne: Yeah ((points)), see? That one.
6) Mom: Oh! ((nods)) Next to the one with the purple spot.

Here, Brianne sought verification that her mother was looking at the same tree (Figure 7-2). Brianne first described the tree in line 1 (“That has the big gap in it”) and then explained its location in line 3 (“next to the one with the purple spot”). When her mom asked, “The purple spot?” (line 4), Brianne answered “Yeah” and sought verification that her mom was looking at the
right tree when she pointed to her tree and asked, “see?” (line 5). In line 6, Brianne’s mom confirmed that they have achieved joint observation when she nodded her head and said, “Oh!” and repeated Brianne’s initial directions that the tree was “Next to the one with the purple spot.”

Figure 7-2: Daughter, Brianne, points to a tree as she seeks verification from her mother that they are both looking at the same tree.

In another learning moment involving the joint observation strategy of seeking verification, a mother, her daughter, Clara (age 11), and son, Zak (age 9), had briefly stepped off the trail in order to get closer to the tree that Clara had previously drawn with the intention of being able to more easily identify it using the images shown in the e-Trailguide:

1) Mom: Oh, there- you know what, actually, honey, there are two trees here. **Is this the one you're doing?** ((points at tree and touches leaves of tree))
2) Clara: No, I'm doing this tree ((points at tree)).
3) Zak: No, you're doing all the trees, aren't you?
4) Mom: Oh, I thought you were doing this one here. **This one here?** ((points at different tree))
5) Clara: ((to Zak)) No, I'm doing this tree.
6) Mom: Oh, look at your tree! Okay! ((touches and inspects leaves of tree))
7) Zak: This one's American basswood ((touching leaves of tree in front of them))
8) Clara: ((looking at iPad)) Basswood? No, it's not that.
9) Mom: ((looks at iPad)) It might be- oh.
10) Clara: It's not that.
11) Mom: Hornbeam? Hmm.

In this example, there was initial confusion as to which tree Clara had drawn and was subsequently trying to identify. In line 1, the mom noted that there were two different kinds of trees right in front of where they were standing and sought verification from Clara when she pointed to one of the trees and asked, “Is this the one you’re doing?” In line 2, Clara responded that her mom was looking at the wrong tree and oriented her to the correct tree, “No, I’m doing this tree.” The mom then sought further verification that they were all three on the same page when she pointed to the other tree and again asked Clara, “This one here?” (line 4). Even though Clara did not directly confirm her mother’s second query, the mom’s reaction of, “Oh, look at your tree! Okay!” in line 6 suggests that they had achieved joint observation of Clara’s tree. This notion is further supported as the family members began to debate over what tree species it was by coordinating their observations of the tree leaves with the images from the e-Trailguide (lines 7-11). In both of these examples, seeking verification was a necessary precursor to establishing joint observation of a natural object across parents and children with regards to the e-Trailguide tasks.

**Confirmation**

The joint observation strategy of confirmation is unique from the others in Table 7-1 in that it was a sense-making action that signaled the successful completion of the collaborative action of pointing out a feature in the landscape to other family members. After being successfully oriented to observe a natural object under discussion, family members would
regularly voice confirmation of achieving joint observation while simultaneously pointing to the object. This typically occurred after (a) a family member sought out the natural object that others were viewing and successfully found that object or (b) when the original observer confirmed to another family member that they had found the pertinent natural object. For example, after reading the e-Trailguide prompt as to where to find evergreens near Juniper’s Bench, a family of four—dad, mom, Mary Catherine (13 years old), and Darren (11 years old)—were surveying their surroundings before the mom claimed to have found one:

1) Dad: Uh, evergreen trees stay green all year round. Instead of leaves they have needles that stay on the branches all year. To see evergreen trees in the area, look closely beyond the leafy deciduous forest.
2) Mom: ((points straight above to a tree)) There's one! Right there!
3) Dad: **Oh yeah ((points up to tree)).**
4) Mary Catherine: ((looks up at tree)) That's a dead one.

In line 2, the mom pointed out an evergreen tree and excitedly proclaimed “There’s one! Right there!” This prompted the other three family members to focus their attention on where the mom was pointing. In confirmation of achieving joint observation of the evergreen tree, the dad pointed to the tree she had found while verbally confirming, “Oh yeah” (line 3), while Mary Catherine observed in line 4 that the tree could be “a dead one.”

An alternative example features a dad, mom, and son, Owen (age 8). Owen had completed his drawing of a tree near the bench the family was sitting on and had begun the task of identifying the tree by referring to the images in the e-Trailguide on the last page at Discovery Spot #3. In order to participate in the identification task with his family, the dad pointed at a tree to verify that he was looking at the same tree that Owen and the mom were observing:

1) Dad: ((pointing at tree)) Is it that the one you're doing?
2) Owen: ((points at tree then nods))
3) **Mom: ((Points at tree)) The one right here, yeah.**
In this example, the mom answered the dad’s question as to which tree they were “doing” (line 1) by conjointly pointing at the tree (Figure 7-3) and verbally affirming, “The one right here, yeah” (line 3). In both of these examples, confirming as either the seeker or confirming as the original observer served as a means to an end with regards to achieving joint observation of a natural object nearby. Once joint observation was confirmed, families could begin collectively working together on an e-Trailguide activity or conclude an activity. Where Povis and Crowley (2015) asserted that joint attention of an object in a museum-based diorama was an important predecessor to parent-child learning talk, I also found in my dissertation study that the families at Juniper’s Bench sought to confirm their joint observations of natural objects before engaging with an e-Trailguide task and associated learning talk.

Figure 7-3: Both son and mother from Family 2 conjointly point to a tree and confirm that the tree the father is pointing at is the tree they are trying to identify as a family.
Inquiry

The final joint observation strategy in the framework for sense making that emerged as a recurring pattern across family groups occurred around an inquiry about a species of trees or other natural objects seen in the area by Juniper’s Bench. An inquiry was denoted when either (a) a family member pointed to a natural object and asked a question about that object, such as “What kind of tree is that?” or (b) an adult family member asked an inquiry that took the form of a prompt for knowledge from their children, such as “Do you remember what we call this type of tree?” In one example of this first type of inquiry, a mother and her 8-year old daughter, Nell, were about to begin the drawing task facilitated by the e-Trailguide. After the mother read the final instructions to “label it as either deciduous or evergreen,” Nell asked her mother about the kind of tree (deciduous or evergreen) she had pointed out:

1)  Mom: *Pick a tree you see and draw it by tapping on the blue pencil! Tap on the purple pencil to draw a tree your family likes- work together. When you're done, label it as either deciduous or evergreen.* Okay, let's sit down to//

2)  Nell:  

3)  Mom: ((looks up at tree)) Those are- I would say- what do you think? There are more pine trees or other kinds of trees?

4)  Nell: Other kind.

5)  Mom: Yeah.

Despite her engagement with the deciduous tree and evergreen tree content from the previous pages at Discovery Spot #3, Nell pointed to and inquired as to the type of tree she had spotted, “Right there- what is that?” (line 2). Instead of simply telling her what the type of tree she was pointing at was, the mom asked Nell, “What do you think? There are more pine trees or other kinds of trees?” (line 3), to which Nell responded, “Other kind,” meaning deciduous trees (line 4). In this conversational exchange, Nell inquired about a tree, the mom responded with her own inquiry to Nell, and Nell was able to answer her original question. Eberbach and Crowley (2009)
suggest that question asking is an important strategy for engaging young children to observe the world around them, and in this study, knowledge-seeking questions were seen most often among children, but was not an uncommon occurrence among the adults.

A second example demonstrates a knowledge prompting-driven inquiry. Here, one family of three was observing the deciduous and evergreen trees by Juniper’s Bench as mediated by the drawing activity in the e-Trailguide. While looking around, the mom pointed out a vine growing up the side of a tree by the bench to her daughter, Kerry (8 years old), and her son, Declan, (6 years old):

1) Mom: I see that (pointing at tree). What's that growing up the side of that tree?
2) ((Kerry and Declan look to where mom is pointing))
3) Declan: Grapevine!
4) Kerry: No, poison ivy//
5) Mom: //Mmm, nope. I think that's poison ivy. Hairy rope, right? Hairy rope, don't be a dope.
6) Kerry: ((to Declan)) Good thing you didn't go up to that!

Although this family was concluding their drawing activity by determining whether or not the tree that Declan had drawn was a deciduous or an evergreen, the mom made a side observation, which led her to prompt her son and daughter regarding their knowledge of a different type of plant, as shown in line 1: “What’s that growing up the side of that tree?” Declan first responded that it was a grapevine (line 3), but Kerry disagreed and said it was poison ivy (line 4), which the mom confirmed by answering, “Nope. I think that’s poison ivy” (line 5). Suggesting that she had shared this information about poison ivy vines with her children before, the mom next said, “Hairy rope, right?” and recited a short rhyme, “Hairy rope, don’t be a dope” in line 6. In all the cases across families, these types of inquiries focused on prompting knowledge were adult-led. Prior research exploring the social and intellectual role of parents and children in the setting of science museums (Zimmerman, Reeve, & Bell, 2008), has documented parents taking on teacher
roles by “asking questions and evaluating responses” (p. 149). In one mother-to-son example, Zimmerman and colleagues identified the mother to be taking on a science content broker role when she asked her son to apply his knowledge to the new setting of the museum. At Juniper’s Bench, Kerry and Declan’s mom assumed similar roles as a teacher and science content broker as she put pointed out an observation and inquired as to whether her children could identify the natural object she had found. These moments of guided participation (Rogoff, 2003) in which parents supported their children’s observations and identification work on the nature trail was a reoccurring trend among families both without mobile devices (Zimmerman & McClain, 2015) and with mobile devices, as was noted in this dissertation study.

**Discussion of families’ pointing-based joint observation strategies**

Analysis of the 31 families’ transcripts and video-records from their learning experience at Juniper’s Bench resulted in a pattern with regards to joint observations of natural objects and the important role of pointing in achieving these joint observations between family members. Pointing is a situated interactive activity that Goodwin (2003) describes as “a situation that contains at least two participants, one of whom is attempting to establish a particular space as a shared focus for the organization of cognition of action” (p. 219). In alignment with this statement, the participant families in this study regularly leveraged six different types of pointing gestures as a means to achieve joint observation with other family members on a natural object of interest. Device-prompted claims about native trees, conceptual knowledge claims about a variety of natural objects, orienting instructions, verification requests with regards to observations, confirming statements pertaining to observations, and inquiries about the local biota were all important collaborative sense-making strategies that were regularly leveraged by the family groups participating in this study. As evidenced by the data excerpts in the previous sections, the families’ collaborative learning moments signaled not only engagement with nature as mediated
by design features within the e-Trailguide at Discovery Spot #3, but also device-facilitated parent-child interactions as the families explored, observed, and learned about native trees at Juniper’s Bench.

**Conclusion**

This chapter has outlined an analytical framework related to the joint observation strategies (that combined verbal dialogue with pointing) to support science-related sense making for family groups using an e-Trailguide at one particular spot along a nature trail. This newly developed framework provides a necessary addition to the field of informal science learning and family learning because it is an analytical tool that research can use to understand learning with mobile computers in the outdoors. While discourse analysis (e.g., Allen, 2002; Ash, 2003; Borun et al., 1996) is a widely used method for studying naturalistic conversations between family members during informal learning experiences, my analytical framework combines the talk with gestures to be important modes of communication between parents and children. Consequently, my study illuminates the utility of including pointing gestures alongside dialogical exchanges in order to more fully understand how families participate in science-related sense-making activities together.
Chapter 8

Discussion

This dissertation was the third iteration of a design-based research (DBR) study that sought to conduct novel research on learning and the development of design recommendations for using mobile technology as a stand-alone facilitator of learner engagement in the outdoors. The findings from my dissertation contribute new empirical evidence with regards to what engagement with nature looks like amongst youth and family groups using a mobile-based e-Trailguide and provide innovative recommendations for practice-based institutions regarding how mobile device programs can be purposely developed using place-based features in order to foster this engagement with nature. In this final chapter, I will discuss the third iteration primarily, but I will use the findings from the first two iterations featured in my pilot study (McClain & Zimmerman, 2016b) to contextualize the overall research project. The first stage of the DBR study was conducted with 83 youth summer campers over the summer of 2013, which involved the documentation of two iterative cycles of DBR enactment and revision of an e-Trailguide developed for Shaver’s Creek Environmental Center. During the following summer of 2014, 31 families groups (rather than just youth) were recruited to participate in the e-Trailguide’s third iteration, which enacted a revised e-Trailguide. This third iteration with families was the focus of this dissertation; its findings are described in-depth in Chapters 5, 6, and 7.

Based on the third iterations’ analyses of families’ overall experience using the e-Trailguide during a nature walk and a deeper analysis of families’ engagement with nature and each other at one interactive Discovery Spot focused on trees, I derived four research implications:

5. Methodologically, the post-hike interviews with families provided a descriptive portrayal of the participant families’ biodiversity-related content knowledge gains.
6. Four place-based design features were integral for facilitating the families’ observations, pointing gestures, and tactile investigations with nature.

7. When an e-Trailguide was utilized at one Discovery Spot focused on native trees, parents/guardians tended to act as the facilitator for their children, as evidenced through their frequent instances of engagement with nature through pointing.

8. Establishing joint observation of natural objects through pointing and associated verbal cues was an important sense-making tool that had six strategies. These six strategies were used when one family member tried to direct other family members’ attention towards specific features of the landscape.

The remainder of this chapter will discuss these four implications from the third research iteration with regards to (a) advancing informal learning research methodologies, (b) developing design guidelines in combination with findings from the first two research iterations, (c) contributing this line of work to the field of informal family learning in environmental education settings, and (d) creating an analytical framework that can be used to understand joint observation during informal science-related sense-making activities. A concluding section in this chapter will discuss how the findings generated from this dissertation may inform future learning sciences and environmental education research efforts.

**Methodological implication: The value of open-ended interviews for understanding families’ biodiversity-related conceptual knowledge gains after a hike with an e-Trailguide**

In my dissertation study, open-ended interview responses from each of the participant families were thematically coded. This piece of data provided a nuanced understanding of how the e-Trailguide influenced family member’s new ways of thinking about the local flora and fauna, including new knowledge about biological functions of trees, plant species identification, and attributes of insects. As such, I posit that the post-hike interviews provided an opportunity for
families to openly share new conceptual knowledge gains that may not have been accurately targeted by a traditional test.

Regarding assessments in informal learning research studies, Bell et al. (2009) argue that “the standardized, multiple-choice test…is at odds with the types of activities, learning, and reasons for participation that characterize informal learning environments” (p. 56). They further stress that testing individuals only on recall of knowledge can cause researchers to miss key learning outcomes, especially because these outcomes are highly influenced by an individual’s prior experiences and knowledge. Consequently, self-reports in the form of questionnaires and interviews have been generally accepted as a means for eliciting new understandings after an individual’s out-of-school learning experience.

Visits to museums and other informal learning institutions are short and isolated, which makes it challenging to parse out the specific factors that lead to learners’ new understandings about the world (Bell et al., 2009). Furthermore, in their recent report on STEM programs in informal learning settings, the National Research Council (2015) wrote that these single learning experiences and their effects on one’s knowledge or interest may not be immediately recognizable or detectable, but they may have a “relatively profound effect if it serves to orient, inspire, or motivate a young person to be open to new STEM learning opportunities” (p. 33).

Regardless of these constraints, there are a number of strategies that can be leveraged by informal learning researchers who aim to evaluate informal learning experiences. For example, in my dissertation study that sought to evaluate the conceptual learning outcomes for family groups who used an e-Trailguide during a nature walk, the open-ended interviews contributed a detailed picture with regards to new understandings about the local biodiversity. As such, my methodological implication suggests that future research studies intending to evaluate family learning outcomes’ during mobile-directed, informal learning experiences will glean a useful and comprehensive report—and possibly unanticipated, yet valuable information—about the mobile
device program’s influence on learning when post-activity interviews with families are implemented, rather than depending on traditional test measurements to assess knowledge change.

**Design recommendations for mobile computing outdoors: Emerging strategies to promote technology-mediated engagement with nature**

This dissertation study’s findings offer recommendations related to mobile program designs that can provide a starting point for both research and practices (i.e., nature centers, museums) that want to develop or integrate technologies into outdoor science learning settings. The Shaver’s Creek e-Trailguide was designed as a tool to engage families with nature and with each other. Dunleavy and Dede (2014) suggest that mobile devices “position the learner within a real-world physical and social context while guiding learning processes such as authentic inquiry and active observation” (p. 737). With this in mind, a main goal in designing the e-Trailguide was to facilitate observations of and gestures towards the physical environment, rather than acting as an obtrusion to the learners’ experience in the outdoors.

Previous research has offered broad design guidelines for mobile technology programs intended for students during field trips to outdoor spaces (e.g., Eliasson et al., 2011). For example, Eliasson and colleagues worked with a small group of middle school students and developed five design guidelines over several iterations where mobile devices supported rather than distracted students from the context relevant to the learning objectives. These included encouraging students to assume roles with the device, using the device as a tool, connecting the physical interaction with the environment, involving teachers in the activity, encouraging face-to-face collaboration, and providing an introductory session for the students with the mobile devices. This work has provided useful suggestions for those interested in designing mobile programs geared for students during outdoor exploration and engagement, yet it does not consider how self-
guiding mobile programs, like an e-Trailguide, can be designed to support outdoor learning. My research provides guidance with regards to how environmental centers, natural areas, and parks can utilize and design mobile programs to include specific design features that can engage visitors with nature on an informal, everyday basis. The design recommendations from my dissertation emphasize the utility of incorporating specific design features such as place-based directed prompts and activities to support families’ direct engagements with the immediate setting, which are featured in Table 8-1. A description of my design intention, an example from the e-Trailguide, and the learning outcome observed among the family groups who participated in this dissertation study are included.
Table 8-1: Four place-based design features to engage visitors with nature during mobile-based, informal outdoor education experiences.

<table>
<thead>
<tr>
<th>Place-based design feature</th>
<th>Example from e-Trailguide</th>
<th>Engagement and learning outcomes observed among learners</th>
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</table>
| Place-based observational questions | Written text in the e-Trailguide that asks, “Do you see any deciduous leaves on the ground around you?” | • Individual observations followed by pointing as a means of communication and understanding of the e-Trailguide’s content to other family members.  
• Joint attention and conversation around scientifically relevant objects. |
| Place-based textual prompts for focusing observations | Written text in the e-Trailguide that states, “To see the evergreen trees in this area, look closely beyond the leafy deciduous trees.” | • Individual observations followed by pointing as a means of communication and achievement of the e-Trailguide’s task to other family members.  
• Joint attention and conversation around scientifically relevant objects. |
| Drawing activities to record observations | Sketchpad widget in the e-Trailguide used for drawing a picture of a tree nearby. | • Shared observations and conversations about local tree species followed by pointing and tactile investigations as a means of communication and demonstration of understanding of tree species.  
• Joint attention and collaboration in the task at hand by family members. |
| Place-based images to support identification of wildlife | Locally collected photographs of tree leaves shown in e-Trailguide that assisted in tree identification. | • Shared observations and discussion of local trees as mediated by images in e-Trailguide followed by pointing and tactile investigations as a means of communication and orientation towards specific tree types to family members.  
• Joint inquiry and sense making around scientifically relevant objects. |
Place-based questions and textual prompts

In their conceptual piece outlining techniques that can mediate mobile-based collaborative learning between parents and children during informal learning experiences, Lyons, Becker, and Roberts (2010) suggest that question-posing strategies, which have “not yet been fully explored” (p. 94), could support parent-child interactions. In my dissertation study, both observational-based questions and textual prompts for focusing observation that were place-based, or specifically associated with the immediate learning setting, were beneficial for facilitating the families to further observe their surroundings along the nature trail. These questions and prompts were beneficial for directing attention to specific features of the landscape in order to “highlight important disciplinary content” (Zimmerman & Land, 2014, p. 76), or in the case of my dissertation, content related to native trees. However, instead of simply providing the content, the questions and prompts in the e-Trailguide were integrated to further connect the information with observations of the place.

**Place-based observational questions.** Questions in the e-Trailguide such as, “Do you see any deciduous leaves on the ground around you?” were effective techniques for encouraging parents and children to first individually observe their surroundings then engage with joint sense making through pointing and a verbal response to the question. Previous museum-based research studies have explored the role of science inquiry-based questions in supporting parent and child learning. In an effort to facilitate family group inquiry in a science museum, Gutwill and Allen (2009) developed and implemented the concept of juicy questions whereby a family chooses a question to answer through the means of manipulating a science exhibit. Through the exploration of their “juicy question,” families reportedly had higher engagement (and time) at the exhibit, collaborative learning moments between family members, and multiple investigation pathways. I found that questions pertaining specifically to the area in which the families were located along the trail facilitated their observations of the natural biota immediately surrounding them and
supported collaborative learning moments as evidenced by their dialogue and associated pointing gestures.

**Place-based textual prompts for focusing observations.** Textual prompts, such as “To see the evergreen trees in this area, look closely beyond the leaf deciduous trees” provided an opportunity for families to jointly seek out the focus of the prompt—in this case, evergreen trees—and leverage pointing gestures to signify their achievement of the task. Developing mobile-based prompts to support learning in both school and informal learning spaces has been a recent area of interest to educational technologists. For example, in a 2014 study with elementary students during a natural science class, Chen, Hwang, and Tsai designed and evaluated a QR-code focused “progressive prompt mechanism” to help scaffold the students’ learning about plants in an outdoor garden. The interface assisted the students in learning about flowers within the garden by providing context-based prompts that appeared in response to the students’ answers to the device’s posed questions. Within the content at Discovery Spot #3, prompts were designed to focus users’ attentions on specific features of the landscape, such as a certain species of trees, in order for the families to make an observational connection between the e-Trailguide content and the real, physical objects found within the nearby natural setting.

**Drawing activity for recording observations**

Creating an observational record (Eberbach & Crowley, 2009) of a specific tree through a drawing task provided an opportunity for the children in the participating families to take on leadership roles during the family learning experience at Juniper’s Bench. Observation is deemed an important and foundational skill for all practices of science, but researchers have argued that it can be difficult for young children and novices to observe the world in the way that scientists do (Eberbach & Crowley, 2009). Because drawing can facilitate closer inspections of one’s surroundings (Fox & Lee, 2013), while it also creates an externalized representation of one’s
observations of particular features in the landscape, I included an opportunity to draw a tree via the sketchpad widget within the content at Discovery Spot #3.

An additional function of this particular activity was that by capturing the features of a chosen tree through drawing, families engaged with place-based observations and collaborative conversations about their tree. Recent work has provided research-supported design guidelines and strategies for place-based education using mobile devices (Zimmerman & Land, 2014). The authors recommend that outdoor-based mobile programs provide opportunities for capturing and annotating artifacts of a place in order to make thinking visible. Consequently, the drawing activity and resulting interactions that were fostered between the families and the natural setting at Juniper’s Bench is one example from the e-Trailguide that further bolsters this suggestion.

**Place-based images to support identification of wildlife**

Previous work with families at Shaver’s Creek without the use of mobile devices (Zimmerman & McClain, 2014) revealed that families who used fieldguides containing line-art representations were often unable to successfully match the two-dimensional drawings to the three-dimensional object observed in nature. In order to provide a more manageable identification activity, the e-Trailguide incorporated place-based images, which were photographs collected locally onsite at Shaver’s Creek, to identify the trees proximal to Juniper’s Bench. By providing these place-based images, families were regularly successful at identifying the trees around them. Furthermore, the families often used these photographs to not only identify their chosen and drawn tree (as instructed by the e-Trailguide), but to also extend their learning by seeking out all of the six trees displayed in the e-Trailguide. This particular identification activity was beneficial for both engaging families with the natural world and supporting their collaboration with each other as they sought to coordinate the photographs in the e-Trailguide to the real, physical natural objects nearby.
Implication to informal family learning theory: Parents are facilitators during mobile-based family learning activities in the outdoors

My dissertation study provides a theoretical contribution that expands the role of parents as learning partners (Barron et al., 2009) during informal, outdoor settings. My study provides a deep analysis of parents adopting teacher-like roles during family learning experiences with self-guiding mobile devices on a nature trail. During the e-Trailguide’s pilot study with youth summer campers, the counselors—originally instructed to let the campers go at their own pace—ultimately became necessary regulators and facilitators for the campers’ learning experience. Likewise, when families used the e-Trailguide during its third iteration, parents and grandparents were necessary for guiding the children’s participation (Rogoff, 2003) and for keeping the families “on track” with regards to the activities and information provided in the e-Trailguide. Through re-voicing the e-Trailguide’s prompts and connecting content to the physical surroundings through pointing gestures, adults were important facilitators of their children’s learning experience at this Discovery Spot.

Prior research focused on outdoor-based mobile device programs with both family groups and youth-only groups has suggested that learners need naturalists to support their technology-mediated engagements with nature (Land & Zimmerman, 2015). Given this finding, Land and Zimmerman suggested that future work should “investigate different configurations of the socio-technical system to scaffold knowledge building activities of families, especially scaffolds for parents who could potentially serve as guides for their children’s explorations” (p. 251). In response to this call for further research on parents’ support of their children’s learning experiences in the outdoors with mobile devices, my dissertation study provides one example of how adults played important facilitation roles for their children as the families learned about the local biodiversity with the aid of an e-Trailguide. Without the assistance of an in-person naturalist, parents routinely supported their children’s observations and sense making about the
natural world by coordinating the information about trees displayed in the e-Trailguide at Discovery Spot #3 to the actual, surrounding trees through situated verbal cues and pointing gestures.

An analysis of the families’ technology-mediated engagements with nature revealed that instances of observation and tactile investigation were relatively even across adults and children at Juniper’s Bench; however, adults more frequently pointed to their surroundings when compared to the children. These parental pointing gestures facilitated the connection between the e-Trailguide’s content to the observations of the physical surroundings so that children could more fully participate with the sociocultural learning activities (Paradise & Rogoff, 2009; Rogoff, 2003). Eberbach and Crowley (2009) posit that in order for children to make purposeful observations of biological phenomena, adults are important for scaffolding the process. Through this adult-led support, children can begin using these observations as a “basis for investigation, argument, and explanation” (p. 54). Correspondingly, the parents and grandparents in my study regularly relied on both verbal cues and pointing gestures to scaffold the children’s observations of the native trees surrounding them as they used the e-Trailguide. Parents are regularly observed taking on teacher-like roles to support their children’s science learning in other learning settings, such as at their homes with technology (Barron et al., 2009), zoos (Patrick & Tunnicliffe, 2013), museums (Crowley et al., 2001; Crowley & Galco, 2001; Gleason & Schauble, 2000; Swartz & Crowley, 2004), nature centers without mobile computers (Zimmerman, McClain, & Crowl, 2013), and science centers (Rigney & Callanan, 2011; Zimmerman, Perin, & Bell, 2010; Zimmerman, Reeve, & Bell, 2008). In alignment with this prior research on family learning, my dissertation study adds to the literature base by providing an account of parents adopting similar teacher-like roles during family group learning experiences with mobile computers (e-Trailguides) on a nature trail.
Analytical framework: Joint observation strategies and the importance of dialogue coupled with pointing in facilitating family sense making moments

My dissertation provides a framework that articulates six pointing-based joint observation strategies that emerged as a result of using a mobile device during a nature walk. Given the importance of parent-child interactions during informal learning experiences (Allen, 2002; Ash, 2003; Crowley et al., 2001; Crowley & Galco, 2001; Ellenbogen et al., 2004; Gleason & Schauble, 2000; Goodwin, 2007; Kisiel et al., 2013; Paradise & Rogoff, 2009; Swartz & Crowley, 2004; Zimmerman et al., 2008; Zimmerman et al., 2010), this dissertation study contributed an analytical account of physical gestures, specifically pointing, alongside verbal cues as an important strategy for achieving joint observation of a natural object between family members when a mobile device facilitated the learning activity. When facilitated by four place-based design features featured in the e-Trailguide at Juniper’s Bench, pointing stood out as one type of technology-mediated engagement with nature that was used by individuals to achieve mutual participation in the activity of observation between adults and children (Rogoff, 2003). For example, pointing was leveraged as an important joint observational strategy when it came to making a claim and supporting a claim, which often happened simultaneously when pointing occurred. Once joint observation had been achieved through a device-prompted claim and related pointing gesture, higher levels of learning talk and mutual bridging of meanings (Rogoff, 2003) related to the observation could proceed between family members.

During the joint observational sense making episodes, pointing and dialogue were considered as co-contributors to the effort; they mutually supported the social activity of attuning others’ attention to a certain feature in the landscape. Accordingly, Goodwin (2003) asserts that, “Crucial semiotic resources for shaping what is pointed at…are provided by the talk that typically co-occurs with the point” (p. 223). For example, during technology-free nature walks, parents and children have used this combination of verbal directives coupled with pointing gestures to
coordinate family members’ attention and observations of their surroundings (Marin, 2013), while families at natural history museums have used low-technology tools, such as flashlights, alongside verbal cues to achieve joint attention with specific objects in dioramas (Povis & Crowley, 2015). My dissertation study advances these findings by providing an analytical framework related to joint observation strategies used across families to support their science-related sense making as facilitated by place-based design features within an e-Trailguide during a nature walk.

The importance of analyzing gestures during family sense making moments

Highlighting the importance of analyzing dialogue and gestures in informal learning settings, Rahm (2004) argues that “meaning-making is too often equated with linguistic meaning” (p. 225) and that nonverbal gestures also constitute conversational sense making between learners. My development of the joint observation analytical framework supports Rahm’s statement by considering both conversation and gesture to be important constituents of families’ learning processes as mediated by a mobile device in the outdoors. A socially-bound and situated interactive activity (Goodwin, 2003), pointing alongside verbal cues supported family members in this dissertation study as they made (a) device-prompted claims about observations and (b) conceptual knowledge claims pertaining to previous understandings about trees and other natural objects, (c) reinforced verbal directions for orienting family members to direct their attention to certain objects in the landscape, (d) aided family members in both verifying and (e) confirming that joint observation between family members had been achieved, and (f) facilitated both parent-led and child-led inquiries about natural objects around Juniper’s Bench.

In science classrooms, gestures are important resources during collaborative student activities as they contribute to students’ interactions, talk, and writing (Roth, 2001); in my dissertation study, individual family members similarly leveraged gestures during collaborative
activities outlined by the e-Trailguide at Discovery Spot #3. For example, pointing gestures often corroborated a family member’s device-prompted claim about a natural object they observed. Forwarding a knowledge claim is a common science practice (Latour & Woolgar, 1986) that allows others to evaluate that claim and subsequently dispute or concur the idea that has been put forth. As such, students in science classrooms are encouraged to support their claims with evidence, such as data or warrants (Toulmin, 1958), and thus engage with dialogical arguments about that claim with others (Driver, Newton, & Osborne, 2000). Relatedly, Eberbach and Crowley (2009) argue that, “children learn to coordinate expectations and observational evidence when they start to think about, talk about, and publicly organize their observations and knowledge in ways that are consistent with a disciplinary learning community” (p. 56)—in this dissertation study, the learning community was the family group. Family members publicly organized their observations about nearby trees when they pointed to and voiced ideas about the trees in response to prompts, questions, and activities featured in the e-Trailguide.

Summary: Implications and recommendations for mobile-based, informal pedagogy for family learning in the outdoors

For environmental education centers, gardens, and parks that wish to engage their visitors with nature in a meaningful way, my dissertation study provides empirical evidence that specific place-based design features within an e-Trailguide can foster families’ learning and engagement with the outdoors and with each other. My findings suggest that in order to support science engagement with the natural world and joint participation in observational activities between family members through the facilitation of a mobile device, content should be place-based, or in other words, anchored within the location and associated biota being interpreted. While my dissertation study took place in a forested area within the mid-Atlantic United States, my analysis of 31 family participants using an e-Trailguide produced four place-based, mobile design features
that can be more broadly implemented in other outdoor education settings. These include the use of purposeful and place-based questions and textual prompts to focus observations on specific features of the landscape, drawing activities to encourage record-keeping and annotation of observations relating to the local flora and fauna, and place-based images to assist learners in identifying natural species in the outdoors. In my study, these design features not only facilitated families’ engagement with the natural world, but they also fostered collaborative sense making opportunities between parents and children, which is a fundamental component of informal, family-based learning.

**Implications for research on family learning with mobile devices**

Based on my research, I make suggestions for other researchers studying informal, outdoor learning—and in some cases, family learning in general. Future mobile-based research with families will benefit from a multitude of data collection techniques including open-ended interviews with families to gauge content knowledge outcomes and video recordings of the families’ learning experiences to capture nuanced learning patterns between family members, the mobile device, and the physical learning setting. Analyses of families using mobile-based technologies during informal learning outings should consider gesture, alongside family conversations, as a measure of engagement with the educational space as mediated by the mobile device. For instance, does pointing figure as prominently in museum spaces when families utilize mobile-based learning tools as it did in this outdoor-based dissertation study? A future focus on gestures as important sense making strategies during family learning has far-reaching implications for the field of informal science learning in that gestures are often seen side-by-side with informal science talk, yet have not been given much consideration as to their relevance to the learning process.
Future avenues for research on family focused, mobile-based learning

When reviewing literature focused on mobile device use during informal learning experiences at the start of my dissertation project, there were no studies that had yet explored how family group learning dynamics are influenced by the incorporation of self-guiding, mobile-based technologies in the outdoors on nature trails. Given that this dissertation study explored how certain design features within an e-Trailguide facilitated families’ engagements with the natural world within the setting of an outdoor-based nature trail, future research on the influence of self-guiding mobile devices specifically designed for family groups in other settings, such as indoor-based museums, would be beneficial for the informal learning and educational technology fields.

During both the pilot study and this dissertation study, three types of technology-mediated engagement with nature were identified and developed: heads up observations, pointing, and tactile investigations. While heads up observations and pointing gestures were the two most frequent types of engagement seen across both the youth summer campers and the family groups, tactile investigations were less common. I posit that this is due in large part to the fact that the instructions in the e-Trailguide at Discovery Spot #3 did not outline specific activities or prompts that explicitly encouraged hands-on investigations of biota along the nature trail; instead, the technology-mediated tactile investigations I observed among the summer campers and individual family members were usually happenstance. If mobile programs designed for outdoor spaces explicitly outlined hands-on activities, would the instances of technology-mediated engagement with nature through tactile investigation increase?
Conclusion

A challenge for environmental educators is introducing mobile-based learning in such a way that it enhances people’s experiences outdoors, rather than creating a dependency on the device’s screen. In my dissertation study, I focused on the implementation of a mobile-learning design set within a forested trail. The two iterations of the design-based research project—the first iteration with summer camp youth (McClain & Zimmerman, 2016b) and the second iteration presented here in my dissertation study—together elucidated the patterns of engagement between a) youth summer campers and the natural world and b) family members and the natural world and each other when an e-Trailguide was introduced into the learning setting. Results from these studies provide important methodological considerations regarding methods used for measuring conceptual knowledge change during research with families in informal learning settings, design features that can promote different kinds of learner engagement with nature through emphasizing the importance of place-based pedagogy, an account of the importance of parental facilitation roles during family mobile-based activities, and the development of an analytical framework related to families’ joint observations of the natural world.
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APPENDIX A

e-Trailguide Design Features, Science Content, Learning Objectives, and Observed Learner Outcomes at Discovery Spots Along Boardwalk Trail

Discovery Spot #1: “The Arching Trees”

Content, prompts, and interactive widgets: Families were first asked to think about the time of year the picture shown in the e-Trailguide was taken (fall season) in order to facilitate their thinking of seasonal changes (families were on this trail during the summer season). Next, families were prompted to verbally share with each other why they thought the tree in front of them was arching over the trail before they looked at the answer box (which shows the answer that was provided by SCEC’s plant scientist).

Learning objective(s):
1) To connect seasonal images in the e-Trailguide to the current season when they were on the nature trail;
2) To understand the natural and man-made processes that occurred in previous years to cause the trees in the area to bend over and remain bent over.

Observed learner outcome(s):
1) Families verbally discussed the seasonal changes of trees (leaves vs. no leaves);
2) After a parent or child read the “answer” out loud, at least one family member summarized the text given in the e-Trailguide and applied it to the arching trees in the area. Families also reflected on each member’s previous hypotheses as they related to the plant scientist’s answer.

On the Move activity in between DS 1 and DS 2

Content, prompts, and interactive widgets: This first On the Move activity facilitated an observational “warm-up” activity by asking the family to count and record (on a notepad widget) the number of arching trees they saw around them as they walked to the second DS.

Learning objective(s):
1) To observe the surrounding forest area by searching for specific types of trees off the main trail.

Observed learner outcome(s):
1) Family members worked together to point out the arching trees they saw around them on the trail and at least one family member recorded, via the notepad widget, the number of trees the family saw as they walked to the second DS.

Discovery Spot #2: “The Grapevine Sign Post”
Content, prompts, and interactive widgets: Families were asked why they thought the post says “Grapevine.” The next page included information about Pennsylvania native wild grapes. Images of wild grape vines were provided and families were asked to use an in-book camera widget to capture a photo of a grapevine they saw nearby.

Learning objective(s):
1) To use the information and images included in the e-Trailguide to find a grapevine in the vicinity where they were standing.

Observed learner outcome(s):
1) Families worked together to observe their surroundings and used the images in the e-Trailguide to find a grapevine. A parent or child pointed out and described where a grapevine was to another person in their family. Once a grapevine was found, at least one family member captured this observation using the in-book camera widget.

On the Move activity in between DS 2 and DS 3

Content, prompts, and interactive widgets: This second observation-based On the Move activity prompted families to explore the different colors in the forest by matching the 8 different colored blocks in the e-Trailguide to natural objects they saw along the side of the trail as they walked to DS 3.

Learning objective(s):
1) To explore and observe the natural objects located between DS 2 and DS 3.

Observed learner outcome(s):
1) Families worked together (i.e., by pointing out, by calling to each other) to find natural objects along the trail that matched the 8 different colored blocks found in the e-Trailguide. Individuals holding the iPad physically put the device next to an object of like color to compare.

Discovery Spot #3: “Juniper’s Bench”

Content, prompts, and interactive widgets: At this spot, information about deciduous and evergreen trees was provided. A sketchpad widget was also included and asked the family to work together to find a tree that interested them, draw the tree, and write at the top of their drawing whether their chosen tree was deciduous or evergreen. After they completed the drawing, the next page showed and identified the species of trees (about 6) found in the area at this DS. The family was then asked to use this information to identify the tree they drew and add the name of the tree to their previous drawing.

Learning objective(s):
1) To understand the difference between deciduous and evergreen trees;
2) To identify at least one tree at DS 3 using the information included in the e-Trailguide.

Observed learner outcome(s):
1) In their drawing of a tree, the family discussed and determined whether they chose a deciduous tree or an evergreen tree and wrote the correct answer at the top of their drawing;
2) Families used the information found in the e-Trailguide to successfully identify the species of tree they drew and wrote the name of that species at the top of their drawing.

<table>
<thead>
<tr>
<th>On the Move activity in between DS 3 and DS 4</th>
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<tbody>
<tr>
<td><strong>Content, prompts, and interactive widgets:</strong> As families moved toward DS 4, they were challenged to walk quietly (without talking) and use their hearing to count the different types of sounds they hear between DS 3 and DS 4. When they arrived at DS 4, individuals were prompted to share with and describe for each other the different sounds they heard while walking to DS 4. As a follow up, common bird songs were embedded into the e-Trailguide’s content so that families could familiarize themselves with the songs of local bird species they may hear during the remainder of their walk.</td>
</tr>
<tr>
<td><strong>Learning objective(s):</strong></td>
</tr>
<tr>
<td>1) To listen for the diversity of sounds in the forest along the Boardwalk Trail.</td>
</tr>
<tr>
<td><strong>Observed learner outcome(s):</strong></td>
</tr>
<tr>
<td>1) Each family member shared with each other the sounds they heard as they walked toward DS 4. If family members did not know what made the sounds they heard, they described the sound or mimicked it; this often led to a family discussion and sharing of ideas about what animals or other natural objects produced the sounds.</td>
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<tr>
<th>Discovery Spot #4: “Shagbark Hickory bench”</th>
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<tbody>
<tr>
<td><strong>Content, prompts, and interactive widgets:</strong> This Discovery Spot acted as a follow up to DS 3: it challenged families to transfer the tree knowledge they gained at DS 3 to determine whether or not the Shagbark Hickory at DS 4 was a deciduous or evergreen tree. The family was prompted to look up at the leaves of the Shagbark Hickory in front of them and determine whether it was an evergreen, conifer, deciduous, or none of these via a quiz widget.</td>
</tr>
<tr>
<td><strong>Learning objective(s):</strong></td>
</tr>
<tr>
<td>1) To identify whether a tree is deciduous or evergreen by looking at the leaves of a tree.</td>
</tr>
<tr>
<td><strong>Observed learner outcome(s):</strong></td>
</tr>
<tr>
<td>1) Families observed the leaves of the Shagbark Hickory tree and correctly selected “deciduous” on the quiz widget.</td>
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<tr>
<th>On the Move activity in between DS 4 and DS 5</th>
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<tbody>
<tr>
<td><strong>Content, prompts, and interactive widgets:</strong> The walk between DS 4 and DS 5 introduced families to the boardwalk, or wooded walkway, that is part of this trail. Families were challenged to find and check off (using a checklist widget) 10 different natural objects commonly seen along the boardwalk through a scavenger hunt activity.</td>
</tr>
<tr>
<td><strong>Learning objective(s):</strong></td>
</tr>
<tr>
<td>1) To explore and observe the diverse biota commonly present along the SCEC boardwalk.</td>
</tr>
<tr>
<td><strong>Observed learner outcome(s):</strong></td>
</tr>
</tbody>
</table>
1) Families worked together (i.e., by pointing or calling out) to search for certain plants or animals illustrated in the scavenger hunt list. At least one person in the family used the checklist widget to keep track of the different natural objects they spotted.

Discovery Spot #5: “Loon’s Lookout”

Content, prompts, and interactive widgets: This DS is located at a spot along the boardwalk that looks out over “Lakebed” Perez (the lake was drained in 2008 due to structural problems with the dam). Images of different species of turtles that live in the lakebed were shown and explanations about the turtles’ different physical features (e.g., shells, colors) were included. A second sketchpad widget was embedded into this section of the e-Trailguide and asked families to work together to draw a picture of what the area would look like when the lake returns\[^8\], including the species of turtles that would live in the lake.

Learning objective(s):
1) To understand the physical differences between terrestrial turtle shells and aquatic turtle shells;
2) To identify at least one type of aquatic turtle native to Pennsylvania.

Observed learner outcome(s):
1) Families read the information about turtle shells and discussed the differences between terrestrial and aquatic turtles.
2) In their sketchpad widget drawings, families included either a painted turtle or a snapping turtle (both aquatic) into their drawing of the future Lake Perez.

On the Move activity in between DS 5 and DS 6

Content, prompts, and interactive widgets: As families walked along the remainder of the boardwalk, they were prompted to “be an entomologist” using the notepad widget. They were challenged to closely observe the plants along the boardwalk for signs of insect activity and to keep notes about the insects they saw and the physical characteristics of those insects. To assist them, an insect “key” was included that showed images of common butterflies, dragonflies, and damselflies in the area.

Learning objective(s):
1) To closely observe plants for signs of insect activity;
2) To identify at least one type of insect using the insect “key” included in the e-Trailguide.

Observed learner outcome(s):
1) Together, families spent time observing at least one insect and documented the visible features of the insect using the notepad widget.
2) Families were successfully able to identify one type of insect they saw by using the insect “key” included in the e-Trailguide.

\[^8\] The lake returned in spring 2015, which was after data collection for this study was completed.
**Discovery Spot #6: “Hemlock Forest”**

**Content, prompts, and interactive widgets:** Families learned about the state tree of Pennsylvania (eastern hemlock) and the invasive insect species, the woolly adelgid, that is hurting hemlocks along the east coast of the United States. Information about how they can help hemlocks in their own neighborhoods was also included. Families also engaged with three quiz widgets to test their knowledge of other Pennsylvania key species (state bird, state flower, and state mammal).

**Learning objective(s):**
1) To understand the current state of health of eastern hemlocks in the eastern US;
2) To identify common key species in Pennsylvania.

**Observed learner outcome(s):**
1) Families read the information about eastern hemlocks and both verbally and non-verbally (i.e., pointing, touching) connected what they read in the e-Trailguide to the hemlocks surrounding them. They also engaged with the interactive photo widget included in this section.
2) Families completed the three quiz widgets to determine the state bird, state flower, and state mammal of Pennsylvania.

**On the Move activity during the walk back to the trailhead**

**Content, prompts, and interactive widgets:** As families walked back to the start of the trail, they were challenged with the following questions to discuss as a family: “What do you see along the trail that you did not see before?” “Are there trees or plants that you can identify?” “Do you see small signs of life, like insects, as you look around you?” “What do you hear?”

**Learning objective(s):**
1) To connect what they saw during their walk down the trail and the information from the e-Trailguide to new observations and new understandings as they walk back up the trail.

**Observed learner outcome(s):**
1) Families shared with one another new things that they learned; they pointed out and identified natural objects that they had seen on the walk down; they made new observations; and they talked about their e-Trailguide experience.
APPENDIX B

Research Tools

Figure B1: Recruitment email sent to the Shaver’s Creek member listserv.
Post-hike family interview

1) What was your favorite part of using the e-Trailguide on this hike today?

2) Was there something new you learned about Pennsylvania plants or animals? What? (Probe: child/children and adults)

3) What was the coolest thing you saw while out on the trail?

4) Did you like using the iPad during your hike? If yes, why? If no, why?

5) What would you change about the e-Trailguide on the iPad? (Add something, take out something, etc.)

Figure B2: Post-hike family interview form.
VITA

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Research Project & Experience


2011: Co-led data collection, organization, and analysis. Tree Investigators. Penn State Arboretum. Dr. Heather Zimmerman (PI) & Dr. Susan Land (Co-PI).

2011: Led data collection organization, and analysis. Family Learning and Exploration Tools Project, Phase II. Shaver’s Creek Environmental Center. Dr. Heather Zimmerman (PI).

2011: Co-led data collection, organization, and analysis. Family Learning and Exploration Tools Project, Phase I. Shaver’s Creek Environmental Center. Dr. Heather Zimmerman (PI).