Supporting Conceptual Understandings Outdoors: Findings from the Tree Investigators Mobile Project

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Abstract: This design-based research project examines two iterations of *Tree Investigators,* which supports science learning with mobile devices in an arboretum. Researchers coded videorecords of children and parents (n=40 people) to understand how digital augmentations influenced observation and understandings about trees. In Iteration 1, learners focused on tree identification; Iteration 2, learners focused on tree life cycles. We focus here on Iteration 2, where children completed a pre- and post-test assessment and participated in a photographic collage task to document a tree's life cycle. Findings suggested that a touch-screen conceptual organizer that provided a model of the life cycle, along with text and contrastive images, supported people's observations. The learners also collected photographic evidence of life cycle stages in a knowledge generative task. Increases in factual and conceptual knowledge of the life cycle were observed pre- and post-test; however, learners did not show consistent appropriation of new scientific vocabulary.

Our *Tree Investigators* research and design intention is to engage people in science learning during their out-of-school time with the use of digital materials deployed on mobile computers. Our goals are to support people so that they become (a) adept *observers* who can coordinate scientific knowledge with their sensory experiences in the outdoors and (b) proficient *explainers* of scientific phenomena related to ecological systems based on their interactions with plants and animals. We adopted mobile computers given their increasing ubiquity in everyday life (Warschauer & Matuchniak, 2010) and increasing reach of mobile computers into families of modest socioeconomic means (Yardi & Bruckman, 2012).

Theoretical Framework

To support learners in outdoor environments with mobile computers, our theoretical framework brings together research findings about technological supports for science learning (Chen, Kao, & Sheu, 2005; Liu et al., 2009; Rogers et al., 2004; Squire & Jan, 2007; Squire & Klopfer, 2007; Tan et al., 2007) and research findings from place-based education (Gruenewald, 2003; Lim & Calabrese Barton, 2006; Semken, 2005; Smith, 2002).

Supporting Learners with Mobile Computers

Researchers have studied learner engagement, content knowledge acquisition, and enjoyment in outdoor settings including historical locations (Tan & So, 2011), woodlands (Rogers et al., 2004), wetlands (Liu et al., 2009), parks (Tan et al., 2007), and gardens (Chen, Kao, & Sheu, 2005). We also consider findings related to learner engagement that come from those mobile learning projects that augment real-world locations with virtual data and gaming scenarios (e.g., Dunleavy & Dede, 2014; Klopfer, 2008; Squire & Jan, 2007). Researchers have reported design elements for mobile devices that encourage data collection (Squire & Klopfer, 2007) and engagement in discourse (Hsi, 2003; Rogers, et al, 2004; Tan et al., 2011) that support science learning.

Place-Based Education

Place-based education is a pedagogical perspective that advocates for designing learning within and about local communities (Greunwald, 2003; Smith, 2002; Sobel, 2004). Researchers (e.g., Lim & Calabrese Barton, 2006) use place-based education to understand the connections between abstracted, disciplinary knowledge and people's local knowledge and practices (Gruenewald, 2003). Place-based education in school (e.g., Sobel, 2004) advocates designing curriculum to make school-based learning pertinent to local issues and considerations. Place-based education in out-of-school settings (e.g., Tzou, Scalone, & Bell, 2010) highlights the problems that arise when the focus on disciplinary concepts disregards the manner in which learners' lives are embedded within local systems, histories, and interactions.

Semken (2005) offers a framework for science-related place-based teaching with five aspects. Semken suggests place-based teaching: (1) focuses on a setting's natural history, (2) considers the varied meanings that a place has for people who use it, (3) incorporates explorations that use authentic artifacts and representations, (4) includes ecologically and culturally appropriate pedagogy and (5) acknowledges and fosters a "sense of place" of learners, educators, and others. We adopt Semken's perspectives on place-based education to connect out-of-school learners using mobile computers to the outdoor settings in their communities. Specifically, we used mobile devices to connect learners to scientific practices and concepts embedded within a natural garden setting of historical and ecological importance—especially in a historically important old growth stand of trees.

Methodology

We conducted two iterations of a design-based research project at an arboretum (n=40) where we collected 7.5 total hours of video. Video data were analyzed to elucidate the role of digital media deployed by mobile devices to support people in scientific observations and explanation-building talk. Our goal was to advance theory related to learning outside of school and to distill design principles related to the development of mobile computer apps and websites that can enhance families' and youths' experiences as they explore the outdoors.

Research Question

Our research investigates the following questions: How do young people and their families talk together about trees and life cycles while using the Tree Investigators mobile computer app? How does a knowledge-building photographic collage task support the development of conceptual understandings of the stages of trees' life cycles for children visiting an arboretum?

Design for Mobile Computers: Tree Investigators

In Iterations 1 and 2 of Tree Investigators, an onsite naturalist directed the families to observe trees and to coordinate their place-based observations with disciplinary information delivered by a mobile computer. Both iterations included child-friendly text, consisting of short sentences; the text's reading level was determined by the Flesch-Kincaid rating system to be at a 3rd grade level. A Ph.D.-level botanist reviewed the tree content for scientific accuracy. The mobile computers augmented seasonally or developmentally unavailable aspects of trees—mostly via digital photographs and descriptive text.

We designed Tree Investigators in Iteration 1 as a mobile website (see Figure 1) that used augmented reality (images and text layered onto the physical space) to support families to develop observations and explanations related to tree biodiversity. Iteration 1 was organized by tree species with each of eight species having its own online materials accessed by a QR code. We re-designed Tree Investigators in Iteration 2 as a mobile app (see Figures 3 and 4) that did not rely on the Internet. Iteration 2 was organized conceptually by aspects of a tree's life cycle in contrast to Iteration 1's species-centered presentation of content. Learners began Iteration 2 with observing evergreen and deciduous tree in a botanical garden and coordinated this sensory information with the conceptual model of a tree's life cycle on a mobile app (Figure 3 and 4). The final Iteration 2 activity included using a photographic collage app where learners collected photographic examples of the stages of a tree's life cycle (i.e., seed, seedling, sapling, mature tree, and dead/snag tree) in a forested area.

Participants and Setting

Across both Iterations, 40 people participated. The participants in Iteration 1 were 25 people from 11 families and the participants in Iteration 2 were 15 people from 6 families. The children were 6 to 12 years old. Given that we designed Tree Investigators for users of informal sites, we strategically recruited families who were current users of nature centers and arboretums for intergenerational education and recreation.

The research setting was the Arboretum at Penn State, which includes various groomed and curated gardens as well as a stand of old-growth hardwood trees with a network of trails. The oldest trees in this 42-acre stand pre-date the construction of the University campus in 1859. Given the logging in this area for development and for the iron industry throughout the 1800s, this old-growth stand of trees holds a protected status due to the historical, scientific, and cultural value to the area. Iteration 1 used the trees in the groomed gardens while Iteration 2 used both the groomed gardens and the old-growth forested area. Inclusion of the old-growth forest allowed for a clearer realization of our study's place-based education aims and for the learners to see actual tree specimens in all stages of the life cycle (e.g., seed, seedling, sapling, mature, dead).

Data Collection and Analysis

Families were videorecorded during a 1-hour guided tour using augmented photographic and textual elements of Tree Investigators on iPad tablet computers and iPod Internet-enabled mp3-players. Given our interest to support science learning in informal spaces, for Iterations 1 and 2 we employed an analytical framework of conversation elaboration (Leinhardt & Crowley, 1998), with talk as both a product and the process of learning. We used a theoretical-driven approach to code transcripts for evidence of observational and explanation-building talk that was derived from Allen (2002): *perceptual talk* (identification, naming, and describing species); *conceptual talk* (inference, interpretation, and prediction); *connecting talk* (life, knowledge, and inter-species connections); and *affect talk* (emotional expressions of positive or negative feelings). We conducted a detailed line-by-line analysis of families' talk using the Allen (2002) coding analysis framework.

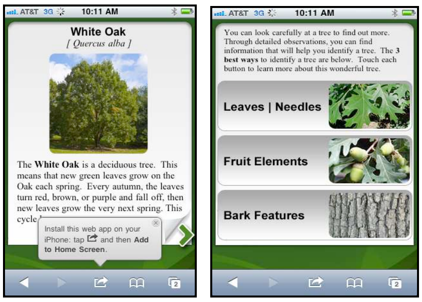
In Iteration 2, we conducted two additional analyses. First, given our interest in digital photographs to foster the connection of local, place-based knowledge to domain knowledge in science (Land, Smith &

Zimmerman, 2013), the children in Iteration 2 took pictures of elements of the forest at the Arboretum and made a tree life cycle photo collage. The photo collages had empty slots for photographs, and the families were tasked to find an example of each stages of the life cycle in their collage, in effect requiring them to apply what they had learned to observations in the forest. We analyzed the debrief interview and the actual collage artifacts. Second, we conducted a brief (7-10 minute) pre- and post-test that was implemented as a short interview.

Findings

Iteration 1: Photographic Images Supporting Observations and Understandings

In Iteration 1, children and their families used the Tree Investigator's mobile media to connect their observations of trees to new understandings of related biological concepts. Given our goals to enhance place-based understandings, families used the mobile devices in the Arboretum to coordinate their on-site observations with abstracted scientific knowledge. Images and prompts (see Figure 1) that were part of a mobile website were used to support family observational practice and to develop explanations about the differences in trees and their characteristics related to biodiversity. As reported in Zimmerman, et al. (2013), Iteration 1 supported learners to: (a) identify relevant aspects of the trees on-site; (b) articulate an understanding of scientifically-relevant characteristics of trees' natural history (Figure 2); and (c) identify salient differences between evergreen and deciduous trees using both mobile images and specimens at the Arboretum. Our findings suggested the importance of augmented photographic elements of trees that were not seasonally or developmentally visible as contrastive cases to the onsite tree specimens.



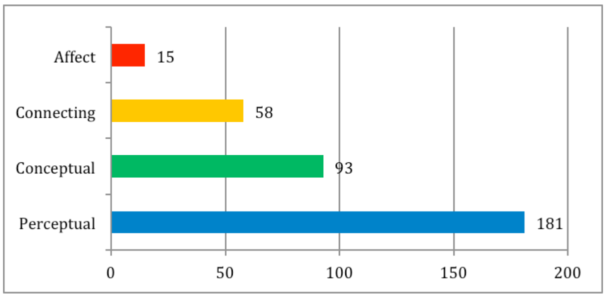
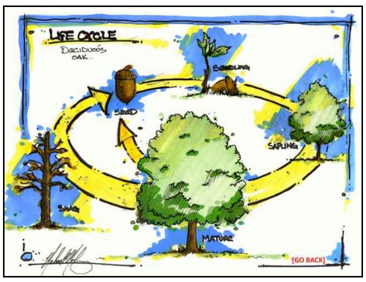
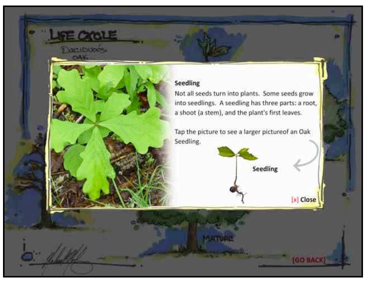


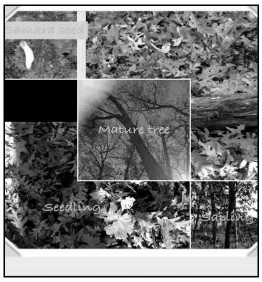
Figure 1. The Iteration 1 interface for the white oak. Figure 2. Chart of types of talk from Iteration 1 families.

Iteration 2: Conceptual Organizer Supporting Observations and Understandings

Iteration 2 was designed to address limitations identified from Iteration 1 and to expand the focus to life cycle elements due to families' observed interests. In Iteration 1, observations of characteristics of trees in the Arboretum (e.g., a pine cone that was open with its seeds dropped vs. a closed pine cone on a tree) often led to discussions of life cycle concepts. Thus, Iteration 2 focused on: (a) providing a graphic organizer (Quintana et al., 2004) of trees' life cycle processes (see Figure 3); (b) indexing science content to local, indigenous trees (Semken, 2005); and (c) including a generative task (Land, Smith, & Zimmerman, 2013) whereby participants used the photographic capabilities of the iPad to document the various parts of the life cycle processes in an old-growth forest (see Figure 5 for a participant's life cycle collage created at the Arboretum).







Figures 3, 4 and 5. Conceptual organizer screen (left); Conceptual organizer seedling (middle); Participant's life cycle collage created onsite with photographs taken at the Arboretum using an iPad (right).

We report Iteration 2 findings from three data sources: (a) an assessment of declarative and conceptual knowledge, (b) photo collage artifacts developed by each participant, and (c) videos of participants interacting at the Arboretum and a final interview. The participating children were given an 8-item assessment of life cycle facts and concepts, provided in an open-ended response format, both before and immediately following the learning activities. Learners received 1 point for each correct answer, and 0 points for an incorrect answer or no response, for a total possible score of 23 points. The pre-test mean score was 4.5 points (standard deviation 2.6) while the post-test mean was 14.3 (standard deviation 2.7) showing significant improvements (t = -8.647, p < 0.001) after the exploration (see Table 1).

Table 1: Paired-samples *t*-test of the pre- and post-test scores

	Mean	N	S.D.	*T*
Pre-test scores	4.500	10	2.6352	-8.647***
Post-test scores	14.300	10	2.7101	

****p* < .001

For the photo collages, we analyzed artifacts and videorecords including: (a) the processes learners used to create the photo collages, (b) elicitation interviews with the children about the photo collages, and (c) the actual photo collages created by the learners. An analysis of the artifacts showed that participating families accurately applied what they had learned during the Tree Investigator activities to identify exemplars of the various life cycle stages in the old growth hardwood forest. In the video analysis, we documented that families shared their life cycle observations aloud with each other and with other families. For example, a mother and daughter who found an oak seedling offered the seedling to other families to include on their photo collages. Overall, we found that the process of creating the photo collage artifacts was a collaborative endeavor between children and adults, child and child, and or child and naturalist. Some children consulted the naturalist to ensure that they were photographing a sapling versus a seedling, as they observed tree species in the woods that they had not encountered during learning with mobile app (which focused on the oak tree). This sapling and seedling distinction was a difficult conception for children in the debriefing interviews, with many children simply stating that the sapling was a "bigger" or "older" tree than the seedling. (The seedling/sapling distinction was also a challenge on the knowledge assessment.) While a few science vocabulary words proved to be difficult for some children to appropriate, the children consistently explained the life cycle conceptually during their debriefing interview. For example, during their interviews, often children used general terms to describe the tree life cycle— such as the seed grew in steps to become a grown tree capable of growing flowers and seed and then trees eventually died. All participating children were able to take photographs and create a life cycle collage; in fact, two learners took over 100 additional photographs while on-site during their visit. These two children did engage in learning tree life cycle concepts even while taking these extra photographs.

Discussion

As indicated by our Tree Investigators Iterations 1 and 2 preliminary findings, mobile devices can be used to deliver science content, support families' scientific talk, provide access to related knowledge not always visible in a place via augmentations, and create artifacts on-the-go through mobile apps. Across the Iterations of Tree Investigators research, we found that mobile devices enabled the engagement with actual specimens at the Arboretum. Researchers have expressed concern about "heads-down" technologies (e.g., Hsi, 2003), where learners spend time looking at the computer, rather than engaged with the scientific phenomenon. Here, we found that the images and text, when supported by a naturalist, encouraged visitors to engage with the trees and other plants around them. Place-based educational aims (e.g., Semken, 2005) that guided our design were successful in using the specific examples at the Arboretum as exemplars, as evidenced by the fact that learners looked for and found seeds, seedlings, saplings, mature trees, and snags (as well as fallen dead trees).

Conclusion

The contribution of our design-based research study is in informing technologically-enhanced designs for learning outside of school. While small in scope, this study suggests that place-based pedagogical efforts that utilize mobile devices to support informal science education can enhance families' learning experiences in the outdoors. We advocate for additional research, based on the results from our exploratory study, on how mobile technologies can be used by families and other learners in out-of-school venues in relation to the creation of photographic artifacts, the need for scaffolding (Yoon, et al, 2012), and the role of different app structures.

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