Chapter 8
Design of Mobile Learning for Outdoor Environments

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Mobile devices are ubiquitous tools in everyday life (Traxler, 2013; Warschauer & Matuchniak, 2010; Yardi & Bruckman, 2012). Although it is not unusual to see people using smartphones or tablets to access the Internet, listen to music, or watch videos at any moment, scholars in the field of Learning, Design, and Technology are still developing theoretical conceptions of the potential of these mobile devices to inspire new forms of learning and engagement. While established theories and design principles have been adapted to mobile designs, emerging research suggests that the role of context needs more prominence in current conceptualizations of mobile learning (Sharples, Taylor, & Vavoula, 2005). Our work at Penn State contributes to this ongoing effort in the Learning, Design, and Technology field to develop empirically grounded design guidelines to advance the development of mobile learning environments.

Mobile technology has the potential to enhance the immersion and participation of learners in the actual settings where the knowledge being learned is to be applied. Perspectives on open-ended learning suggest that the learning context is defined not only by what occurs within one setting (such as a classroom) but also by the ideas and experiences that are uniquely established and pursued by learners across settings (Hannafin, Land, & Oliver, 1999; Land, 2000; Land, Hannafin, & Oliver, 2012). These interpretations originate from the learner's own experience, enhancing a constructive process of meaning making. Identifying learning as a process of constructing knowledge, rather than a simple, singular, and passive acquisition,

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promotes the learner to assume responsibility of the learning process, potentially creating a deeper learning experience (Hannafin & Land, 1997).

Similarly, mobile learning can be interpreted as a way to achieve seamless, open-ended learning. According to Looi et al. (2010), mobile learning can enable users to seamlessly transfer from one setting to another without disruption during the learning process. With the help of mobile devices, learning can occur across formal and everyday settings. Change of settings is one of the key concepts of mobile learning (Sharples, Arnedillo-Sanchez, Milrad, & Vavoula, 2009).

The potential of mobile technology to provide interactive elements, gamified narratives, and digital augmentation of informal learning spaces such as museums, parks, or botanical gardens is an emerging area of study (Hsi, 2003; Land & Zimmerman, 2014; Yoon, Elinich, Wang, Steinmeier, & Tucker, 2012). This focus on mobile computers in informal learning settings creates unique opportunities for learning research within open environments, complementing the anytime-anywhere affordance of mobile learning. Informal learning environments use various pedagogical forms to support learning, such as 2-h self-directed visits, 1-h guided tours, week-long summer camps led by an informal educator, and short 10-min demonstrations led by volunteers or staff. Regardless of the form, the design of informal learning environments requires respecting both the free-choice element of the informal spaces (Falk & Dierking, 2002) and the learners' multipurpose agenda, which blends leisure and education, in the design decisions (Zimmerman & Land, 2014). In our work, we argue that mobile devices, due to their portability and ubiquity, can be integrated into informal learning spaces on demand with informational resources, media, and additional learning activities that can enhance the free-choice learning experience.

Education researchers and practitioners have been exploring the use of mobile devices to enhance outdoor learning environments. More specifically, researchers have conducted outdoor learning studies in settings such as woods (Rogers et al., 2004; Zimmerman et al., 2014), gardens (Chen, Kao, & Sheu, 2003; Huang, Lin, & Cheng, 2010; Zimmerman, Land, et al., 2013), urban watersheds and ponds (Kamarainen et al., 2013; Liu, Peng, Wu, & Lin, 2009; Squire & Jan, 2007), trails (Tan & So, 2011), and parks (Chen et al., 2003). These studies used mobile devices to enable observation, data capturing, or data sharing of the outdoor setting (e.g., Chen et al., 2003; Liu et al., 2009; Rogers et al., 2004). In this chapter, we present design theory based on our research conducted at the Arboretum at Penn State in order to advance conceptions of how mobile computers can enhance learning within technologically enhanced informal learning environments.

The Tree Investigators Informal Mobile Learning Environment

Through our work with the Augmented and Mobile Learning Research Group (http://sites.psu.edu/augmentedlearning) at Penn State, we have conducted a series of design-based research studies on the use of mobile technologies in outdoor settings like arboretums and nature centers (e.g., Salman, Zimmerman, & Land, 2014; Zimmerman, Land, et al., 2013, Zimmerman et al., 2014). Our focus is on enhancing families' scientific observations and explanations and the role of mobile devices in supporting those practices. *Tree Investigators* is designed as an open learning environment (Land, Hannafin, & Oliver, 2013), rather than a stand-alone app to support a self-guided tour. Taking the open learning perspective within our informal mobile learning environment means that we design for interactions that include other learners, a naturalist guide, mobile technology resources, and the specimens within the natural setting. Our technologically enhanced pedagogy relies on a naturalist to guide groups of families through the Arboretum. The naturalist works with learners on guided tours to deploy the mobile resources we developed to help them look more deeply at ecological concepts, which, inherent within the space, are not readily visible.

Our initial *Tree Investigator* learning environment was designed to support families in the process of tree identification as they were guided to explore a variety of broadleaf and needle leaf trees at the Arboretum at Penn State. Our early research findings (Zimmerman, McClain, & Crowl, 2013) suggested that the mobile app supported learners to engage in high levels of describing and naming talk (see perceptual talk Allen, 2002) around scientific observations; however, learners' conceptual talk that was interpretive and explanatory was less prevalent. Given our focus on ecology, we intended to enhance conceptual thinking and talk around natural cycles (e.g., life cycle, seasonal cycle, water cycle, rock cycle), which led our team to refine our *Tree Investigators* design to support open-ended and conceptually focused activity (Land & Hannafin, 2000; Land, Hannafin, & Oliver, 2012). This second iteration of the *Tree Investigators* mobile app design and research on life cycles of trees is the focus of this chapter.

For our second iteration of our design, called *Tree Investigators II*, we utilized the literature on scaffolding (Ge & Land, 2004; Land & Zembal-Saul, 2003; Quintana et al., 2004) as a stronger grounding for our redesign. We refined *Tree Investigators* based on three primary considerations: (a) increasing the conceptual focus of the learners' experience by focusing the app design and naturalist-led activities around ecological cycles; (b) fostering more learner-directed activity during the mobile learning experience through the utilization of digital photography; and (c) documenting additional evidence of learning through the creation of a knowledge artifact. Given our pedagogical focus was on guided tours in informal learning settings, our redesign work incorporated changes to both the guided participation from a naturalist on-site and the technological supports that were delivered through mobile computers.

Informal Mobile Learning Environment Design Guidelines

Based on our review of the literature as well as our own research findings, we employed the following general guidelines for enhancing our *Tree Investigators* mobile redesign:

1. Design a learning environment, not a stand-alone technology.
2. Use mobile computer content and prompts from the naturalist to amplify observations to see the disciplinary aspects of an informal setting.

3. Use mobile computer content and prompts from the naturalist to scaffold connections between on-site observations and scientific concepts that explain and represent them.
4. Use digital photography attributes of the mobile computer to allow learners to articulate and reflect on their observations and disciplinary concepts.
5. Support all family members, not just parents, to engage as epistemic agents.

Table 8.1 provides an overview of these five design guidelines, along with supporting strategies and examples, which are discussed more fully in the paragraphs that follow.

Design a Learning Environment, Not a Stand-Alone Technology

Overarching theoretical perspective on our design comes from the presumption that learners are engaged in a sociotechnical system where the technology, people, and setting all contribute to learning. These perspectives are build from a framework of distributed cognition (Hutchins, 1995), sometimes referred to as distributed intelligence (Pea, 1993) where thinking is accomplished with both internal mental resources and external resources in one's setting, including technologies, language and inscriptional systems, and other people. Distributed intelligence/cognition focuses on the learning within a sociotechnical system (Halverson, 2002; Hutchins, 1995), where individuals are understood to be only one part of a learning network. We used distributed cognition as a theoretical tool to understand how families think together about the trees they saw based on their interactions with mobile learning devices, each other, and the naturalist present on-site. Pea (1993) suggests that researchers can leverage distributed intelligence in their designs; here, we focus on distributed intelligence manifests through (1) augmenting through computing and (2) augmenting through guided participation.

Consequently, our first design guideline was conceptualized holistically as a sociotechnical system that relied on guided participation with a naturalist, technologically enhanced learning with a mobile app, sensory experiences on-site with trees, and social interactions with others as needed for learning. Table 8.2 shows the activities within the Tree Investigators II informal mobile learning environment.

Use Mobile Computer Content and Prompts from the Naturalist to Amplify Observations to See the Disciplinary Aspects of an Informal Setting

Our second design guideline for informal mobile learning environments specifies the selection of prompts for the naturalist and app because it entails structuring the activities of learners. Our goal is to use the mobile materials and the naturalist to

Table 8.1 Design guidelines for *Tree Investigators II* (expanded and adapted from Zimmerman & Land, 2014)

Informal mobile learning environment design guideline	Design strategies to support learning	Example from our Tree Investigators (T.I.) project
1. Design a learning environment, not a stand-alone technology	Consider the learners engaged in a sociotechnical system where the technology, people, and setting all contribute to learning	• We relied on guided participation with a naturalist, technologically enhanced learning with a mobile app, sensory experience on-site, and social interactions with others as needed for learning
2. Use mobile computer content and prompts from the naturalist to amplify observations to see the disciplinary aspects of an informal setting	Direct attention to specific features and characteristics that highlight important scientific concepts (Eberbach & Crowley, 2009; Huang et al., 2010)	• We employed digital photography on the T.I. app to include ideal specimens that the learners could compare to the actual specimens on-site to begin to see important aspects of shape, texture, and color of tree components
		• We also designed T.I. materials to amplify observations *across* trees to see broader disciplinary concepts embodied in the space (i.e., tree life cycles)
	Provide visualization of non-visible scientific aspects through technological augmentation (Rogers et al., 2005)	• The T.I. mobile app provided contrasting images of scientifically relevant characteristics not evidenced in the gardens (e.g., seasonal elements)
3. Use mobile computer content and prompts from the naturalist to scaffold connections between on-site observations and scientific concepts that explain and represent them	Provide a conceptual organizer (Quintana et al., 2004) illustrating conceptual processes present in the informal setting	• The mobile app interface represented a conceptual organizer of the tree life cycle. All mobile materials were indexed through that life cycle organizational scheme
	Design activities and mobile resources that allow for application of concepts to new instances	• Learners were supported to investigate tree life cycle concepts across two contrasting specimens (e.g., oak and pine)
	Provide contextualized expert guidance (Linn & Slotta, 2000) to encourage deliberate comparison and explanation with images (Liu et al., 2009) or text and guiding questions (Yoon et al., 2012)	• Naturalist-guided families to make comparisons between the images and text in the T.I. app to the specimens on-site. These comparisons encouraged conversations related to scientific concepts and ecological explanations of phenomena

(continued)

Table 8.1 (continued)

Informal mobile learning environment design guideline	Design strategies to support learning	Example from our Tree Investigators (T.I.) project
4. Use digital photography attributes of the mobile computer to allow learners to articulate and reflect on their observations and disciplinary concepts	Capture and annotate photographic artifacts in order to support extended thinking about an informal site (Land, Smith, & Zimmerman, 2013; Smith & Blankinship, 2000)	• Participants were supported to take photographs as evidence to support claims, and then they use these photographs to make a collage that represented their understanding of a tree's life cycle stages
5. Support all family members, not just parents, to engage as epistemic agents	Design materials so the whole family, not just the adults, to have access to the scientific information (Zimmerman, Reeve, & Bell, 2008, 2010)	• Use photographs and clear line art and simple text to allow for children to be able to see the important scientific ideas
		• When text is used, it was written at third-grade level

Table 8.2 Illustration of activities within the Tree Investigators II informal mobile learning environment that blend across the sociotechnical system

Location	Activities
Needle leaf tree at the Arboretum	• Families and naturalist visit a pine or spruce tree (as an example of a needle leaf, evergreen tree)
	• Families use the Tree Investigators app to read and look at digital images about its life cycle
	• Naturalist provides additional content and directs their attention to individual life cycle characteristics
	• Families engage in conversations about what they see and how their observations relates to science
	• Naturalist asks clarifying questions regarding what learners have read and what they are observing on-site
Broad leaf tree at the Arboretum	• Families and naturalist visit an oak tree (as an example of a broad leaf, deciduous tree)
	• Learners use the Tree Investigators app to read and look at digital images about its life cycle
	• Naturalist provides additional content and directs their attention to individual life cycle characteristics
	• Families engage in conversations about what they see and how their observations relate to science
	• Naturalist asks clarifying questions regarding what learners have read and what they are observing on-site
In the woods at the Arboretum	• Learners collaboratively search for evidence of tree life cycle growth stages
	• Learners discuss and collect photograph evidence of individual life cycle stages of trees
	• Learners discuss and arrange their photos into collage depicting each stage in life cycle in order
	• Learners add text to identify individual stages to articulate their understandings and come to a consensus across group members

channel the learners' attention (Pea, 2004), so that they are engaged in conversations related to their own observations on-site with disciplinary concepts in science (Eberbach & Crowley, 2008; Huang et al., 2010). Without a foundation of disciplinary knowledge, it is difficult for novices to know what is relevant to attend in a complex setting (Land, 2000; Smith & Reiser 2005); consequently, in our design work, we employ prompts to assist learners to discern important features of the informal setting from the unimportant features. This level of learning included noticing bark texture and variation in leaf size and shape, and it allowed learners to understand what is the scientific relevance (Zimmerman & Land, 2014) for discerning the types of trees and stages of a tree in its life cycle.

In *Tree Investigators*, these prompts to support observations came from both the naturalist and app material, signifying our goals to develop distributed, synergistic scaffolds (Tabak, 2004). Typical prompts included suggestions that highlighted observations across various trees that taken together reveal more conceptual characteristics of trees' life cycles. In addition, rather than use mobile computers to trigger information about specific trees as solitary objects that were being observed, we designed materials and scaffolds to amplify observations *across* trees to illustrate ecological principles. In this way, the learners engaged in the *Tree Investigator* informal mobile learning environment to see how the ecological cycles were embedded within the gardens and forested areas of the Arboretum.

In addition to needing to discern the scientifically relevant from the irrelevant, another challenge facing the learners in the Arboretum is that the outdoor landscape is dynamically complex. The flora and fauna within the informal setting are constantly changing in response to the seasons, weather, growth variations, and animal migration patterns. Learning about tree life cycles in the fall, for instance, allows for discussions of evergreen versus deciduous trees, yet it constrains the observations that can be made outdoors compared to the spring, when deciduous trees may have flowers present. As such, we designed our mobile app materials to provide visualization of non-visible aspects of the place through technological augmentation (Rogers et al., 2004). It would be impossible to observe all four seasonal characteristics of trees in one visit to an informal site; instead, learners would need to return multiple times over an extended period to see that an oak tree has small budding leaves in spring, deep green lobed leaves in summer, vibrant yellow and red leaves in fall, and bare branches in the winter. Within our app, we incorporated photographs to illustrate the varying seasons, growth, and conditions of the trees at the Arboretum. For instance, one of the photographs that generated the most talk was one that showed learners three different images of a pine cone to illustrate what a cone looks like before, during, and after its seeds are released. By comparing the image on the app, the families could talk about the specimens on-site with each other and the naturalist, in a more conceptually sophisticated manner.

Use Mobile Computer Content and Prompts from the Naturalist to Scaffold Connections Between On-Site Observations and Scientific Concepts That Explain and Represent Them

While the second strategy simplifies the scientific information to allow learners to focus on what is important, the third strategy supports learners to connect their observation to relevant conceptual information. The third design guideline related to informal mobile learning environments that we incorporated into the *Tree Investigators II* design was to scaffold learners to make explicit connections between what they observe and the broader ecological concepts. One strategy we used to foster conceptual connections was the inclusion of a graphic organizer (Quintana et al., 2004). The learners began their educational program at the Arboretum by starting on an app page that served as a graphic organizer of the tree life cycle (Fig. 8.1). To support conceptual thinking about trees, we used the graphic organizer of the tree life cycle as the main organizational structure for all of the app material. This graphic organizer provided an implied structure to the content flow from seed to seedling to sapling to mature tree and to the seed and snag. This allowed learners to recognize how each step of the life cycle was connected to other steps as well as the whole life cycle.

In order to promote learning in such a way that would lead to a more flexible application of concepts, we also designed activities and mobile app materials to allow for application of concepts across various instances in the Arboretum. For example, learners investigated tree life cycle concepts while looking at two contrasting

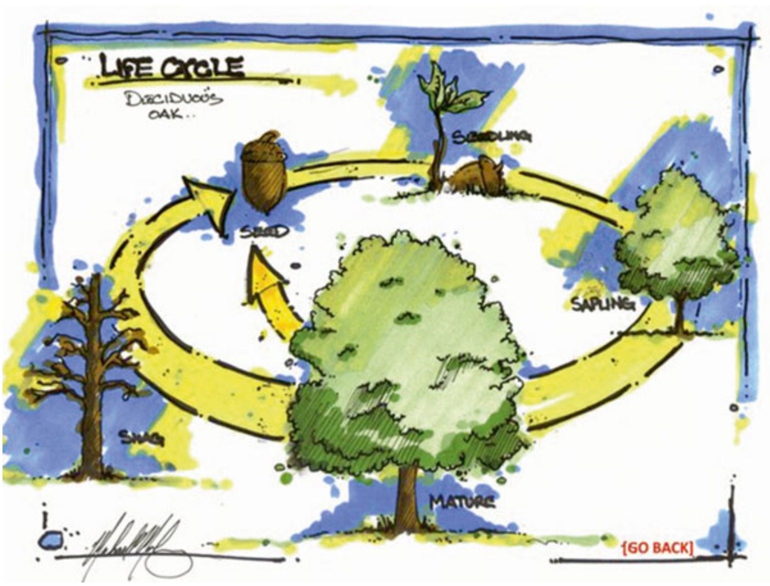

Fig. 8.1 *Tree Investigators II* graphical organizer that organized the concepts of informal mobile learning environment

tree types—an oak tree (broadleaf and deciduous) and a pine tree (needle leaf and conifer). This way, learners explored tree life cycle concepts across examples that looked different from each other at each life cycle stage (e.g., a pine tree grows from seeds within a pine cone and an oak tree grows from seeds within an acorn) but were related conceptually (e.g., both trees grow from seeds).

We also fostered this process of applying concepts to new instances by varying the complexity of the informal setting, by first observing an individual mature tree and then next going to a forested area that contained a variety of tree species and a variety of the same species within life cycle stages. To support the application of these ideas, we designed opportunities for the learners to receive contextualized expert guidance (Linn & Slotta, 2002) to encourage deliberate comparison and explanation with images (Liu et al., 2009) and with text and guiding questions (Yoon et al., 2012). This strategy was enacted via question prompts by the naturalist for learners to make comparisons between the images and text in the app and to the specimens in front of them in the gardens or woods.

Use Digital Photography Attributes of the Mobile Computer to Allow Learners to Articulate and Reflect on Their Observations and Disciplinary Concepts

Our work with open learning environment pedagogy (Land, Hannafin, & Oliver, 2013; Land et al., 2013) highlights the importance of creating learner-centered experiences, where learners construct technological artifacts that they personalize to represent their understanding. This literature suggests that it is important for learners to reflect on what they are learning, especially when they are engaging multiple investigations or resources (Land & Zembal-Saul, 2003).

We used these perspectives to enact the fourth design guideline for informal mobile learning environments by supporting learners to use the photographic capabilities of the iPads to capture and annotate learner-created collage artifacts (Fig. 8.2) that made their thinking visible (Land et al., 2013). Learners were asked to use the iPad to take photographs of five different phases of the tree cycle (seed, seedling, sapling, mature, and snag). By doing so, learners applied what they learned through guided interactions and discussed it within their family as they selected image for their own tree life cycle.

Support All Family Members, Not Just Parents, to Engage as Epistemic Agents

Finally, last design guideline for informal mobile learning environments is at the level of the selection of language complexity and the inclusion of multiple visual elements (instead of text, when applicable). This design guideline is meant to allow

Fig. 8.2 Example photo-collage artifact created by a participant in a Tree Investigators II study

all participants—regardless of age and reading ability—to engage as capable knowledge-building agents in the area of tree life cycle concepts. Prior work in informal learning settings (Crowley & Jacobs 2002; Zimmerman et al., 2008, 2010) has shown that children, not just parents, can have high levels of interest and expertise about the science topics explored together. Families also have been shown to engage in mutual knowledge building with various family members supporting each other (Palmquist & Crowley, 2007; Zimmerman, McClain, et al., 2013).

We built on these findings of shared epistemic agency through design choices that allowed both parents and children to have access to the scientific content. Specifically, we included realistic photographs that focus on key scientific features along with hand-drawn conceptual elements that created visualizations of the relationships between the ecological cycles' content and learners' observations of the Arboretum setting. When text coincided with the image, the research team limited the text to two to three short sentences. This ensured that materials were written at a third-grade reading level as measured by the Flesch–Kincaid score so that the upper elementary and middle-school children could read the information (third grade is between 8 and 9 years old in the USA).

Conclusion

Through the paper, we have presented design guidelines that can be implemented in designing an informal, outdoor learning environment. Five design principles were discussed: (1) Design a learning environment, not a stand-alone technology; (2) use mobile computer content and prompts from the naturalist to amplify observations to see the disciplinary aspects of an informal setting; (3) use mobile computer content and prompts from the naturalist to scaffold connections between on-site observations and scientific concepts that explain and represent them; (4) use digital photography attributes of the mobile computer to allow learners to articulate and reflect on their observations and disciplinary concepts; and (5) support all family members, not just the parents, to engage as epistemic agents. Our preliminary design-based research studies have provided initial support for these design considerations (Zimmerman, Land, et al., 2013, Zimmerman et al., 2014). Our future research and design efforts seek to gain more insights into how specific synergistic scaffolds—across components of the informal mobile learning environment—best support making scientific observations and explanations in outdoor learning settings.

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