Photo-Capture and Annotations Supporting Observations in Outdoor Mobile Learning

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Abstract

Our research builds upon work on designing technological supports for science learning outdoors using mobile devices. In our research, people use mobile technology to help them look deeply at the natural world to engage in observation, identification, articulation, and explanation-building practices. Given that scientific observation is complex for children, we are exploring the role of photo annotation in informal learning settings to support identifying and observing scientific features of trees in the woods. This design-based research project explores how various mobile learning scaffolds for photo-capture and annotation support learning and observational practices of tree life cycle across two iterations of research and design. Findings suggested that (a) making connections between concepts introduced on the mobile app and application of them "in the wild" was challenging for learners without explicit social and/or technological support during identification tasks; specifically, appropriation of scientific vocabulary, noticing relevant features, and accurately identifying life cycle stages needed structured, on-demand support; and (b) significant gains in knowledge of tree life cycles were observed from pretest to. Findings point to empirically-based implications for design of mobile learning outdoors.

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Advances in mobile technology have led to conceptualizations of learning that entail new forms of engagement that are afforded by on-demand, contextualized, and media-rich interactions (Sharples, 2010; Squire & Klopfer, 2007). Mobile learning perspectives are shaped by the overarching view that mobile computers afford contextual sensitivity to, and hence potential seamlessness with, people's activities (Milrad et al., 2013; Sharples & Pea, 2014). Context-sensitive learning (Sharples), also referred to as context awareness (Dunleavy & Dede, 2014), suggests that natural settings, when augmented by mobile resources, can foster different kinds of learning interactions and experiences. Sharples' conceptualization presumes that context encompasses more than solely location; instead, he suggests that, by moving computational tools off the desktop and into the world where people participate in activities, rich opportunities for distributing learning across socio-technical systems of people, artifacts, technologies, and environment are afforded. In this view of context-sensitive learning, activities and thinking are mediated by designed artifacts and social interactions within the educational environment.

We have conducted a series of design-based research projects (Authors et al., 2013a; Authors et al., 2014) to design mobile technologies to augment scientifically-meaningful experiences for youth and families during their out-of-school time in outdoor informal learning institutions (ILIs) (Bell et al., 2009; Falk & Dierking, 2000). Our goals are to support young people and their families 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 cycles. 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: Supporting Observation and Explanation Practices Outdoors

Learning research in informal learning institutions (ILIs) (Paris, 2002) has focused on the ways that people learn with and from objects, especially the observation of objects (Bell, et al, 2009). Research has found that when people are learning to make scientific observations from objects, novices need support to see the object and its related phenomena in new ways (Eberbach & Crowley, 2009; Smith & Reiser, 2005). To help learners look deeply at the natural world, people need support in observation, identification, articulation, and explanation-building practices (Eberbach & Crowley, 2009; Lehrer & Schauble, 2006).

Our research uses technological supports for science learning using mobile devices (Chen, Kao, & Sheu, 2005; Liu et al., 2009; Rogers et al., 2004; Squire & Klopfer, 2007; Tan et al., 2007) to support science inquiry (Quintana et al., 2004; Author & Colleague, 2003). Prior mobile learning studies in outdoor settings have augmented the natural space to enhance access to information, record field observations, search databases to identify species present, and to personalize learning (Chen et al.; Rogers et al.). In some projects, the mobile technology serves a stand-alone role for self-guided exploration of specimens. For instance, Chen et al. developed a mobile image-retrieval system to support bird watching and butterfly watching, with the goal of simulating the learning support provided by a naturalist. Likewise, Liu et al. used mobile devices for learners in Taiwan to learn more about ponds using close-up images and detailed information tied to aquatic plants in the habitat. Research findings across these studies demonstrated that learners increased factual knowledge of the plants (Liu et al), identification skills (Chen et al.), engagement with nature (Rogers et al., 2004) and conceptual understanding (Liu et al.) — suggesting that augmenting natural settings with technology enhances learning.

Technology scaffolds can serve many purposes to support thinking; we adapt three purposes from Quintana et al. (2004): (1) f*acilitate learner sense-making* as learners participate in science practices; (2) *provide structure for complex tasks* to both constrain the focus of the learning activity and to channel the learners' attention to the science phenomena of interest; and (3) *support articulation and reflection* using human guidance and technology representations such as photos, graphs, diagrams.

Research Purpose

Given that observation is challenging, we are exploring the role of technology tools in mobile learning contexts to support novice learners to see trees scientifically. Research has shown that making annotations over photographs and videos (Chen, Hwang, & Wang, 2012; Sung, Hwang, Liu, & Chiu, 2014; Stevens, & Hall, 1997; Stevens, & Martell, 2003) supports learners to observe disciplinary content. The mobile annotation strategies we employed were designed to support learners to identify and observe scientific features of trees by annotating photographs they took in the woods. Our research investigated the following overarching question: *How do various scaffolding strategies for photo-capture and annotations support learning and observational practices of tree life cycles?*

Methods

Our overarching methodology is design-based research (Sandoval & Bell, 2004; Hoadley, 2004), which informs theory and practice through iterative implementations. Our research team worked for over four years with an arboretum and nature center on educational programming. We conducted two design research studies focused on the role of photo capture and annotation by children in the outdoors while learning about tree life cycles.

Participants

Across the two studies, 28 people participated. The participants in Study A were 15 people from 6 families (children 6-12 years old); and Study B had 13 children from 12 families (9-12 years old). Given that we designed our mobile materials for ILIs, we strategically recruited people who were current users of nature centers for intergenerational education and recreation.

Setting

The site for Study A was the Arboretum at Study Site, which includes curated gardens and an old-growth hardwood forest. The oldest trees pre-date 1859 and hold a protected status due to its historical and cultural value. Study A used both the curated gardens and the old-growth forest. Study B was held at Study Site Environmental Center during a summer camp, which included many kilometers of trails. The Nature Center and Arboretum have a hardwood forest that allowed for learners to see trees in all *five stages of a tree's lifecycle* (e.g., seed, seeding, sapling, mature, dead).

The Mobile Learning Environment and Photo Annotation Strategy

Across both iterations, a naturalist guided people to observe trees and to coordinate their observations with scientific information delivered by a mobile device. The naturalists were qualified (M.Ed., M.S.) instructors of environmental education or plant sciences at our

University and were members of our research and development team from the outset. To enact the theory within our design, the naturalist worked from a script that detailed questioning strategies and activity sequences for the learning environment. The naturalist led groups of 5-10 learners at a time through a tour lasting approximately 1 hour. All studies utilized iPad 2's or iPad Mini's to provide content information tied to specimens at the site, and to augment seasonally or developmentally unavailable characteristics of trees via digital photographs and text. The naturalist directed learners as to when and how to use the mobile materials. A Ph.D-level botanist reviewed the content presented within the socio-technical system for scientific accuracy. Figure 1a-d shows screen captures of the mobile learning interfaces for the two studies.

--figure 1a-1d--

A Ph.D-level botanist reviewed the content presented within the mobile resources for scientific accuracy. The mobile resources were designed to support the following three goals:

Support learners to make scientific observations outdoors. The mobile technology served three main purposes to support observations. First, we designed digital resources to channel the learners' attention (Pea, 2004) to specific features of the environment that highlight disciplinary concepts (Quintana et al., 2004). Without a foundation of disciplinary knowledge, it is difficult for novices to know what is relevant to attend to in a complex setting (Author, 2000; Smith & Resier, 2005). In response, we designed text and photographs to assist learners to notice the features of the environment needed for discerning types of trees and the stages of a tree in its life cycle. For instance, we provided photos of a prototypical example of a pine seedling, bark texture, and leaf size and shape. Likewise, we provided contrasting images that revealed important visual distinctions (Bransford et al., 2000) that might otherwise go unnoticed (e.g., different branching structures). Second, given that the outdoor landscape is constantly changing in response to the seasons, weather, growth variations, and animal migration patterns, it is impossible to observe all important characteristics of trees in one visit to an informal site. Accordingly, we provided images to help learners visualize non-visible scientific elements of the gardens or forest (Rogers et al., 2004), such as tree characteristics across seasons and life cycles stages.

Use conceptual models to foster conceptual connections. Our mobile resources scaffolded learners to make explicit connections between what they observe and broader ecological concepts. One mobile technology strategy we used to foster conceptual connections across specimens was the inclusion of a graphic organizer (Quintana et al., 2004) of the tree life cycle for two species (pine vs. oak) (Figure 1b). This provided an implied structure to the content flow from seed to seedling to sapling to mature tree and then to snag, allowing learners to recognize how each step of the life cycle was connected to other steps as well as the whole life cycle. In contrast to mobile learning approaches that provide content tied to objects (e.g., audio about a specific object at a museum), we sought to support broader conceptual applications across multiple objects and settings.

Scaffold complex disciplinary practices in natural settings. We incorporated strategies and tools that enabled learners to participate in complex practices of identification that normally would have been challenging or imprecise without such support (Pea, 2004). One form of mobile technology support included making identification practices explicit during learners' interactions with the mobile resources (Quintana et al., 2004). For example, we used existing tools or developed customized tools to support learners to capture and annotate photographs of their observations in order to make their thinking visible. In Study B, we designed a photo-capture tool directly within the mobile app (see figure 1c and 1d), which also included a checklist of observations that were superimposed onto learners' photographs of trees in various life cycles (described in more detail later). These elements supported learners during minimally-structured, independent explorations in the forest to both identify trees at their life cycle stages and to document and share them with the group and naturalist. This provided a method for the naturalist to monitor what learners were observing and interpreting. The naturalist guided the progression of activities across various settings and prompted learners to provide evidence for their identification.

Data Collection and Analyses

All people were videorecorded during their guided tours and follow-up interviews. We collected 5.5 total hours of video in Study A and B. Video data were transcribed line-by-line and analyzed how photo-capture and annotations supported people in scientific observations as they explore the outdoors. Video records were collected and analyzed in keeping with ethical recommendation for research (Derry, et al., 2010).

We analyzed scores from an 8-item pretest-posttest assessment on tree life cycle knowledge (open-ended format) using paired t-tests (n=25). The participating children were given an 8-item open-ended assessment of life cycle facts and concepts, both before and immediately following the learning activities. The assessment investigated knowledge acquisition about tree life cycles and included questions like "What are the seeds of an oak tree called?" and "What holds the seeds of a pine tree?" For these types of questions, one point was assigned for each correct answer. Other questions asked participants to list as many characteristics as they could about tree life cycles: "List the stages of the life cycle for trees" and "What are some of the differences between sapling and mature trees? List all the differences you can think of.” For these questions, one point was given for each correct characteristic or stage listed. The points for each item were summed to form a score for the knowledge assessment test, and all students were measured individually. The two researchers scored each test together to ensure agreement on the score. We also examined photo collage artifacts created by the children of their photographic evidence of tree life cycle stages.

Results

Based on our prior studies (Authors, et al, 2013; 2014), we re-designed a mobile app (Figure 1a) that did not rely on the Internet, since Internet connections were not reliable outdoors in the woods. Study A and B redesign focused on: (a) providing a graphic organizer (Quintana et al., 2004) of trees’ life cycle (Figure 1a) and (b) including a generative task (Authors & Colleague, 2013b) using the photographic capabilities of the iPad to document life cycle stages outdoors.

Study A: Conceptual Organizer with Photographs

Learners began with the naturalist leading them to observe an evergreen and deciduous tree in the Arboretum and coordinate this sensory information with the conceptual model of a tree’s life cycle on the mobile app. To foster conceptual connections across specimens, we included a graphic organizer (Quintana et al., 2004) of the tree life cycle for the two species (Figure 2b), which provided a conceptual structure to the content from seed to seedling to sapling to mature tree and then to snag, allowing learners to recognize how each step of the life cycle was connected to other steps as well as the whole life cycle. The naturalist directed learners’ attention to the app at each tree and guided them through the material.

Study A presented learners with the challenge to identify evidence of tree life cycles in the nearby forest, an activity that required application of concepts from one setting to another (Bransford et al, 2000). Learners extended what they experienced in the structured garden environment that used pre-selected trees to a more complex woodland setting with new species and elements not previously encountered. We added a culminating activity that supported learner-created artifacts with mobile technologies, given that this is a common strategy used to support conceptual integration in classroom, learner-centered frameworks (Author & Colleague, 2012; Quintana et al., 2004). Participants used the photographic capabilities of the iPad to document various life cycle processes in an old-growth forest. Learners explored the environment in an unstructured way to capture observations of tree life cycles by taking photographs and organizing them into a digital photo collage using the app *InstaCollage*. The naturalist circulated among the families to provide assistance as needed during the photo capture task. Our goals were to support child-directed engagement with science practices in ways that required them to *apply concepts* to a new setting (the forest), as well as *create representations* of their understanding, hence supporting conceptual talk.

Pretest-Posttest. The participating children were given an 8-item open-ended assessment of life cycle facts and concepts, both before and immediately following the learning activities. Table 1 reports a significant gain in knowledge score ($t = -8.647$, $p < 0.001$), and Cohen's effect size value ($d = 3.67$) suggests a high practical significance.

--- insert Table 1 here---

Video Analyses of Identification Practices. We analyzed video of (a) the processes learners used to identify life cycle stages in the woods; (b) elicitation interviews about the photo collages; and (c) the completed photo collage artifacts. Creating the photo collage (Figure 1b) was a collaborative endeavor between the children, adults, and naturalist. Learners applied what they had learned with the mobile app to identify specimens in the forest that were exemplars of the five life cycle stages. Learners shared their life cycle observations with each other. For example, a mother and daughter who found an oak seedling offered the seedling as an example to include on others' photo collages.

The identification process in the forest was challenging, as evidenced by frequent consultations with the naturalist and parents for identifying stages. The complex forest setting meant observing specimens that they had not encountered during learning with mobile app. The distinction between sapling and seedling was difficult for children. Some children simply (but correctly) concluding that the sapling was an "older" tree than the seedling, while others simply could not recall the criteria for distinguishing seedlings from saplings. We noted that this seedling/sapling distinction was also a challenge on the assessment.

In some instances, children could correctly identify a life cycle stage, but the criteria provided for its selection was irrelevant. This is shown in the following excerpt with Emory (age 9) and Rosa (mother):

1. Rosa: What about a mature tree?
2. Emory: I'm trying to find one right now. Like right there.
3. Rosa: You think that is a mature tree?
4. Emory: Cause, like that one with the red leaves on it. Because that has red leaves on it and that usually means it is mature. Or some of those yellow trees over there.

Although her identification of a mature tree was accurate (line 4), Emory attended to characteristics that were relevant for seasonal cycles (line 6), but not for identifying a tree's life cycle, meaning she did not accurately *explain* the evidence for her identification. Similarly, other children, when asked to explain their photo collage selections, relied on simple criteria such as "the tree is mature because it is big", and or were unable to apply life cycle vocabulary. Pairing criteria for conceptually distinguishing trees and identifying them in the forest was challenging for most learners observed.

Although a few vocabulary words proved to be difficult for some children to appropriate, they consistently explained the ideas of life cycle conceptually during their debriefing interview—in general terms such as the seed grew to become a grown tree capable of growing seeds and trees eventually died. All the children were able to take photographs and create a collage with assistance from adults and each other. In fact, two learners took over 100 additional photographs during their visit, yet both still engaged in learning tree lifecycle concepts while taking these photographs. These observations point to the influence of learner agency and child-centered interactions using mobile technologies.

Implications for Design of Study B. Based on Study A results, we made the following design change: We added explicit annotation scaffolds (Figure 1c) to support making connections between in-field observations and conceptual material (Sung et al., 2014) using pre-identified criteria for the 5 life cycle stages that could be applied easily outdoors as annotated check boxes. The checked items annotated the learners' photos, which were compiled into a photo-collage (Figure 1d).

Study B: Conceptual Organizer With Annotations

Study B used a similar set of mobile materials and procedures as Study A, but the setting changed to a summer camp at an environmental center. This new setting enabled us to extend our design strategies to peer learning interactions. As in Study A, the naturalist led children on a structured tour of two mature trees: an oak and a pine tree, but in this new forest setting, the naturalist was often able to point out nearby trees on the trail at other stages of the life cycle (e.g., saplings). Unique to Study B, children used a customized tool that was embedded into our mobile app for managing the complexity of capturing, organizing, and annotating photographs around tree life cycle concepts at the time of identification. This tool embedded pre-identified criteria for distinguishing life cycle stages that can be applied quickly in the forest as "check boxes" (figure 1c); Criteria for each life cycle stage were visible to learners as they took photos, which were "checked off" as they saw them. The checked items annotated the learners' photos, which were compiled together into a collage that mirrored the conceptual life cycle model (figure 1d). The naturalist circulated among the children to provide assistance as needed during the photo capture task.

Pretest-Posttest. Similar to Study A, Study B (Table 1 above) reports a significant gain in knowledge score ($t = 11.5022$, $p < 0.001$), with very high effect size ($d = 2.46$).

Video Analyses of Identification Practices. We analyzed video of the processes the children at camp used to identify life cycle stages and their elicitation interviews about the photo collages. Regarding identification practices of tree life cycles, the annotation scaffolds assisted learners in articulating criteria for their selection at the point of photo capture, as shown by the following excerpt with two children:

1. Migel: We are doing seedling now.

2. Beth: wait, you don't know what we have to look for, we have to look for a root, a stem and at least one leaf.

3. (Migel holds tablet)

4. Beth: (over his shoulder) It has to have a root, a stem and at least one leaf.

During photo elicitation interviews, these two peers and their third partner elaborated evidence for their artifacts:

1. Migel: And we knew this one was a, um, a sssssseedling, because we knew that the tree that it was smaller, than a sapling but bigger than a pine cone.
2. Researcher: So what were the criteria that you looked for when deciding that was a seedling?
3. Migel: Well it was less than 2 ft. It had less leaves than a sapling.
4. Researcher: Okay, so let's move on to your . . .
5. Beth: The sapling is bigger than the seedling but smaller than the mature tree. And also taller than two feet which is how-
6. Researcher: Any other criteria that you use when you were trying to decide if it was a sapling?
7. Migel: We, really thought about it.
8. Caroline: that you could put your hands around it [the trunk].

These kinds of conversations, while both identifying species in the forest and later explaining them, were present across most participants, reflecting more integrated connections between observations, explanations, and the environmental setting.

Discussion and Implications

As indicated by our findings, mobile devices enabled engagement with concepts related to trees and observation in the forests. Researchers have expressed concern about “heads-down” interactions with technologies (e.g., Hsi, 2003), where learners spend time engaged with the screen, rather than in the ILI. We found that the photo capture tool—when supported by with annotation scaffolds— encouraged visitors to observe deeply within the natural setting. Learners needed a combination of a naturalist, mobile-delivered content, technology tools for collecting and annotating evidence, and scaffolds for noticing relevant features. This finding points to the utility of distributed scaffolding strategies (Tabak, 2004).

We incorporated into our design supports that enabled learners to participate in complex practices of observation and identification that are challenging without such support (Pea, 2004). Study A found that learners' efforts at identification in the forest were limited without observational support at the time of identification. Given that informal programs like ours might employ only one guide for a small group of people, we investigated in Study B whether part of this expert guidance could be offloaded to the technology to support both identification practices in real time and connecting science explanations to learners' in-field observations (Sung et al., 2014). Our photo capture and annotation tool shows promise as a scaffold to provide this support, as evidenced by our observations of learners engaging identification practices in the field. The photo artifacts served an important role in mediating learner agency, communicating what is known to the guide/teacher, and as a photo elicitation method supporting articulation and reflection. Table 2 provides a summary of our design goals and strategies for supporting observations and explanations outdoors.

--Insert Table 2---

In conclusion, the contribution of our design-based research study is in informing technologically-enhanced designs for learning outside of school. This study suggests that pedagogical efforts that utilize mobile devices to support informal science education can enhance children's learning experiences in the outdoors. We advocate for additional research, based on the results from our studies, on how mobile technologies can be used by learners in out-of-school settings to support observation and identification practices.

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Figure 1: Screen Captures of Mobile App Designs

1a. Studies A and B: Conceptual Organizer	1b. Study A: Example Photo Collage	1c. Study B: Annotation Check List	1d. Study B: Example Photo Collage

Table 1: Paired-samples t-test of the pretest and posttest scores.

	Mean	N	S.D.	*t*
Study A				
Pretest	4.5	10	2.6352	8.647***
Posttest	14.3	10	2.7101	
Study B				
Pretest	4.9	13	2.6287	11.502***
Posttest	11.4	13	2.6312	

***$p < .001$

Table 2: Design Strategies for Supporting Observations and Explanation

Design Goal	Mobile Technology Design Strategies
Support learners to make scientific observations outdoors	• Use digital resources to channel the learners' attention (Pea, 2004) to specific features of the environment that highlight disciplinary concepts (Quintana et al., 2004): - text and photographs to assist learners to notice relevant features of the environment (e.g., photos illustrating a prototypical example of a pine seedling); - contrasting images that revealed important visual distinctions for identifying what is scientifically relevant that might otherwise escape attention (e.g., contrasts in branching structures) (Bransford et al., 2000) • Provide photos/images to help learners visualize non-visible scientific elements of the gardens/forest (Rogers et al. 2004). - photos of tree characteristics across seasons (e.g., tree flowers) - photos of features that cross seasons and/or life cycles that might not be present at the same time in a place (e.g., pine cone at different stages of releasing seeds)
Use conceptual models to promote making conceptual connections across specimens vs. discrete factual knowledge	Provide a conceptual organizer (Quintana et al., 2004) of the tree life cycle to illustrate concepts present in the setting that extends across specimens. - All mobile materials were indexed via a model of the tree life cycle organizational scheme. - Mobile resources presented the conceptual organizer across specimens (e.g., oak and pine tree life cycles) - Tools and pedagogy supported applying concepts across settings (groomed gardens vs. the forest)
Scaffold complex disciplinary practices in natural settings	Structure complex tasks (Quintana et al.) required for engaging in science practices of observation, identification, explanation: - Learners use digital cameras to capture observations and make them visible. - mobile app included tools for organizing photographic representations into artifacts; - photo-capture/annotation tool was developed to provide just-in-time support for linking identification practices with observable criteria or evidence.