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Abstract

This study aims to advance learning outdoors with mobile devices. As part of the ongoing Tree Investigators design-based research study, this research investigated a mobile application to support observation, identification, and explanation of the tree life cycle within an authentic, outdoor setting. Recognizing the scientific and conceptual complexity of this topic for young children, the design incorporated technological and design scaffolds within a narrative-based learning environment. In an effort to support learning, 14 participants (aged 5-9) were guided through the mobile app on tree life cycles by a comic-strip pedagogical agent, “Nutty the Squirrel”, as they looked to explore and understand through guided observational practices and artifact creation tasks.

In comparison to previous iterations of this DBR study, the overall patterns of talk found in this study were similar, with perceptual and conceptual talk being the first and second most frequently coded categories, respectively. However, this study coded considerably more instances of affective talk. This finding of the higher frequency of affective talk could possibly be explained by the relatively younger age of this iteration’s participants, in conjunction with the introduced pedagogical agent, who elicited playfulness and delight from the children.

The results also indicated a significant improvement when comparing the pretest results (mean score of .86) with the posttest results (mean score of 4.07, out of 5). Learners were not only able to recall the phases of a tree life cycle, but list them in the correct order. The comparison reports a significant increase, showing evidence of increased knowledge and appropriation of scientific vocabulary.

The finding suggests the narrative was effective in structuring the complex material into a story for sense making. Future research with narratives should consider a design to promote learner agency through more interactions with the pedagogical agent and a conditional branching scenario framework to further evoke interest and engagement.
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Chapter 1

Introduction

With the proliferation of mobile technologies, people’s everyday experiences can become relevant contexts for learning (Bell, Lewenstein, Shouse, & Feder, 2009; Chen, Kao, & Sheu, 2005; Squire & Klopfer, 2007; Zimmerman, Land, Seely, Mohney, Choi, & McClain, 2014). Ubiquitous mobile technologies have attributes that can involve young learners in meaningful interactions and richer experiences within contexts such as homes, neighborhoods, or outdoor spaces (Chen, Chang, & Wang, 2008; Park, 2011; Kearney, Schuck, Burden, & Aubusson, 2012). Designing opportunities for young learners to interact with peers and technology, in context, is essential as young learners learn together (Chen et al., 2008; Järvelä, Näykki, Laru, & Luokkanen, 2007; Quintana, Reiser, Davis, Krajcik, Fretz, Duncan, Kyza, Edelson, & Soloway, 2004; Sharples, 2013;) and connect more with the physical environment (Hidalgo & Hernandez, 2001).

In lieu of classroom-based decontextualized activities and materials, which can limit learner engagement, designing learning environments that take advantage of the physical, material, and social context of a setting can enhance the learning process (Zurita & Nussbaum, 2004). Theory on learner-centered design suggests that efforts should be made to immerse young learners in more realistic, authentic situations, which closely resemble the contexts wherein knowledge can be applied (Land, 2000; Land, Hannafin, & Oliver, 2012). Consequently, learning experiences should be designed with attention to interacting elements of the learners, the designed activity, and the environment (Barab,

Yet, prior research has shown that learner-centered environments that engage learners in authentic contexts and activities are also complex (Herrington & Oliver, 2000; Puntambekar & Hubscher, 2005) and can be challenging for learners both strategically and conceptually (Land & Hannafin, 1996; Land, Hannafin, & Oliver, 2012). Consequently, learner-centered environments must have sufficient scaffolding or support to minimize excessive complexity, while maintaining an emphasis on engaging authentic practices such as observation and explanation (Eberbach & Crowley, 2005; Land, 2000). Prior research on scaffolding has demonstrated that technology can be used to support learners in complex, authentic tasks, of which they may not be able to achieve on their own (Chen, Kao, & Sheu, 2003; Pea, 2004; Land & Zembal-Saul, 2003; Quintana et al., 2004; Smith & Reiser, 2005; Sawyer, 2006; Tabak, 2004; Zimmerman et al., 2014). Prompts, cues, resources, and hints are often provided by way of technology, peers and guided synergistically to assist learners with skills out of reach (Reiser & Tabak, 2014; Tabak, 2004). By keeping the learning environment complex and authentic, in conjunction with scaffolds for managing that complexity (Kirschner, Sweller, & Clark, 2006), learner participation can be enhanced (Falk & Dierking, 2002; Pea, & Moldonado, 2006; Sha, Looi, Chen, & Zhang, 2012; Zimmerman, Land, McClain, Mohney, Choi, & Salman, 2013).

**Mobile Learning Outdoors**

Mobile devices have become a heavily embraced technology within most economic settings (Yardi & Bruckman, 2012) and continue to grow in importance
personally, professionally and academically. Emergent areas of study for mobile learning are informal learning spaces, which can expand on learner-centered outdoor designs. Learner-centered outdoor mobile learning provides the notion of agency (Lindgren & McDaniel, 2012) and sense of control (Dunleavy & Simmons, 2011), which empowers young learners to be more active while encouraging exploration during the learning process (Jones, Scanlon, & Clough, 2013; Kearney et. al, 2012). Mobile learning outdoors is a means to establish an attachment between the learner and the physical environment (Hidalgo & Hernandez, 2001). The configuration of mobile devices and learner-centered environments establishes an opportunity to design and create context-specific content; creating opportunities for learners to associate content to the world they directly know and see (Dunleavy, 2014; Järvelä et al., 2007).

Mobile outdoor learning has been readily endorsed as a means to increase learner sense-making of content in relation to the explored physical environment. Research has been conducted in woodlands (Klopfer & Squire, 2008; Squire & Jan, 2007; Zimmerman, Land, et al., 2014; Land, Zimmerman, Choi, Seely, & Mohney, 2015), gardens (Chen Kao, & Sheu, 2005; Zimmerman, Land, et al., 2013), and trails (Tan & So, 2011). These mobile learning studies provided immediate, on-demand information that supported learners’ thinking and understanding through immersion (Dede, 2009), identification, data capturing, or data sharing (Chen Kao, & Sheu, 2005; Rogers et al., 2004; Zimmerman, Land, et al., 2013; Zimmerman, Land, et al., 2014). Designed applications and learning for these outdoor spaces suggested enhanced learning by promoting observation and choice through learner-centered guided tasks (Falk & Dierking, 2002;

Albeit these studies suggest that learning can be supported in the outdoors using mobile devices, the complexity of a learner-centered design is only addressed with upper-grade level elementary participants (and above). Little research focuses on young children in lower elementary grades. Mobile outdoor learning for this audience could still be effective, yet requires additional design strategies. As the research suggests, empowering learners with exploration (Liu et al., 2009) and choice (Falk & Dierking, 2002) can lead to effective informal or outdoor mobile learning experiences. As the attention and focus of young learners is still developing, the perception of choice and open-exploration through structured end goals and tasks could be important. Presenting learning goals in the form of a narrative with complementary gamified tasks could be a compelling strategy to engage young learners throughout the learning process.

Narrative-Based Learning & Gamification

There are many ways to introduce complex material to young children within learner-centered environments; Gilbert, Hipkins, and Cooper recommend wrapping complex information and concepts within narrative-based instruction, which complements the young learner (2005). Narratives structure complex information for sense making, enhancing value and relevance (Rowe, Shores, Mott, & Lester, 2011). In general, narratives are a common approach when communicating, as most everyone understands how to think in a story sense, which is often a reflection of individual’s perceived reality, a pertinent role in constructing meaning of their world (Gilbert,
Hipkins, & Cooper, 2005; Rowe, Shores, Mott, & Lester, 2011). Consequently, using narrative-based instruction within a designed contextualized mobile learning environment can promote meaning-making, be it figuratively or emotionally, by focusing the narrative directly to the actual setting (Andrews, Hull, & Donahue, 2009). Narrative-based, mobile learning fosters a connection between the content and the environment, as story elements direct learners to pertinent aspects within the environment to appreciate the unseen (Dunleavy, 2014).

When narratives are implemented with sound domain knowledge, they can provide a way of assimilating and reasoning with new information (Andrews et al., 2009). New information presented via narrative not only provides terms, concepts and facts, but can also situate them in practice. Supporting learners to apply knowledge and concepts in real contexts can increase learner understanding (Andrews et al., 2009; Hodson, 2014). This embedded practical application allows the learner to make the necessary assimilation of prior knowledge with new knowledge, establishing a credible foundation for future learning.

As narratives can be a viable approach to garner learner engagement, gamification within a narrative can then sustain commitment. Gamification is the use of game-like elements and mechanics in a non-game context that can promote problem solving and achievement (Kapp, 2012). The notion of Gamification has been implemented and applied in several domains with the simple consistent premise of making content more engaging. Designers of gamified learning environments address elements of pedagogical agents, levels, and badges, to foster motivation and commitment, which should be the
focus of the design; it does not imply creating a game (Kapp, 2012; Schroeder, Adesope, & Gilbert, 2013).

**Problem Statement**

Although research on mobile learning is prevalent, designing learner-centered mobile experiences for young children has been understudied. Prior research has shown that narrative or gamified elements to mobile materials show promise for helping learners engage in more complex practices (Andrews et al., 2009; Gilbert et al., 2005; Radich, 2013). In this study, introducing a narrative story and virtual character that serves as a pedagogical agent (Schroeder et al., 2013) into learners’ exploration of an outdoor setting could be an effective strategy for engaging young learners in complex learning practices.

Pedagogical agents can be any type of character within a design that facilitates instruction through interaction with the learner (Schroeder, Adesope, & Gilbert, 2013). Mobile learning can complement many areas, but little has been studied in conjunction with a narrative-based contextualized setting design.

**Research Purpose**

Prior research on mobile learning has an established foundation worth expanding. This study is built on that foundation, to include informal learning theories, with the intent to inform the design and development of mobile learning environments. Context and experience are assumed to be critical components to understanding, being most effective when learners have the opportunity to create, establish and revise understanding-in-action (Hannafin, Land, & Oliver, 2012). Through narrative and
gamified elements, this study examines how learners engage in extended exploration, sense making, and creation of learning artifacts in the outdoors.

More specifically, the purpose of this research is to investigate how various features of a mobile learning environment designed for use in informal, outdoor learning environments support young children to: (a) engage in science talk about tree life cycles; (b) demonstrate knowledge of terms and concepts related to tree life cycles; and (c) create digital artifacts of tree life cycles, using customized tools to documenting photographic evidence.

**Research Questions**

This study was guided by a focal research question: How does implementing a narrative-based, mobile learning experience influence learning among young learners in an informal, summer camp experience? Related sub-questions further guiding the study:

1. Did children’s knowledge of the life cycle increase after participation within the created mobile learning environment and subsequent mobile app experience, as measured by scores on a pretest and posttest of the 5 stages of an oak tree life cycle?
2. How do children talk together about trees and life cycles while using the mobile learning experience outdoors during summer camp?
3. How did designed elements of the mobile learning environment (pedagogical agent; narrative strategies; photo-documentation tool for identifying and photographing tree life cycles) assist learners to observe, identify and create artifacts of tree life cycle concepts?
Chapter 2
Literature Review

Mobile devices have grown in popularity in recent decades, developing into a viable medium to support learning (Pachler, Bachmair, & Cook, 2010). Research on mobile devices has seen opportunities for learning integrated into most facets of our lives (Warschauer & Matuchniak, 2010; Traxler, 2013; Yardi, & Bruckman, 2012; Kearney, Schuck, Burden, & Aubusson, 2012) with the potential to promote and enhance learning opportunities (Dunleavy & Simmons, 2011; Pachler et al., 2010). Emerging complementary technologies of cloud-based storage and context/proximity awareness further promote and establish mobile device implementation for learning.

Mobile devices are also becoming more common within the child development process (Cumbo, Paay, Kjeldskov, & Jacobs, 2014). When used in moderation with appropriate scaffolding and accompanied with the immediacy of feedback, facilitated development can occur (Radich, 2013). The spectrum of learners able to operate and interact with mobile devices has shifted to include the youngest of learners (Cumbo, Paay, Kjeldskov, & Jacobs, 2014; Pachler et al., 2010), further enhancing the value and support of learning with mobile devices.

Pedagogical design considerations for mobile device implementations align with foundational informal learning elements of scaffolding, imitation, motivation, and collaboration, which informs and acknowledges the social aspect of teaching and learning (Bransford, Brown, & Cocking, 2006). These design considerations are used to prompt learner agency, regulation and efficacy as learners assume some control of their learning (Kearney, Schuck, Burden, & Aubusson, 2012). Perception of control empowers young
learners to be more active, adventurous, and encourages exploration within learning and knowledge acquisition (Jones, Scanlon, & Clough, 2013; Kearney et. al, 2012).

Implementing such designs within an authentic mobile learning environment allows learners to discover available opportunities and choose how they’ll participate (Falk & Dierking, 2002; Pea, & Moldonado, 2006; Sha, Looi, Chen, & Zhang, 2012).

**Learner Agency**

The ability and willingness to accept the consequences of choice reflects the notion of responsibility (Anderson, 1936). Ideally, the habits of choice lead to accepting full responsibility for all actions while informing responses to future direct, or indirect, actions (Mitton & Harris, 1954). Training for responsibility should begin early, through practice, allowing children to recognize their actions will have an effect, positive or negative, in any context (Anderson, 1936; Mitton & Harris, 1954). According to Gao (2010), promoting awareness to the cause/effect relationship leads to the development of action causation, establishing agency within young learners. Agency is theoretical, similar to motivation, and is defined as involving an individual’s will to act (choice), to include their capacity to act in sociocultural terms (Gao, 2010; Mercer, 2012) that makes a difference in their lives.

As agency is theoretical and dynamic, conjoining contextual factors are also dynamic and include all things relevant, from artifacts to environment (Mercer, 2012). According to van Lier (2008), learners make sense of contextual factors through interacting in ways that are meaningful and relevant to them. Consequently learner agency is what emerges from the interaction between resources and contexts, to include the learners’ perceptions, use, and value of them (van Lier, 2008). Providing learners
with options and choice, establishes learner agency and awareness to the fact their behaviors will affect learning (Bandura, 2008; Mercer, 2012).

The comprising elements of this concept: choice, contexts, and interaction, portrays how agency can have the ability to shape the process and outcome of learning (Lindgren & McDaniel, 2012). Notably, individuals are more compelled to achieve tasks they have established and accept arising challenges with more effort, giving personal agency a strong motivational component (Lindgren & McDaniel, 2012). Learning designs considering agency are perceived more relevant to the learner (Mercer, 2012), establishing, in theory, a more personalized learning experience. Agency complements learning while informing theories and design for mobile learning, which continue to develop.

**Mobile Learning Outdoors**

The near ubiquitous nature of mobile devices, complemented with an increasing aptitude and comfort by users, provides new learning opportunities to promote knowledge acquisition (Cochrane, 2010; Sharples, 2010; Squire & Klopfer 2007). Mobile device portability can enhance immersion and participation of young learners to content, reinforcing learning within the actual context where knowledge is to be applied (Krajcik, Blumenfeld, 2006, Edleson, Reiser, 2006; Sharples, 2010; Land & Zimmerman, 2015; Land, Zimmerman et al., 2015, April). Implementing mobile devices for outdoors can further enhance the learning to be more authentic and relatable (Looi et al., 2010). Outdoor mobile learning also complements an open-ended learning framework, where the context of learning is the establishment of ideas and experiences across multiple settings, not a singular location (Hannafin, Land, & Oliver, 1999; Land, 2000; Land,
Hannafin, & Oliver, 2013). Learners can interpret and create meaning through their own experiences across these settings, further personalizing the learning process (Sharples, Arnedillo Sanchez, Milrad, & Vavoula, 2009). This identifies with a constructivist approach, prompting the responsibility of learning to the learner, promoting a deeper learning experience (Hannafin & Land, 1997).

Mobile learning also provokes the social aspect of learning, which observes learning as a process of transformation through participation and interaction rather than simple acquisition (Rogoff, 1995, Dunleavy & Simmons, 2011). Learners construct knowledge through participation and interaction with the environment, deducing that participation (sensory, mental, and physical) is a precursor to learning (Jonassen & Murphey, 1999; Chen, Chang & Wang, 2008). Subsequently, a collaborative environment is established by way of social participation, enhancing peer supported learning of shared ideas and reasoning (Kolodner, 2006, Hmelo-Silver, 2008). Through the mutual exchange of ideas, feedback, and reflection, learners are provided opportunities to explain their thoughts, as it relates to content (Sung et al, 2009). This explanation and encouraged reasoning then prompts negotiation and/or reinforcement of discourse to further establish their learning (Zurita & Nussbaum, 2004). These iterations of shared reflection and explanation provide new opportunities for social and interactive learning that promotes an active mind across multiple contexts (Järvelä, Näykki, Laru & Luokkanen, 2007).

Mobile learning continues to evolve. Pachler et al. (2010), report mobile learning designs can be used to encourage collaborative learning experiences, engage reluctant learners, enhance attention, and raise learner efficacy. Furthermore, designs for mobile
learning should support experiences that extend time, space, and conceptual boundaries to connect with the learner’s personal knowledge, interests and learning needs (Kukulska-Hulme, Sharples, Milrad, Arnedillo-Sanchez, & Vavoula, 2009). Mobile learning and designed interactive elements, in conjunction with an authentic context, can enhance learner agency and endorse effective anytime, anywhere learning.

While theories and design principles continue to be adapted to mobile learning design, research continues to support context as a pertinent construct (Land & Zimmerman, 2015; Sharples, Taylor, & Vavoula, 2005). Informal learning contexts such as museums, parks, or arboretums, can be enhanced with mobile learning (Hsi, 2003; Land & Zimmerman, 2014; Yoon et al., 2012). Informal learning has dynamic learning outcomes and a perception of being unintentional, various forms of mobile learning can be implemented to support and enhance the learning process. Implementing a mobile device component to informal learning requires recognition of casual natured education (Zimmerman & Land, 2014) and the element of learner choice within the informal learning space (Falk & Dierking, 2002). Furthermore, integrating designed interactive elements of mobile learning can support free choice and agency as learners have on demand access to content.

Mobile outdoor learning is a viable means to increase learner sense-making, responsibility, and engagement of content within authentic informal learning spaces. Research has been conducted in woodlands (Klopfer & Squire, 2008; Squire & Jan, 2007; Zimmerman, Land, et al., 2014), gardens (Chen Kao, & Sheu, 2005; Land & Zimmerman, 2015; Land, Zimmerman, et al., 2015, April; Zimmerman, Land, et al., 2013), and trails (Tan & So, 2011). These mobile learning studies provided choice driven
on-demand information that supported learners’ comprehension through immersion (Dede, 2009), identification, data capturing, or data sharing (Chen Kao, & Sheu, 2005; Rogers et al., 2004; Zimmerman, Land, et al., 2013; Zimmerman, Land, et al., 2014). Designed applications and learning for these outdoor learning spaces suggested enhanced learning through learner-centered guided tasks (Falk & Dierking, 2002; Land, Zimmerman, et al., 2015, April; Liu, Peng, Wu, & Lin, 2009; Zimmerman, Land, et al., 2013; Zimmerman, Land, et al., 2014).

**Scaffolding**

Mobile learning designs have established potential, more so with an appropriate scaffolding implementation (Zimmerman, Land et al., 2013; Zimmerman, Land et al., 2014; Zimmerman, Land et al., 2015, April). When referencing scaffolding, Vygotsky’s Zone of Proximal Development concept should be discussed and understood. Vygotsky (1978) determined this zone to be the distance between an individual’s ability to solve problems independently and the increased potential of solving problems with guidance from a more knowledgeable individual or collaboratively with peers. Vygotsky brought attention to the theoretical concept of the gap between a learner’s actual development and their potential development (Kirschner et al., 2006; Land & Zembal-Saul, 2003; Vygotsky, 1978). Scaffolds are designed and implemented to assist learners in achieving tasks outside of their own capabilities to reach their learning potential (Puntambekar & Kolodner, 2005; Puntambekar & Hubscher, 2005; Sharma & Hannafin, 2007; Quintana et al., 2006).

There are many types, levels, and degrees of scaffolding that can be implemented to achieve learner potential, which have evolved from the initial thought of scaffolding
being nothing more than assistance from a more knowledgeable person (Puntambekar & Hubscher, 2005; Sharma & Hannafin, 2007). Accepted scaffold types now include tools, technology, resources, instruction, peers, and settings. While levels of scaffolds have also evolved to be ongoing, specific to learners, distributed within collaborative efforts, generic for all learners, and only when needed. Scaffolding can also have a variety of descriptions and applications; Puntambekar and Kolodner (2005) provide 5 central characteristics of scaffolding, (1) Common Goal, (2) Ongoing Diagnosis, (3) Dynamic and adaptive support, (4) Dialogues and interactions, (5) Fading and transfer of responsibility, of which were considered for this study.

Common goal is the notion there is a shared understanding for the overall goal of the activity. The activity should include elements that are beyond the abilities of the participants.

Ongoing diagnosis provides appropriate support in relation to the child’s current level of understanding. This requires the more knowledgeable individual (e.g., parent, teacher) has a complete and thorough understanding of the tasks to be performed and its components. They should also be aware of the child’s changing (improving) capabilities as the instruction progresses.

Dynamic and adaptive support is the result of the ongoing diagnosis. The knowledgeable individual must calibrate their support to match the participants changing needs. Support should be provided in a manner that allows the learner to advance.

Dialogues and interactions enable the knowledgeable individual an ongoing assessment of the participants understanding and provide an opportunity for participants to play a role in negotiating the interactions.
Fading and transfer of responsibility is reducing the support provided to the learners so they can assume more control and take responsibility for their learning. Vygotsky (1978) referred to this as internalization, a cognitive process that shows the child is capable of independent learning.

Specific scaffolds for this study recognized the aforementioned core characteristics and were designed for explicit, embedded delivery. The design included a pedagogical agent and naturalist (instructor) who provided conceptual and instructional scaffolds throughout the activity. The conceptual scaffold is used to direct learners to think and consider about certain aspects of the learning, through prompts and cues (Azevedo, Cromley, & Seibert, 2004; Hannafin, Land & Oliver, 1999). Naturalist prompts and cues are the dynamic and adaptive characteristic of the scaffolding core, while embedded pedagogical agent prompts and cues are static and ongoing. The instructional scaffolds are used to facilitate achievement of goals beyond the learner’s capabilities through directing focus and task guidance (Xun & Land, 2004). Designed learner-centered tasks for this application exceeded the capabilities of most of the participants; directing focus and providing guidance were necessary for task completion.

Technological scaffolds were also implemented by way of the mobile devices. Technology scaffolds are used to provide users with cognitive and direct supports (McNeill, Lizotte, Krajcik, & Marx, 2006; Quintana et al., 2006). The application provided participants with constant access to the context-specific content with opportunities to review material. Technology can also foster distributive cognition (Reiser, 2004; Tabak, 2004), as more advanced learners’ assist others, assuming the traditional scaffold role of a more knowledgeable individual (Huang, Wu, & Chen, 2012;
Additional scaffolding can be made available through narrative designs, assisting the learner’s comprehension of content through story elements (Dickey, 2006).

**Augmented Learning**

Augmented learning is a strategy where content and context are adaptable for, and often by, the learner (Klopfer, 2008). Learners have the potential to enhance sense making of content through encouraged discovery, creating a more stimulating learning experience. According to Klopfer, the incorporation of technology augments a learning experience that adapts, or designed in conjunction, to the learner’s current context, making the experience more relatable (2008). Studies that focused on augmented learning reported augmentation can further enhance and influence learning (Dunleavy, Dede, and Mitchell, 2009; Squire & Klopfer, 2007). Additional reports discovered students’ viewed learning as a more authentic and unique way to learn with increased task accuracy during interactions. There were also reports of increased interest, motivation, and problem solving through the designed collaboration (Dunleavy, Dede, and Mitchell, 2009; Squire & Klopfer, 2007). The collaboration within an augmented learning design establishes distributed learning, as participants remain active, promoting interactions with each other, learning resources, and the environment (Dunleavy, Dede, and Mitchell, 2009). There are various techniques to augment a learning experience, which include mobile devices with gamified, narrative-based instruction.

Dunleavy, Dede, and Mitchell (2009) designed and enacted an immersive mobile narrative-based learning study called “Alien Contact!” The intended instruction for the lesson was an inquiry format designed to teach math, language arts, and science
(Dunleavy, Dede, & Mitchell, 2009). The lesson was designed for students to act collaboratively around the schoolyard through an augmented narrative on mobile devices. Results from the data reported a majority of the participants, students and teachers, considered the exploration aspect to be motivating, authentic, and a non-typical approach to learn math. Dunleavy, Dede, and Mitchell (2009) also found students perceived this type of augmented learning to be motivating, which noticeably transformed previously disengaged students into more active learners.

Squire and Klopfer (2007) performed a similar study entitled Environmental Detectives. This study augmented learning by designated participants as environmental engineers attempting to discover the source of a toxin that had leaked into the local watershed. The participants, high school and university students, investigated their actual geographic locale (i.e., High School, Campus) with mobile devices for added authenticity. Participants were asked to recognize and account for real constraints of their respective location; use of water, water sources, topology, attitudes of the community, potential remediation, and use of chemicals in the vicinity (Squire & Klopfer, 2007). Mobile devices delivered supporting information and samples. Participants were also charged with collecting relevant information through observing and interacting with the augmented environment. Their design goal was to assist participants in negotiating between the various types of data that would be encountered in a genuine field of practice (Squire & Klopfer, 2007).

Along with the findings relatable to Dunleavy, Dede, and Mitchell (2009), Squire and Klopfer (2007) recognized the augmented narrative-based instruction had the potential to provide a sense of authenticity, as it can involve actual constraints of real
time with the valuable possibility of failure. Augmenting narrative-based learning also provides suggested techniques and proven approaches for actual practice, which can be grounded in genuine scenarios (Squire & Klopfer, 2007). Embedded pedagogical agents can be additional enhancements to narrative-based instruction.

**Pedagogical Agent**

Pedagogical agents are embedded characters that can facilitate instruction by interacting with the learner in the context of a learning environment, with adaptable behavior (Schroeder, Adesope, & Gilbert, 2013). Agents can be implemented in various ways with many characteristics. For this study, the role of the embedded agent was used for scaffolding, demonstrating, modeling, and coaching, informing the socio-constructivist elements of learning (Jonassen & Land, 2012). Through suggestive prompts and cues, the agent directs and scaffolds the user to perform and complete tasks that may be out of their own zone of proximal development (Vygotsky, 1978). Throughout the photo capture task the agent provides instructions on how to properly operate the device and directs, with clues, on where to explore and what to capture. The agent can also demonstrate and model by showing what is required to complete a task while articulating problems, strategies, and necessary information for understanding the task (Choi & Clark, 2006; Johnson, Rickel, & Lester, 2000). Most essential to this design, the coaching element an agent can provide. In theory, and practice, the instructional agent activates the learner during the task and provides guidance when students experience difficulties (Barab & Duffy, 2000).

Mayer and DaPra, Schroeder, Adesope, and Gilbert, Tze Wei, Su-Mae, and Jayothisa (2012; 2013; 2013) examined the use of pedagogical agents on learning by
reviewing multiple studies, considering context of each. Pertinent and consistent characteristics emerged and were considered in design. Pedagogical agents using on-screen text facilitated learning more effectively than agents using narration (Schroeder, Adesope, & Gilbert, 2013). Learners assigned higher trust and reported less anxiety with content presented by expert-like agents (Tze Wei, Su-Mae, & Jayothisa, 2013), which prompted the implementation of a squirrel character presenting the tree life cycle. Also, learners showed enhanced transfer when agents displayed human-like gestures, facial expression, eye gaze, and body movement in comparison to a static agent, yielding an embodiment effect (Choi & Clark, 2006; Mayer & DaPra, 2012). Working a pedagogical agent into a narrative-based design has proven potential with empirically reported data; supplementing such a design with gamified elements promotes further attention and engagement with learners (Kapp, 2012).

**Gamification**

Gamification is described as the concept of using game elements in non-game contexts to motivate and increase user activity and retention (Deterding, Dixon, Khaled, & Nacke, 2011; Kapp, 2012; Schroeder et al., 2013). There is some debate on the effectiveness of such a design, but its characteristics, when applied appropriately can influence the learning process. Gamification is not creating a game (Kapp, 2012); it is using the elements of games, such as, characters (pedagogical agents), narratives (story) and badging to sustain motivation of the learner. Essentially, gamification refers to the use of design for game elements, or characteristics of games, in a non-game context.

Per the effectiveness of gamification, or gamified learning, researchers (Blunt, 2007; Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012; Sitzmann, 2011) reported on
three causal-comparative exploratory studies. These studies examined academic achievement among students enacting with a gamified learning environment. Each environment imposed identical assessment, while data collected included, test scores, gender, ethnicity, and age. Analytic methods testing game-use effectiveness included ANOVA, chi-squared, and t-tests. Findings indicated the mean scores of students in the gamified environments were significantly higher than those of the traditional environment (Blunt, 2007), with no reported difference in genders, ethnicities, or age.

Connolly, Boyle, MacArthur, Hainey, and Boyle (2012) also examined gamified learning studies, conducting a meta-analysis on research reporting empirical data to the impacts and outcomes of gamification, with respect to learning and engagement. The strongest and most consistent claim noted enhanced knowledge acquisition with content understanding and motivational outcomes (Connolly et al., 2012). Further evidence for gamified learning is the often-reported enhanced efficacy (Hays, 2005; Kapp, 2012; Sitzmann, 2011), as the simulation and badging elements creates relatable application of learned knowledge and builds confidence.
Chapter 3
Research Methodology

The chosen research questions were derived as part of a series of design-based research studies (Tree Investigators) spanning several, prior iterations of research on mobile technologies and informal learning spaces (Land & Zimmerman, 2015; Zimmerman, Land, Seely, Mohney, Choi, & McClain, 2014; Zimmerman et al., 2015). For each of the prior design iterations, I served as a research team member and lead technology developer for the Mobile and Augmented Learning Research Group. In these prior iterations, mixed methods were implemented as a means to provide evidence of tool use, content design, and learning. These iterations began with a simple web-based application that focused on tree identification and tree characteristics (e.g. leaves, needles, bark) (Zimmerman, Land et al., 2015). The subsequent iteration focused on tree life cycles, a more complex concept for young learners, which was designed and implemented to scaffold learner-directed activity (Zimmerman, Land et al., 2014). Learners were asked to interact, through guided facilitation by a naturalist, with a custom tree life cycle application and then, through a third-party photo collage application (InstaCollage), to capture and create their own tree life cycles with photographs of trees they found in the forest. In a third iteration, a custom photo capture and annotation tool was developed to better support tree life cycle identification practices in the outdoors (Land & Zimmerman, 2015).

The present study was informed from the aforementioned iterations and utilized the life cycle and photo collage framework, but included learning strategies of narrative-based and gamified elements for young children. This study employs mixed
methodology (Creswell, 2013), relying on both a qualitative case study design (Yin, 2003) to describe and explain how learners used the mobile learning environment to learn about trees and a quantitative pretest-posttest design to analyze changes in outcomes of learning.

**Research Setting**

The study setting was the Hartley Woods acreage within the Arboretum at Pennsylvania State University. The Arboretum is roughly 395 acres of controlled and maintained gardens, adjacent to the University Park campus in State College, Pennsylvania. The Arboretum was established with a mission to engage the academic strengths of the University in promoting scholarship and education about plants and their history and importance on earth. The Arboretum is well supported and displays quality collections of trees, plants, and flowers in functional, interactive designs. The Arboretum also includes the Hartley Woods, an old-growth forest, which includes trees predating a widespread clearing that occurred during the late 18th and 19th centuries. The old-growth forest holds a protected status due its historical, scientific, and cultural value to the area. Hartley Woods is located behind the controlled and maintained gardens of the Arboretum (see Figure 1).
This setting was selected based on the natural aesthetics and availability of both groomed gardens and nearby forest. The provided app content was aligned to the context of the Arboretum, and conjoining Hartley Woods. Specifically, the walking path that conjoins the Arboretum to the Hartley Woods includes a fully mature oak tree that is an ideal specimen for both the initial instruction of the study and introducing the narrative. The nearby Hartley Woods would then allow ample room for open-ended exploration, as its natural condition contains specimens for each phase of a tree life cycle. These settings created an opportunity for both structured learning interactions led by a guide, and more learner-centered interactions in the wilderness.

**Participants**

All participants were aged 5-9 and part of a summer camp program from a University Child Care Center, which holds summer programs for children having completed grades kindergarten, 1st, 2nd, 3rd, 4th, and 5th. This study complemented the
programs’ planned activities, which included community involvement (e.g., reduce/reuse/recycle), getting ready for school (e.g., reading for readiness), and exploring the wilderness, a remaining portion of old-growth woods that also pre-dates the University. Eighteen participants consented to participate in the study; however, 14 remained for the required duration, of which each consented for data capture of audio and video.

**Material**

All resources for this study were designed and developed for the iPad Mini, 2nd generation. The iPad Mini was chosen over the larger iPad due to its smaller size, increasing portability and use by the younger participants. The need for participants to use the camera function of the device, a critical part of the study, also informed the decision to use the smaller iPad Mini. Also, less pertinent, was the assumed familiarity participants may have with Apple products.

**Adobe Flash Professional™**

The material for this study was developed using Adobe Flash Professional, an authoring program capable of creating content applications for web, games, and movies, to include mobile phones and other devices. Through an object-oriented programming model, Flash can create and program applications and animations. Flash is a robust and useful program, but for reasons only known by the parties involved, on April 8, 2010, Apple modified its Developer License terms and conditions to effectively ban the use of the Flash-to-iPhone compiler, hindering Flash-based application from functioning on Apple’s mobile operating system (iOS) (Apple, 2013,
archived). However, in 2011, Apple revised their iOS developer terms and Adobe released Flash Professional CS5.5, which included support for publishing iPhone applications. When Apple initially announced Adobe Flash Player would not be supported on with their iOS platform, many assumed Flash content would never function on the iPhone or iPad. On the contrary, after the 2011 revision, many iOS apps were built, supported, and deployed using Flash; Adobe continues to invest in tools and frameworks to make it easier to create and deploy such apps. At present, an estimated 20,000(+) Flash-based apps and games are available in Apple App Store (Adobe, 2015).

**Development**

The application was developed using Adobe Flash Professional and published with Adobe AIR 13.0 for iOS. Adobe AIR is a basic runtime engine that translates language, in this case ActionScript 3.0, into simple machine language for the central processing unit (CPU), for any standard computing operating system to understand. Comparable to a computer requiring Java installed to run certain programs or web features. Consequently, the AIR application developed with ActionScript was packaged, digitally signed with .p12 certificate, and installed on the iOS device.

This application was coded entirely in ActionScript 3.0 with hand-drawn images and graphics imported through Adobe Photoshop. All images and functionality were optimized for the Apple iOS 6.0(+), but could easily have been published and installed on any Android device. Development decisions excluded common swipes and pinches to establish a consistent user experience and avoid learner confusion; simple tap events were used across all levels of navigation and interactivity.
Mobile Learning Environment Design

This study was as an iteration of the aforementioned Tree Investigators design-based research (DBR) study (Land & Zimmerman, 2015). DBR seeks to study learning within authentic contexts with the goal to inform both theory and design simultaneously (Sandoval & Bell, 2004). DBR methodology can been characterized with five central features: (1) designed learning environments that are grounded in developing theories of learning; (2) have continuous cycles of design, enactment, analysis and redesign; (3) lead to sharable theories that communicate to practitioners; (4) must document success and failures in authentic settings; and (5) relies on methods that can document and connect processes of enactments to outcomes (Barab & Squire, 2004; Koschmann, Stahl, & Zemel, 2004; Sandoval, 2014). In line with DBR methodology, this study extends research on designing technological supports for science learning outdoors using mobile devices (Chen, Kao, & Sheu, 2005; Liu et al., 2009; Squire & Klopfer, 2007) as well as prior iterations of the Tree Investigators design more specifically (Land & Zimmerman, 2015; Zimmerman, Land et al., 2013; Zimmerman, Land et al., 2014; Zimmerman, Land et al., 2015).

This was the most recent iteration of Tree Investigators design-based research study (Zimmerman & Land, 2014; Zimmerman, Land, et al., 2013; Zimmerman, Land, et al., 2014). In the prior iterations, a custom developed app was designed and implemented, used in conjunction with a naturalist (facilitator), to support an outdoor mobile learning experience.
The first iteration introduced a tree life cycle app, accompanied with a 3rd party photo-collage creation app (InstaCollage Pro - Pic Frame & Photo Collage & Caption Editor for Instagram), within an outdoor setting (Zimmerman, Land et al., 2014). The design of these studies looked to inform the role of mobile devices as technological supports (Chen et al. 2005; Land & Zimmerman, 2014; Liu et al. 2009; Squire and Klopfer, 2007), a pedagogical design of guided participation (Rogoff 2003), and the use of a contextualized setting (Bell et al., 2009; Eberbach & Crowley, 2009) to enhance observation and identification. The setting of this iteration began in the Arboretum at Penn State and ended within the Hartley Woods. This iteration also introduced our conceptual model design (see Figure 2) and photo documentation task (3rd Party app). The conceptual model assisted the learners in organizing observations of tree life cycles through naturalist-led activates at each phase, while the photo documentation app fostered learner-directed activity. The naturalist guided participants through each phase of the life cycle with instruction and prompts, and upon completion, learners were asked to open the InstaCollage app to capture images and document (create) their own observation s of tree life cycles.
The next iteration implemented a custom photo documentation task to better facilitate learners to accurately observe trees at various stages of life cycles at the point of photo capture. Creating a more seamless experience allowed learners to be more connected and aligned with the material and environment (Hidalgo & Hernandez, 2001). This iteration also implemented a dual-purpose checklist (see Figure 3), during photo documentation, to organize the task and further instruct on life cycle phase criterion. These additions established a more inclusive experience, enhancing observation and identification. Different from the previous iteration, the setting changed to the Shaver’s Creek Environmental Center during a summer camp. The role of the facilitator in this iteration was to introduce the concepts and model observation practices during the first half of the experience. With the implementation of the check list and photo capture task, the app became more inclusive to the experience, allowing the facilitator to assume the role of resource versus primary instruction.
These prior iterations were instrumental to the design of this study, the successes and failures, in conjunction with the intended audience, to establish the design. To start, the notion of attention was considered, given the young ages of the learners. With this at the center of the design, a decision was made to add a context-specific pedagogical agent within a narrative design for ideal appropriation of the content. Although previous iterations reported an effective design, the maturity and pre-established interest in nature (outdoor summer campers) of the participants could have been a factor. Redesigning the experience with more age-appropriate strategies was necessary.

In addition, this iteration included a redesigned checklist screen, which implemented the conceptual model (see Figure 4). The initial checklist was effective in organizing the learners and reinforcing the content. Ultimately, this redesign focused on the youth of audience, with design elements and strategies aiming to keep them more engaged. By adding the narrative, the content could be delivered as a relatable story, not
just as facts. The addition of the context-specific pedagogical agent then connected the content directly to the environment (Hidalgo & Hernandez, 2001), further enhancing the learner experience. The role of the facilitator was implemented, for this iteration, as a faded scaffold. Based on the progression of the previous iterations, where the naturalist faded to a resource, versus facilitator, the same intention was designed here. With the additional design scaffold of the pedagogical agent, this study was to have two distinct episodes. The first was guided facilitation of the educational content, to foster instruction of the content and acclimate the learners to the app interface and functions. The second episode was the combined learner-centered tasks of capturing observations and building a tree life cycle. Prompts were built, with instructions, delivered by the agent to lessen the need for the facilitator.

![Tree life cycle observation checklist](image)

**Figure 4.** Displays contrast of the checklist used in iteration 2 and this iteration.

**Design Conjectures**

This study looked to inform the role of mobile devices as technological supports, a pedagogical design of guided participation, to include the pedagogical agent and narrative, in a contextualized environment to enhance observation and identification. The following table (Table 1) lists the implemented design conjectures:
Table 1: Technological, Pedagogical, and Environmental design elements.

Design Conjecture 1: *enhance observation and identification*

<table>
<thead>
<tr>
<th>Technological</th>
<th>Pedagogical</th>
<th>Environmental</th>
</tr>
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<tbody>
<tr>
<td>Digital elements were designed for a mobile learning experience to channel learner attention (Pea, 2004).</td>
<td>Naturalist encouraged observation of the contextualized setting to prompt comparisons with digital elements (Liu et al., 2009)</td>
<td>Graphics and images were context specific to focus learners to relevant aspects of the environment.</td>
</tr>
<tr>
<td></td>
<td>Naturalist looked to prompt talk specific to the digital elements and the environment.</td>
<td>Narrative was designed specific to the environment</td>
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<tr>
<td></td>
<td>Naturalist looked to promote inquiry and explanation from the learners.</td>
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Design Conjecture 2: *create a learner-centered design experience*

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<th>Technological</th>
<th>Pedagogical</th>
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<tbody>
<tr>
<td>Information was appropriated to accommodate the age of the learners.</td>
<td>Naturalist established talk and tasks through an initial episode of basic instruction of content.</td>
<td>Learners use the mobile device camera to capture photos and document of the contextualized setting.</td>
</tr>
<tr>
<td>Tasks, to be completed by learners, were implemented to enhance exploration and sense-making (Chen Kao, &amp; Sheu, 2005; Rogers et al., 2004; Zimmerman, Land, et al., 2013; Zimmerman, Land, et al., 2014)</td>
<td>The Naturalist used questioning to trigger previous instruction and prior knowledge.</td>
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Design Conjecture 3: *implement conceptual models throughout the design*

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<th>Technological</th>
<th>Pedagogical</th>
<th>Environmental</th>
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<tbody>
<tr>
<td>Each episode of the app used a conceptual organizer to organize the content and concepts (Quintana et. al, 2004) of each phase of the tree life cycle.</td>
<td>The Naturalist promoted the conceptual organizer throughout the guided instruction.</td>
<td>The setting was complex and natural; conceptual models enhanced organization.</td>
</tr>
<tr>
<td></td>
<td>The Naturalist supported the conceptual organizer throughout learner-centered tasks.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Narrative design complemented the conceptual organizer.</td>
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Design Conjecture 4: *design scaffolds for complex learning*

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<th>Technological</th>
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<tbody>
<tr>
<td>The experience was reduced to identification and organization of the 5 phases of a tree life cycle.</td>
<td>The Naturalist used strategies of demonstration and modeling with examples in context.</td>
<td>Learners were provided free exploration of the setting for discovery.</td>
</tr>
<tr>
<td>Device cameras were used to capture, and make visible, learner observations.</td>
<td>Naturalist asked follow-up questions to promote evidence-based explanation.</td>
<td></td>
</tr>
<tr>
<td>Labeled templates of conceptual organizer was included.</td>
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Design Conjecture 5: *Narrative design to establish sense making*

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Narratives structure complex information for sense making, enhancing value and relevance (Rowe, Shores, Mott, & Lester, 2011).

A story was developed around the educational content. Comic strip style interactions within the app established and progressed the story.

The story attempted to connect learners more emotionally, portraying the environment, not just as “the woods” or “nature”, but as a home and resource.

<table>
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<tr>
<th>Technological</th>
<th>Pedagogical</th>
<th>Environmental</th>
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<tbody>
<tr>
<td><em>An animated pedagogical agent to facilitate learning and attention (Schroeder, Adesope, &amp; Gilbert, 2013).</em></td>
<td>An animated agent, “Nutty” offered directions and prompts to support the learner during tasks.</td>
<td>Learners connect Nutty’s story to the setting.</td>
</tr>
<tr>
<td>Nutty delivered the story and offered personal information (i.e., Snag as winter shelter) to further establish emotional connection of content to environment.</td>
<td>The Naturalist referenced Nutty during instruction of the life cycle phases.</td>
<td>Story elements were content specific.</td>
</tr>
</tbody>
</table>

Design Conjecture 6: *Pedagogical agent to foster and facilitate instruction*
Mobile Application

The mobile application designed for this study focused on an implemented pedagogical agent, ‘Nutty the Squirrel’ and his NuttBook (see Figure 5a). The pre-determined intentions of the content and learning goals were introduced and implicitly established by Nutty, through a comic-strip style narrative. His story begins with hiding an acorn that he discovers has grown into a small tree when he returns to retrieve his snack the following Spring (see Figure 5b).

Figure 5a. Welcome screen with directions

Figure 5b. Comic strip; Establishing narrative and theme for the experience.

Upon this discovery, Nutty decides to record all events of this phenomenon in his NuttBook, which becomes the focus of instruction for each stage of the tree life cycle (see Figure 6a). Nutty’s Nuttbook becomes a scrapbook of events where he records notes about what he observed and provides a picture (see Figure 6b). The content is displayed as educational, while Nutty provides more literal comments on his perspective and how each stage affected him. This information was introduced and guided by a naturalist, then used by learners in a more minimally-structured photo capture and annotation activity in the woods. Nutty also prompted learners to explore and interact with the environment (see Figure 6c). By offering his perspective on what he saw through each stage of the
cycle and how it affected him, the science concepts could be further connected via narrative to the natural setting.

**Figure 6a.** Nutty offering perspective comments in an effort to emotionally connect learners to the content.

**Figure 6b.** Educational content for learners.

**Figure 6c.** Nutty prompting learners to explore the environment.

Throughout the structured content presentation, learners earned a ‘topic visited’ badge as they navigated through each stage of the life cycle (see Figure 7a). Once each badge was achieved, they were able to progress to the outdoor exploration portion of the app where they were charged, by Nutty, to use their mobile device to capture images within the environment that represent each stage of the tree life cycle, in any order (see Figure 7b). Nutty provides criteria for each stage, which is prompted on screen for reference (see Figure 7c). The learner is able to check boxes of the recognized criteria prior to capturing the desired image to enhance learner confidence while scaffolding accuracy of observation. Further scaffolding for this process was provided by internal prompts of the pedagogical agent, the naturalist, and the available peers with the designed collaborative environment.
Once learners captured an image for each stage within the life cycle, Nutty instructed them to use those images to create a personalized life cycle photographic model (see Figure 8a) by loading the selected image into the corresponding stage of the provided life-cycle model template (see Figure 8b).

**Procedure**

Participants were required to have parental consent and verbal assent to participate in the study. The consent forms were provided to each of the participant’s parents by way of the Child Care Center in advance of the study. To acquire verbal assent, participants were gathered at the steps of the Arboretum’s Overlook Pavilion. I
introduced myself as a Penn State researcher and provided an overview of the study. Upon receiving assent from all those present, I explained the forthcoming pretest portion of the study. I made the appropriate effort to explain the pretest as being a very informal survey for us to determine what they already know about tree life cycles.

Once all pretests were completed, the naturalist was introduced. To acclimate the learners to the study, he began with a simple, yet appropriate, question of, “What do squirrels eat?” then followed the ensuing discussion with, “What happens to uneaten nuts?” Most participants raised their hands to answer and the emerged concept that a tree can grow from the discarded nut of a squirrel did not appear to be surprising. The naturalist closed the orientation with a brief introduction to the “adventures of Nutty the Squirrel” and what happened to his nut. Participants were then asked to line up, in groups of two, and begin walking the path conjoining the Arboretum to the Hartley Woods. The participants were asked to stop as a group at the fully matured oak tree, which resides approximately half the distance to the Hartley Woods entrance. The naturalist asked various questions (e.g., “How do you think this tree got here?”), to solicit initial theories about how trees grow in nature and to connect to prior knowledge. The instructor then asked that the iPad Minis be distributed, one for every two learners. Each Mini was fully charged with the Nutty Nature app previously installed and tested. As the initial location was a fully mature oak tree, it was a logical point to introduce the Nutty Nature app. Once the narrative was described, the learners’ forest explorations began, which included instruction and narrative elements of the seed (acorn) then continued to the Hartley Woods.
As the group entered the Hartley Woods, the naturalist led the learners through the app material on the remaining stages of the life cycle: seedling, sapling, mature, and snag, prompting observations of the surroundings for each stage. As learners interacted with the Nutty Nature app and their immediate environment, scaffolding from technology, peers and naturalist supported their observations in a structured manner. Once learners completed the app material for each stage within the cycle, earning their respective badges, they proceeded to the photo capture task, guided by Nutty to explore and capture photos of each stage in the forest. When they launched the camera to capture a respective stage, Nutty appeared with details on how to operate the camera and focused learner attention to specific characteristics of the tree specimens they wanted to capture. Once learners captured photos for each stage of the life cycle, Nutty (and the naturalist) instructed them to proceed to the final task of creating a photographic life cycle model from their images. Learners chose a stage within the depicted cycle, selected a magnifying glass icon to launch and then search the photo library of the device, which stored their saved photos from the photo capture task. Once they completed their photographic models, they were instructed to type their names and submit the final image of their tree life cycle.

**Data Collection & Analysis**

Data was captured on August 21, 2014 from 10:00am to 12:00pm, resulting in approximately 3 hours and 40 minutes of transcribed and analyzed data. This study relied on the following data sources for analyses: (a) written pretest-posttest scores on a 5-item assessment on the stages of a tree’s life cycle; (b) video observations and/or transcripts of
participant interactions and verbalizations; (c) learner photo artifacts. Data collection procedures were put in action to ensure I captured both fundamental and critical practices throughout the study.

**Pretest/Posttest**

Participants were tested prior to the start of study to determine prior knowledge of terms and concepts related to the life cycle of a tree. Each participant received a clipboard and a “golf” pencil to complete the test. They were instructed to complete the test to the best of their ability without the assistance from anyone. The pretest was given immediately after the introduction of the study. Participants were then tested again, with the same questions, after the study; same conditions applied. The posttest was given upon completion of the photo documentation task and after the group returned to the Arboretum. The time between tests was just over an hour and forty minutes. The results of these tests were then compared to determine study significance.

Directions for the test were listed in bold at the top of the page and read, “Please answer the following questions. If you do not know the answer, leave the question blank.” As the directions imply, the test was a fill-in, open-ended response form with one 5-item question: (1) List the 5 parts of a tree life cycle. This question provided 5 lines to write responses. The content for the implemented app, as well as the assessment content, was validated by a plant scientist instructor at Penn State University.

**Video/Audio Recordings**

In an effort to systematically study how learners used the mobile app in the outdoors to learn about tree life cycles, video analyses were used as the primary data source (Barron, 2007; Koschmann, Stahl, & Zemel, 2004). Video recordings were used to
capture multiple levels of interaction (Glense, 2011), which occurred throughout the study. Three cameras were used; each designated to follow a group of learners, to record the entirety of the study from instructor introduction through Harley Woods exploration and Nutty Nature app task completion. Three learners were equipped with lapel wireless microphones, which were connected at the audio port of the camera, to capture as much of the experience as possible.

At the conclusion of the data collection, each recording was extracted, converted to a QuickTime movie file, and transferred to a password protected hard drive. Video files were saved with naming structure of date and camera number (e.g., 2014_8_21_cam1_arb.mov). I then transcribed each video using Inqscribe by uploading the exported QuickTime movie file, creating a searchable and dynamic document. The transcript includes pseudonyms and line-by-line text of all talk, to include time stamps. Transcriptions were used for coding, in reference to the corresponding research question.

**Analysis**

The coding scheme was adapted from previous iterations informing this study (Zimmerman, Land et al., 2013; Zimmerman, Land et al., 2014). These previous iterations focused on observation and explanation for science talk in learner-centered informal learning environments (Allen, 2002). Zimmerman et al. (2015) examined talk, to also include non-verbal communication, adapted from the Leinhardt, Crowley, and Knutson concept of “learning-talk” (2002), as evidence of learning. The video and transcripts were analyzed in conjunction to clarify talk and/or further verify talk related to the environment.
This study’s analysis was aligned with the guiding research questions of this study. To determine if children’s knowledge of the life cycle increased after the mobile learning experience (Question 1), the one-question pretest/posttest (maximum of 5 points) on tree life cycle knowledge was compared using paired t-tests (n = 14). To analyze the second question, how do children talk together about trees and life cycles while using the mobile learning environment outdoors during summer camp (Question 2), a coding and analysis scheme, derived from Sue Allen (2002), as applied by Zimmerman, Land, et al., of perceptual talk (identification, naming, and describing species); conceptual talk (inference, interpretation, and prediction); connecting talk (life, knowledge, and interspecies connections); and affect talk (emotional expressions of positive or negative feelings) was used. Interrater reliability was established through methods that used a second rater. Three researchers coded one transcript together fully to agree on an initial codebook of definitions. Two researchers coded a second transcript independently, and the interrater reliability was 88%. Based on this threshold, I coded the remaining transcripts, with a second coder spot-checking the results. Disagreements in coding were resolved via discussion. In total, three separate transcripts were analyzed.

For question 3, to determine how designed elements of the mobile learning environment assisted learners to observe, identify and create artifacts of tree life cycle concepts (Question 3), excerpts were analyzed by examining talk specific to episodes of how learners interacted with the mobile app to identify trees and create tree life cycle artifacts based on photographic evidence. The analyses were applied to transcribed talk during both the guided-facilitation episode and the learner-centered photographic tree identification task. This analysis focused on two primary areas: (a) how learners
interacted with the app to connect their identifications of tree life cycles in the forest to evidence or criteria; and (b) how design elements, such as the pedagogical agent of Nutty or narrative storyline, influenced their interactions with each other, the app, and their interactions with the environment.

**Confidentiality**

Approval of the Institutional Review Board (IRB) at Penn State University was acquired prior to the study. Participants were provided pseudonyms in organization, storage, and during analysis. A Microsoft Excel spreadsheet, stored on my password-protected laptop in a password-protected drive, documented the participant’s real names, parental/own consent confirmation and results to pretest/posttest.

All files: video transcripts, raw video with audio, and images collected were stored on an encrypted Western Digital external hard drive with no option to save password details to the Disk Utility Keychain. File naming structures started with date of the study, camera number, and “arb”, depicting the arboretum, the study location.
Chapter 4

Results

This study explored how narrative elements of a mobile learning environment engaged learners in extended exploration, sense making, and creation of learning artifacts in the outdoors. More specifically, the study was enacted to investigate how various features of a mobile learning experience designed for use in informal, outdoor learning environments support young children to: (a) engage in science talk about tree life cycles; (b) demonstrate knowledge of tree life cycles; and (c) create digital artifacts of tree life cycles, using customized tools to document photographic evidence. The results will be represented in accordance to each research question, which combines all participants.

Research Question One

The first question, “Did children’s knowledge of the life cycle increase after participation within the created mobile learning environment and subsequent mobile app experience…?” was analyzed through a 5-item assessment of life cycle facts and concepts. The assessment was provided immediately before and after the mobile learning experience. Learners received 1 point for each correct response and 0 points for incorrect responses, with a possible 5-point total. A paired-samples t-test was conducted to compare the scores of each learner for the pre- and post-test. The pre-test mean score was .86 points with standard deviation .535, while the post-test mean was 4.07 with a standard deviation 1.141 (Table 2), showing a significant improvement (t = -11.444, p = .000) after the experience (Table 3). These results suggest the mobile learning experience had a positive effect on learning life cycle facts and concepts.
Table 2: Paired-Samples Statistics

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>N</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>.86</td>
<td>14</td>
<td>.535</td>
</tr>
<tr>
<td>Posttest</td>
<td>4.07</td>
<td>14</td>
<td>1.141</td>
</tr>
</tbody>
</table>

Table 3: Paired Samples Test

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>S.D.</th>
<th>t</th>
<th>Sig (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1 Pre-/Post-test</td>
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<td>1.051</td>
<td>-11.444</td>
<td>.0000000368</td>
</tr>
</tbody>
</table>

**Research Question Two**

Question two, “How do children talk together about trees and life cycles during the mobile learning experience outdoors...?”, was analyzed through transcripts of video. Transcripts were coded through a scheme, derived from Allen (2002), as applied by Zimmerman, Land, et al. (2015), of perceptual talk, conceptual talk, connecting talk, affective talk and device use. The chart below (see Figure 9) displays a summary of the coded talk during the mobile experience.
Through a line-by-line analysis of the transcripts, the Allen (2002) coding scheme was applied to the data set to discover and reveal patterns. Of the categories, perceptual talk was the most commonly coded, with 149 instances (37% of coded talk). Perceptual talk included: (1) self-directed reading that is attached to tree (nature) or picture (device); (2) talk that shows describing, observing, or noticing; (3) a visual comparison between app (device info.) and specimen (nature) without applying a tree life cycle conceptual category; or (4) referencing location of an object. Examples of coded perceptual talk:

1. Naturalist: The seedling, how big is the seedling again?
2. Chance: Under two feet. [Per]
3. Naturalist: Under two feet so we can find a seedling under two feet and we can photograph it. How high is two feet?
4. Chance: ((puts hand at stomach)) About to our belly. [Per]
5. Avril: ((points to a very small seedling-like plant, then a sapling.)) About under this, above that. [Per]
6. Avril: Um, it's a little higher than two feet. Because this is what… ((Reaches for a tall weed-like plant)) [Per]
7. Minnie: ((points to a larger Sapling)) This is about, this is a little taller. [Per]
8. Avril: Ah, but anyone can put their hand around it. It takes two, at least two. Okay, I know but adult hands could probably do it. [Per]

The next most frequently-coded category was conceptual talk, (119 or 29% of coded talk) described as, (1) talk that makes a connection from the app content to a tree (life cycle phase); linking a tree (phase) and its specific properties; (2) talk reflecting prior knowledge that is not explicitly ‘sourced’ to contexts outside of the research setting; (3) answering questions beyond “yes and no” that require interpretation; (4) identifying instances of trees in a life cycle stage, by applying the conceptual category (seed, seedling, sapling, mature, snag), rather than solely the object’s (tree, acorn, etc.).

Examples of coded conceptual talk:
1. Minnie: It could have fallen off another tree. [Cpt]
2. Learner: Maybe it came from another ... Like a plant, ((points to a bush in the distance)) like that plant right there. [Cpt]
3. Avril: Hey, sapling, I know a very good sapling. [Cpt]
4. Minnie: ((points to a Sapling)) This is like a sapling? [Cpt]
6. Minnie: I know which, where one it could be, ((points to a large mature tree)) that one? [Cpt]
7. Avril: Okay. And then a snag could be ((points to a standing snag, then a fallen snag)) that or that. [Cpt]

Affective talk was the third most frequently coded at 98 instances (24% of coded talk). Affective talk was coded as, (1) expressions of feeling, positive, negative, or curious towards app material; (2) playfulness with pedagogical agent, each other or surroundings; and (3) showing interest in nature or features of environment. Examples of affective talk:
1. Brent: I touched his butt. (Laughs) [Aff]
2. Avril: ((entering Hartley Woods)) Good, it looks like we're going into a mini maze. [Aff]

3. Brent: Look at Nutty. He's so cute. Oh look, his tail is going up. … ….That is so funny. [Aff]


Perceptual, conceptual and affective talks were the most predominant types identified, with connecting and device talk, collectively only representing 10% of coded talk.

Connecting talk was described as, life, knowledge, or inter-species/object connections (e.g., “in my backyard…” “oh, this is like the pine”, “at home”, “in school”, etc.), and was only 13 instances (3% of coded talk). Examples of coded connecting talk:
1. Chance: My grandma had a, had a tree that only grows like the size of that bush. [Cnn]
2. Pippy: My grams- my grams now had a- had a tree that only grows like the size of my foot. [Cnn]

Device talk was described as, (1) questions about what to do next to complete photo documentation task; (2) device talk related to the activity or app; and (3) discussing intentions to use the app, had 28 recorded instances (7% of coded talk). Examples of coded device talk:
1. Patti: Where does it say camera roll? [Dvc]
2. Zander: I think I can ... I'm pressing it, but it's not working. [Dvc]

In comparison to previous iterations of this DBR study, the overall patterns of talk were similar, with perceptual and conceptual talk being the first and second most
frequently coded categories, respectively. However, this study coded considerably more instances of affective talk (4.6% averaged of coded talk in a previous study, in comparison to 24% for this study). This finding of the higher frequency of affective talk could possibly be explained by the relatively younger age of this iteration’s participants, in conjunction with the introduced pedagogical agent, who elicited playfulness and delight from the children.

**Research Question Three**

Question three, “How did designed elements of the mobile learning environment assist learners to observe, identify and create artifacts of tree life cycle concepts?”, was analyzed through transcripts of video, using episodic analyses. In reference to the previous iterations of the study, the app content remained identical, but the design was changed to accommodate the younger audience. The focus of the design was to complement the participants developing attention by using gamified elements of narrative, earned badges, and a pedagogical agent. The narrative was designed to assist in establishing a connection among the learner, the content and the woodland environment. In conjunction, a content-specific pedagogical agent, who was part of the narrative not merely a facilitator, delivered educational content through a told story. The desired affect was to achieve an emotional response with the outdoor environment by adding a level to the narrative, which portrayed the environment as a resource and home to the implemented pedagogical agent, Nutty the Squirrel.
Pedagogical Agent

To determine the role Nutty had on the learning experience, interactions, which involved the pedagogical agent, were recorded and analyzed. Throughout the transcripts, any interaction that referred to, or referenced, Nutty, by the learners totaled 35 instances (of the 406 recorded) any interaction with Nutty referred or prompted by the Naturalist, was 27 instances (of the 406 recorded). The following excerpts show how the children playfully incorporated Nutty into the natural woodland environment:

1. Brent: I can see nutty.
2. Patti: Where?
3. Brent: He's in this hole. He's down there now.
4. Patti: Did you see him?
6. Patti: Oh, did he climb right there?
7. Brent: I don’t think he's up there. He’s in his den right there.
8. Patti: There?
10. Patti: I don’t know.

11. Naturalist: A seed. Now there are- there are two ways that that seed could have got here; one, it could have got here by an animal, or ...

In these instances, the learners discuss Nutty, in relation to the local environment. The verbalizations were unprompted and occurred early in the experience, shortly after the Naturalist’s introduction of the app and Nutty’s adventure. It was an interaction that showed support for our design intention to help connect the learner to the environment by way of the context-specific agent, creating an emotional attachment.

It should also be noted, however, that some interactions with Nutty did not show evidence of science talk or of connection with the environment, as shown in the following excerpts:
1. Brent: I touched his butt.
3. Brent: I touched his butt. (Laughs)
4. Mitlon: Nutty is so cute!

In some instances, Nutty appeared to be more of a distraction than a facilitator:

1. Brent: Look at Nutty. He's so cute. Oh look, his tail is going up. … … …That is so funny…. he's blinking.

5. Naturalist: Everybody looking at the Nut Book?
6. Brent: Buddy instead of Nutty?
7. Naturalist: Okay, so-
8. Patti: Nutty sit on Buddy. Buddy, get it, from Dinosaur Train?

Of all recorded learner interactions with Nutty, none of them implied guidance or facilitation by the agent. Although there is positive evidence for the role Nutty played in the learning experience, especially in engaging affective talk, there was little evidence that he served a guiding or teaching role. Throughout the analysis, it became clear that Nutty was positive for the design, but lacked a pedagogical element. His intention was to be a scaffold and facilitator, complementing the Naturalist, but appeared to be more of an avatar. Future design should consider implementing instructional strategies to establish Nutty pedagogically.

**Guided Facilitation vs. Learner-Centered Tasks**

The mobile learning experience was designed with various levels of instruction and interaction. The overall level was a narrative, which established a theme that was carried throughout, followed by a level of guided facilitation and ending with a learner-
centered digital artifact construction task. The initial level was the guided facilitation of the educational content by the Naturalist (facilitator). This level was designed to acclimate the learners to the iPads, the app functionality, and tree life cycle concepts, all while allowing learners the freedom to inquire and explore when desired. Throughout this episode, the naturalist read app content aloud and asked prompting questions, initializing interaction and talk among the learners. The final level, the learner-centered task, required learners to use their iPads to capture photographic evidence of tree life cycles in the forest. Learners were asked to capture one image for each phase of the life cycle then correctly import them into the provided collage template, creating their own, personalized tree life cycle model.

In the line-by-line analysis of transcripts, the coding scheme was examined again for patterns of science talk during the guided facilitation phase (GF) and then the learner-centered (LC) task. In comparing the coded talk, 166 instances were coded in the GF episode (41%) versus 240 instances in the LC episode (59%), showing an 18% increase in talk during the learner-centered photo documentation task. Although an increase was reported, it should be noted the time span of each episode was not equal. The overall experience was 70(+-) minutes, with a larger majority being allocated to exploration within the learner-centered episode.
Table 4. All Coded Talk; GF episode in comparison to LC episode.

Perceptual talk in the GF episode had 58 instances (14% of coded talk) versus 91 instances (22% of coded talk) in the LC episode, showing an 8% increase during the learner-centered task.

Table 5. Perceptual Talk; GF episode in comparison to LC episode.
With conceptual talk, there were 52 instances (13% of coded talk) in the GF episode versus 67 recorded instances (17% of coded talk) in the LC episode; a 4% increase in talk during the learner-centered task.

Affective talk, the third most frequently coded category of talk, showed 44 instances (11% of coded talk) in the GF episode and 54 recorded instances (13% of coded talk) in the LC episode; a 2% increase during the learner-centered task, suggesting that the children were affectively engaged during both GF and LC phases of the experience.

Table 6. Conceptual Talk; GF episode in comparison to LC episode.
Of the remaining categories, connecting talk remained the same between both GF and LC activities with 6 recorded instances in each episode (1% of coded talk) and device talk increased during the learner-centered activity, with 6 recorded instances in GF (1% of coded talk) and 22 instances during the LC task (5% of coded talk). The consistent increase among all categories during the learner-centered task shows that, not surprisingly, more learner talk took place across most categories as the result of their collaborative discourse. The larger increase in the amount of perceptual talk during the learner-centered activity can perhaps be explained by learners recalling the general content of the app in an effort to convince himself/herself, or a peer, about a choice:

1. Patti: We need to find a big one. [Per]
2. Brent: ((points to a mature tree)) It's right there.

Perceptual talk was described, in part, as talk that shows describing, observing, or noticing. In this instance, the learner (Patti, Line 1) knew the next image to capture in the phase was a mature tree, but referenced it as “a big one” instead. Her peer (Brent, Line
2) was able to understand and apply her descriptor to successfully notice a mature tree.

In other instances, learners knew the correct term to use, but still voiced descriptors to prompt and/or confirm their decisions:

3. Zander: Where's the bendable trunk one? [Per] Ooooh, I saw a sapling. Let me look and see ... Oh, I think this is a sapling. [Cpt]

These findings show that these young learners were able to engage in perceptual, conceptual, and affective talk as they worked together collaboratively. This suggests the overall experience was effective in supporting processes of noticing, describing, and applying conceptual categories to tree characteristics in the woods. Although the Naturalist often prompted interactions, much of the talk became more specific. Particularly, as the learners progressed through the experience, their talk evolved from perceptual descriptions of each life cycle phase, to applying correct life cycle phase terminology.

**Observation and Identification**

The most pertinent intent of the study was to provide learners the necessary instruction and experience to enhance observation, identification and creation of artifacts in reference to the life cycle of a tree. Each design element, and recorded results, discussed to this point were focused on this intent. During the experience, the Naturalist tailored instruction, to both the content and pedagogical agent, to enrich and organize the presentation/delivery of material appropriate for the young audience. The desired result was for learners to practically apply learned information to the natural context, as well as appropriate new scientific vocabulary, which was supported by data presented previously.
Ultimately, learners identified each phase of the tree life cycle in the environment, and also explained, with evidence, how they came to a conclusion.

In the initial guided facilitation episode, the Naturalist initiated most of the recorded perceptual and conceptual talk through inquiry prompts:

1. Naturalist: Usually the trunk is smaller than 12-1/2 inches around at about chest height. So it's about the size of two adult hands wrapped around it. So for example, if I was to look at this tree right here. This tree, can I put my hands around it?
2. Group: Yes. [Per]
3. Naturalist: Okay. So one of the ways to tell if this is a sapling is by putting your hands around it, and if you look the, the trunk ... [bends the trunk]
4. Group: (laughter)
5. Naturalist: The trunk is still a little bendy.

This example shows how the Naturalist connected the app content by wrapping his hands around the tree and then “wobbling” to test its pliability.

In another example (below), learners first comprehend and understand the content by successfully agreeing to the Naturalists comments, but as he elaborates, a learner, Avril, applies the content further by successfully pointing out a standing snag within the environment, consequently receiving confirmation from her peers.

1. Naturalist: This is an example of a dead tree. This is an example of a snag. It was once alive, and now it has fallen over. It is dead. Can a tree that has not fallen on the ground, still be dead?
2. Group: Yes.
3. Naturalist: Can it be a standing snag?
4. Avril: ((Points to a standing snag)) That? [Cpt]
5. Group: Yes.

As the experience progressed, learners became more apt with observation, to the point of questioning/correcting the Naturalist during his instruction. In the following example, the Naturalist quickly points out a potential sapling without analyzing the entire scene:
1. Brent: He's already dead.
2. Patti: Who?
3. Naturalist: There we have, there we have a sapling.
4. Learner: He's dead.
5. Brent: It is dead. He doesn't have leaves anymore. [Per]
6. Naturalist: Now he could be dead. Yeah, he actually might be. I didn't look way up there. I should have.
7. Brent: Well, he is dead because he doesn't have any leaves.
8. Naturalist: Okay

Although the tree being discussed had enough characteristics to be mistaken as a sapling at first glance, it did not have all the characteristics, missing leaves (during summer). Some learners were able to observe this, and were confident enough to share.

As the experience progressed to the learner-centered episode, the Naturalist remained a facilitator, prompting learners to recall previous instruction and provide evidence of discoveries. In the following example, the learner is able to answer the naturalist’s question and provide evidence of her understanding.

1. Naturalist: The seedling. How big is the seedling again?
3. Naturalist: Under two feet. So we can find a seedling under two feet and we can photograph it. How high is two feet?
4. Avril: Up to our belly.
5. Naturalist: Up to your belly. And then-
6. Avril: About, under this, above that. […uses her chest (under) and waist (above) to show the two feet ]

As the learners continue through the life cycle phases, the discourse without the Naturalist (facilitator) continues to include recalled app materials and evidence-based conclusions:

1. Minnie: This is like a sapling?
2. Avril: Ah, but anyone can put their hand around it. It takes two, at least two. Okay, I know but adult hands could probably do it ...Because I can only, yeah.
Even the youngest of learners (5 years-old) was able to engage the learner-centered experience. His (Zander) discourse was coded as perceptual at times, but evolved to conceptual throughout the experience, as depicted below.

1. Zander: Where's the bendable trunk one? Ooooh, I saw a sapling. Let me look and see... Oh, I think this is a sapling.
2. Zander: Oh, I saw a big one!
3. Researcher3: Where?
4. Zander: There!
5. Researcher3: Where?!
6. Zander: There, that’s a mature tree.

In the coded talk, the frequency at which learners used descriptors versus each life cycle phases terms decreased. Learners not only began to recognize each phase correctly, but apply evidence and reason to their conclusions.

Overall, most of the perceptual and conceptual talk was prompted by the Naturalist, whom either called attention to content or asked a clarifying question to the group by way of ongoing and dynamic/adaptive scaffolds (Puntambekar & Kolodner, 2005). As the experience progressed, perceptual and conceptual talk did increase among the learners, but was often prompted through Naturalist, or more knowledgeable adults, not the learners. The following examples depict a progression of the talk, as learners initially agreed to questions, but progressed to specific answers and then eventually discovery with minimal guidance.

*Early in the experience:*

1. Naturalist: Usually the trunk is smaller than 12-1/2 inches around at about chest height. So it's about the size of two adult hands wrapped around it. So for example, if I was to look at this tree right here. This tree, can I put my hands around it?
2. Group: Yes. [Per]
3. Naturalist: Okay. So one of the ways to tell if this is a sapling is by putting your hands around it, and if you look the, the trunk... [bends the trunk]
4. Group: (laughter)
6. Naturalist: The trunk is still a little bendy.

**Mid way through the experience:**

1. Naturalist: The seedling. How big is the seedling again?
3. Naturalist: Under two feet. So we can find a seedling under two feet and we can photograph it. How high is two feet?
4. Avril: Up to our belly.
5. Naturalist: Up to your belly. And then-
6. Avril: About, under this, above that. […] uses her chest (under) and waist (above) to show the two feet

**Late in the experience:**

1. Zander: Where's the bendable trunk one? Ooooh, I saw a sapling. Let me look and see … Oh, I think this is a sapling.
2. Zander: Oh, I saw a big one!
3. Researcher3: Where?
4. Zander: There!
5. Researcher3: Where?!
6. Zander: There, that’s a mature tree.

Through the video analysis of group, more knowledgeable individuals (e.g., researchers, camp counselors) observed interactions and often found it necessary to interject and facilitate (Puntambekar & Hubscher, 2005; Sharma & Hannafin, 2007; Puntambekar & Kolodner, 2005).

1. Researcher3: Now you need a really big tall one. Which was the really big tall one?
2. Patti: This one.
3. Researcher3: Excellent work. This is great.
4. Brent: This one?
5. Researcher3: Now you need one that's kind of like ... yep, there you go.
6. Brent: So the seed?
7. Researcher3: This is the sapling, so that's kind of like the wiggly one. Is there a wiggling one? Which one was the wiggly one?
8. Brent: I think it was this one.
Although this was a planned design scaffold, the intent was for the scaffolds to fade for learners to assume more control and take responsibility for their learning (Vygotsky, 1978). The pedagogical strategy prior to the study called for the Naturalist to be a facilitator amongst the group as they interacted with the mobile application and the environment, but fade throughout the experience to allow the learners to rely more on the technological (McNeill et al., 2006; Quintana et al., 2006) and design scaffolds. The young ages of the learners, however, might have been a mitigating factor in the naturalist’s goal to fade the scaffolds.

**Usability**

Many factors were considered regarding the usability of the application, including using the iPad Mini over the standard iPad to make it easier for smaller users to carry and operate. Ease of use was also considered for each design element, for instance, “back” and “next” interface buttons were placed in the bottom left and bottom right corners, respectively, to allow for easy access when operating. To capture an image during the identification task, users simply tapped anywhere on the screen, in lieu of a specific button, to simplify the process. Interface functionality was also consistent with interactive elements. Buttons consistently were displayed in the same place, with exact or complementary design.

The implemented elements of earned badging were also part of the interface design to help organize and track user progress. During the guided facilitation episode, badges were provided when content was visited to both motivate the learner and to inform them that the content was visited. In the learner-centered episode, green checks would appear when an image was successfully captured for a particular phase. Each of
these elements were used effectively with few issues. Unfortunately, even with the information from prior iterations and the many factors considered, two specific design decisions caused grief and frustration for the learners; an ill placed back button and device settings permission.

**Back Button**

During the image capture task, a back button was implemented for the user to return to the educational content of the app for review. This screen contained a counter variable to record when a phase of the life cycle was visited; it also displayed an earned badge for the learner. Once the counter variable reached 5, reflecting that each stage was visited, the next button would appear, progressing to a comic introduction for the upcoming task. During the image capture, which followed the comic introduction, the back button was coded with the intent of allowing the user to navigate between the task and the content. Unfortunately, when learners navigated away from the image capture screen to the educational content, the counter variable did not cache and learners would be required to navigate through all 5 phases again in order for the next button to reappear. They then needed to navigate through the comic introduction to return to the image capture screen. Upon returning, the learner would discover their previous progress, had they taken any pictures earning a green check, was also not cached, resulting in going through the image capture process again, for each phase. Because there was a counter variable on this screen as well, revisiting each image capture phase was unavoidable, even though images may have already been saved to the camera roll, the next button appearing was contingent upon phases being in the visited state. This caused a lot of frustration among the young learners.
There was also a back button on the photo collage creation screen, which was coded to navigate to the image capture screen, providing the learner an opportunity to retake an image. Unfortunately, like the previous back button, the variable did not cache. Once learners navigated away from this screen all content was reset to an empty collage, resulting in another understandable point of frustration for the learners.

A suggested solution to both of these scenarios would have been to create global variables, instead of the two separate local variables, that would have carried throughout the entire mobile app. Once each respective variable reached 5, learners would have been free to navigate through all content and screens with no requirements. Another solution, based on video analysis, would be to remove the back buttons all together, but allow users to redo the experience once complete.

Device Setting

The other point of grief and frustration was related to the device settings camera permissions. Once the learner reached the image capture portion of the app, they where required to tap a camera icon to launch the camera. The camera launched quickly and obviously, creating no confusion for the learner. Once the learner selected the desired criteria and captured an image, they were offered the options of ‘use image’ or ‘retake’ (see Figure 10a).
If the learner chose ‘retake’ the camera would reload. When the learner chose the ‘use image’ option, this button was coded to save the capture to the devices camera roll, causing the device to prompt the learner if they would like to allow this happen (see Figure 10b). If the learner selected ‘OK’ all captures were saved to the camera roll to be used later in the app. Consequently, if the learner selected ‘Don’t Allow,’ the device camera and app functions would appear to be working as expected, but the captures would not be saved to the devices camera roll to be used later. If ‘Don’t Allow’ was selected, learners would attempt to create their collage when prompted, but the camera roll would not have their captures to do so, resulting in recapturing all desired images.

As one could imagine, this was a large frustration for some learners:

1. Avril: What the?
2. Naturalist: Press the select button.
3. Avril: What the heck?
4. Naturalist: Then go to camera roll, and the select your seed picture.
5. Avril: What happened? We lost all of our pictures.
6. Brent: We have to take the same pictures all over again.
7. Researcher3: All over?
8. Brent: Yeah.
9. Researcher3: From the start?

This was only the case on devices that first ran the app, this permission would have been cached had the app been launched previously. The proposed solution would be to launch and run the app on each device prior to distributing to the learners.

As indicated by the findings, implementing a narrative-based, mobile learning experience supported learning among young learners in an informal setting. The designed elements of a pedagogical agent; narrative strategies; photo-documentation tool for identifying and photographing tree life cycles, assisted learners to observe, identify and create artifacts of tree life cycle concepts. The contribution of this design-based research study further informs mobile-enhanced designs for learning outside of school while supporting informal science education.
Chapter 5

Discussion

This study examined how learners engaged in extended exploration, sense making, and creation of learning artifacts in the outdoors within a narrative-based mobile learning environment. The study looked to expand research on designing opportunities for young learners to interact with peers and technology, in natural settings (Chen et al., 2008; Järvelä, Näykki, Laru, & Luokkanen, 2007; Quintana, Reiser, Davis, Krajcik, Fretz, Duncan, Kyza, Edelson, & Soloway, 2004; Sharples, 2013), to connect more with the physical environment (Hidalgo & Hernandez, 2001). More specifically, the purpose of this research was to investigate how various features of a mobile learning environment supported young children to: (a) engage in science talk about tree life cycles; (b) demonstrate knowledge of facts and concepts related to tree life cycles; and (c) create digital artifacts of tree life cycles, using customized tools to document photographic evidence. A learner-centered design was the guiding theory, which suggests and supported immersing young learners in a more realistic, authentic situation wherein knowledge can be applied (Land, 2000; Land, Hannafin, & Oliver, 2012).

Guided by a focal research question of implementing mobile learning outdoors, this study supported and extended prior iterations of our Tree Investigators design-based research studies (Land & Zimmerman, 2015; Zimmerman et al., 2014; Zimmerman et al., 2015). It also expanded on using narrative-based instruction within a designed contextualized mobile learning environment to promote meaning making (Andrews et al., 2009) by focusing the narrative directly to the actual setting, further complementing a learner-centered design. Within the narrative, a context-specific pedagogical agent
Schroeder, Adesope, & Gilbert, 2013) was implemented for scaffolding, demonstrating, modeling, and coaching throughout the educational content. Gamified elements supplemented the narrative to enhance knowledge acquisition, content understanding and motivational outcomes (Connolly et al., 2012; Hays, 2005; Kapp, 2012; Sitzmann, 2011). In addition to the focal research question, this study investigated three related sub-questions, which follow with summaries, findings, discussion and implications for design.

**Research Question One: Knowledge of Tree Life Cycles**

The first research question was: “Did children’s knowledge of the life cycle increase after participation within the created mobile learning environment and subsequent mobile app experience, as measured by scores on a pretest and posttest of the 5 stages of an oak tree life cycle?” The results indicated a significant improvement when comparing the pretest results (mean score of .86) with the posttest results (mean score of 4.07, out of 5). Learners were not only able to recall the phases of a tree life cycle, but list them in the correct order. The comparison reports a significant increase, showing evidence of increased knowledge and appropriation of scientific vocabulary. More specifically, the results show content was presented and delivered in an effective and comprehensible manner for the young learners, allowing them to recall information when needed.

**Implications**

The pretest/posttest provided insight into Design Conjecture 3: implement conceptual models throughout the design. The mobile app used a consistent conceptual model of the tree life cycle as a scaffold (Quintana et al., 2004) throughout the
experience, which may have played a role in helping learners to gain life cycle vocabulary; this would need to be investigated more systematically in future studies. When triangulated with evidence from the videos showing learners were able to apply life cycle concepts to specimens in the woods with the aid of an AR-inspired tool, this study provided evidence that the overall mobile learning design improved knowledge and application of life cycle concepts.

The Naturalist was instrumental in promoting the conceptual organizer throughout the guided instruction, also complemented by the narrative. A consistent implementation of the conceptual organizer, within the design, and ongoing support, enhanced retention of content, as seen in the posttest results.

These results also inform ‘Design Conjecture 4: design scaffolds for complex learning’. Within the design, scaffolding was implemented within the application and the experience to minimize the complexity of the learning environment. The Naturalist used strategies of demonstration and modeling with examples in context (Xun & Land, 2004) and asked follow-up questions to promote evidence-based explanation, enhancing participation (Kirschner, Sweller, & Clark, 2006).

**Research Question Two: Categories of Talk**

Research question two was: “How do children talk together about trees and life cycles during the mobile learning experience outdoors during summer camp? Results reported perceptual talk had the highest frequency, followed closely by conceptual talk and then affective talk. Connecting talk and device talk were the least frequently recorded talk, respectively. These findings extended and supported the results of our
prior iterations; however, the higher frequency of affective talk differed. This difference could be explained by the implementation of the pedagogical agent (Nutty) to the design. Affective talk was coded as (1) expressions of feeling, positive, negative, or curious towards app material; (2) playfulness with pedagogical agent, each other or surroundings; and (3) showing interest in nature or features of environment. Nutty was implemented to garner interest of the participants to the educational content and establish a connection with the environment. Although instances of interactions where Nutty prompted a connection to the environment were infrequent, many interactions were recorded depicting participant interest in the agent. There was clear playfulness and delight from the children to Nutty and his animated features, a positive and desired response.

**Implications**

With analysis of coded talk, determination of design ‘*Design Conjecture 1: enhance observation and identification*’ was established. Designed digital elements appeared to be effective, as learners were able to consistently identify phases of the tree life cycle within the natural environment from the educational content of the app. These elements worked well in conjunction with the Naturalist’s role.

Throughout analysis, it became evident the Naturalist was an integral component of the learning process, as well as progressing the experience. Although this role was intended and pre-determined, the frequency and volume of his involvement was not intended to be so high. Because this was designed as open-ended to immerse learners in experiences to foster understanding through extended exploration, manipulation, and opportunities to "get to know" an idea, rather than simply being told about it (Hannafin, Land, & Oliver, 1999; Land, 2000), little scripting was established for the Naturalist.
Establishing a more defined role with deliberate instruction, questions, and prompts for the learner could prove to enhance the learning experience. The Naturalist encouraged observation, prompted comparisons and aligned talk, when able, to the digital elements of the experience.

**Research Question Three: Design Elements**

Research question three was, “How did designed elements of the mobile learning environment; (a) pedagogical agent; (b) narrative strategies; and (c) photo-documentation tool for identifying and photographing tree life cycles, assist learners to observe, identify and create artifacts of tree life cycle concepts? The overall experience elicited a positive response from the participants, explicitly noticeable through their attention. The study, from start to finish, was over 70 minutes (not including pre/posttest); only two instances in that time called for adults to intervene and refocus the collective. The first of which was due to unexpected rain, causing the group to find coverage under a large oak tree, an understandable distraction for the young learners and adults, but it was recovered quickly. The second occurred in the Hartley Woods when the Naturalist switched from the guided instruction to the learner-centered task, also a quick recovery. Ultimately, the design effectively sustained the attention of the participants and they remained motivated to complete the each task.

Surprisingly, even when pictures were not correctly saved (camera roll permissions) or tasks unintentionally reset, participants remained committed and focused on completing them. Emotions of frustration were evident at times, but short-lived. An unintended consequence of those whom had to redo their images was a noted confidence
in their ability to re-do the task. Understanding it was repeated material, learners were much more efficient with completing the task the second time around and required little assistance.

**Implications**

Analyzing the effectiveness of the designed elements informed ‘Design Conjecture 6: Pedagogical agent to foster and facilitate instruction’. The results of this research and analysis showed the pedagogical agent did have an impact of garnering learner interest, but there were few indications of impacting the learning process, aside from affective talk. When comparing this study to our previous iterations (Land & Zimmerman, 2015; Zimmerman et al., 2014; Zimmerman et al., 2015), the similar results in perceptual and conceptual talk further support this finding. Although interest can be a factor in learning (Schiefele, 1991), there were more supporting pedagogical strategies implemented (e.g., naturalist, collaboration), beyond the pedagogical agent. The results suggest a pedagogical agent can assist with an element of the learning process, but should have supporting pedagogy within the design.

In considering how well the users adapted to the interactive elements within the design, future research will implement more interaction with the pedagogical agent, beyond a complement to the narrative. In this design, Nutty prompted learners to explore and interact with the environment, in the form of simple statements. The agent did not demonstrate or model information for understanding or completing tasks (Choi & Clark, 2006; Johnson, Rickel, & Lester, 2000) beyond standard directions. Had Nutty been used more as a scaffold for learning (Barab & Duffy, 2000), he may have been more significant in influencing the learning process. **Future designs will consider**
implementing Nutty’s prompts as questions or tasks, restricting the user to progress, until answered or completed. This could engage the learner more, lessening the need for a facilitator.

In conjunction with the pedagogical agent, there was little evidence of a direct effect on the learning process related to the badging element. Participants appeared to reference the earned badges as an organizer more than affecting achievement and motivation (Deterding, Dixon, Khaled, & Nacke, 2011; Kapp, 2012; Schroeder et al., 2013). This was noted in talk of, “we already did that one”, and “we didn’t do that one yet”. The badges did not provoke any form of competition among the group (Kapp, 2012); instead, peers collaborated and helped each other. This could be explained by the delivery of the narrative being a ‘told’ story versus an augmented learning experience with mystery or adventure (Dede, 2009; Klopfer & Squire, 2008; Squire & Jan, 2007). Future research designs could include Nutty framing his discoveries with an element of unknown, prompting the participants to assist him through levels and tasks, perhaps establishing a gaming attitude, making these elements more influential.

This analysis also informed ‘Design Conjecture 5: Narrative design to establish sense making’, Finding suggests the narrative was effective in structuring the complex material for sense making (Rowe, Shores, Mott, & Lester, 2011). Learners may have attributed more value and relevance to the content through the narrative, supporting when learners apply knowledge and concepts in real contexts, it can increase learner understanding (Andrews et al., 2009; Hodson, 2014). Future research with narratives should consider a design to promote learner agency through more interactions between resources, settings, and the narrative, to enhance learner perceptions, use, and value (van
Lier, 2008). With the already created comic-book style narrative, a conditional branching scenario framework could be implemented to evoke more options and choice within the design. Providing learners with options and choice (Falk & Dierking, 2002), establishes learner agency and awareness to the idea their decisions affect learning (Bandura, 2008; Mercer, 2012).

Pertinent to this experience was the learner-centered task, which was derived from ‘Design Conjecture 2: create a learner-centered design experience’. To ensure the task was achievable, educational content was appropriated to accommodate the age of the learners. The intent of each task was to enhance exploration and sense making (Chen Kao, & Sheu, 2005; Rogers et al., 2004; Zimmerman, Land, et al., 2013; Zimmerman, Land, et al., 2014), allowing learners to make connections and discoveries with the designed elements and the contextualized environment. Throughout the tasks, the Naturalist prompted talk through inquiry and referenced previous instruction to encourage accurate task completion. Throughout the photo capture and life cycle creation tasks, learners remained attentive and exhibited a desire to complete each task.

This sustained attention intrigues future research on the element of interest within an outdoor informal learning experience. There were many factors within this design to engage learners, but what combination of strategies was most effective in supporting learner persistence on task? Were they fully immersed in attempting to understand the content through its presentation? Did learners retain content beyond the posttest and later share or apply, or were these results specific to this study context? This calls to established research on the concept of situational interest (Hidi & Renninger, 2006; Renninger & Hidi, 2011; Rotgans & Schmidt, 2011). Hidi and Renninger (2006) consider
situational interest as an immediate affective response to conditions and/or stimuli of the learning environment that focuses attention on the task, which may or may not last over time. Other research shows stimuli of choice and challenging tasks, as designed for this study, can increase situational interest (Rotgans & Schmidt, 2011), but did that increase the level of learning?

**Future Design Considerations**

An underlying intent of this study was to create a design to exploit learner agency in order to shape the process and outcome of learning (Lindgren & McDaniel, 2012). During the learner-centered activity, learners could choose when and where to begin as an effort to empower the learners to be more active, enhancing exploration (Jones, Scanlon, & Clough, 2013; Kearney et. al, 2012). To achieve this, learner-centered environments must have sufficient scaffolding to minimize excessive complexity, while maintaining an emphasis on engaging in observation and explanation (Eberbach & Crowley, 2005; Land, 2000).

**Future Research**

Future research will look into expanding available situational interest research more explicitly within this design. Given the noticed attention and interest in elements of this study, it would be valuable to consider how interest can be conceptualized, measured, and provoked within an outdoor mobile learning experience. Discovering the implications of situational interest to evoke an affective-cognitive response for maintained engagement with content (Ainley, Hidi, & Berndorff, 2002) could potentially enhance the learning process. Actions and prompts by the pedagogical agent, for
instance, could be designed explicitly to advance learners’ situational interest both over time and beyond the initial setting.

In addition, there is a need to enhance the narrative to be more dynamic and interactive; conditional branching logic would be a substantial enhancement. Within that, it also necessary to implement a more inclusive pedagogical agent, which aligns more with the intended scaffolding (Puntambekar & Kolodner, 2005) and gamification research (Kapp, 2012) to make the design more learner-centered. From a pedagogical perspective, a more inclusive and deliberate plan of inquiry could be implemented, by way of the inquiry continuum framework. The inquiry continuum framework defines a more appropriable inquiry and allows for active scaffolding of students’ engagement in scientific practices (Biggers & Forbes, 2012). This study was not designed as inquiry-based instruction, but some processes of student inquiry were expected. The intention was to create a design that evolved to a more learner-directed experience, but the general youth of the learners may have hindered this. With the inquiry continuum framework, Biggers and Forbes (2012) suggest more teacher-directed inquiry to foster desired student engagement and drive instruction. Aligning this framework with Puntambekar and Kolodner’s 5 central characteristics of scaffolding, could prove to be an effective design.

**Limitations**

A limitation to this study lies in the scalability of this design. The heavy involvement of the Naturalist and counselors in progressing the experience would be difficult to replicate. In addition, the developed app was installed on each device with a developer certificate and not readily available for distribution. Without the app, it would be not be practical to recreate this experience.
The pedagogical agent did not function as a scaffold of the learning process as intended. In future iterations, Nutty should provided task oriented instruction within each interaction, in addition story telling. He kept learners interest playfully, which was not taken advantage of in the design.

Finally, the study lacked a learner perspective upon completion. Interviewing the learners and/or allowing for reflection could have provided more insight into the effectiveness of design elements.
References


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**Peer-reviewed conference papers:**


