# Using Augmented Reality to Support Children's Situational Interest and Science Learning During Context-Sensitive Informal Mobile Learning

**Heather Toomey Zimmerman, Susan M. Land and Yong Ju Jung**

**Abstract** This research examines how augmented reality (AR) tools can be integrating into informal learning experiences in ways that support children's engagement in science in their communities. We conducted a series of video-based studies over 4 years in an arboretum and a nature center with families and children. In this study (the four iteration of the *Tree Investigators* design-based research project), 1-hour sessions were conducted at a summer camp for 6 weeks at Shaver's Creek Environmental Center. The sessions supported children to learn about the life cycle of trees with iPad computer tablets. Data collected included pre- and post-assessments and video records of children engaged in the science practice of observation. Analysis included the Wilcoxon signed-rank test of 42 paired assessments, the microethnographic analysis of transcripts of dyads and triads engaged with AR tools, and the creation of one case study of a pair of boys, who were representative of others in the dataset. Across the dataset, we found three sociotechnical interactions that contributed to triggering situational interests during the summer camp learning experience: (a) discoveries in the environment related to nature, (b) prior experiences that led to anticipation or expectation about what would happen, and (c) hands-on experiences with natural phenomenon. Implications of the study include that AR tools can trigger and maintain children's situational interest and science learning outcomes during context-sensitive informal mobile learning.

H.T. Zimmerman (✉) · S.M. Land · Y.J. Jung
Learning, Design and Technology Program, Penn State University,
317 Keller Building University Park, 16802 PA, USA
e-mail: heather@psu.edu

S.M. Land
e-mail: sland@psu.edu

Y.J. Jung
e-mail: yyj5102@psu.edu

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**Abbreviations**

AR Augmented reality
ILI Informal learning institution

## 1 Introduction

Modern perspectives on mobile learning recognize the situated nature of the sociocultural contexts in which learning occurs [1]. Context, in this sense, is broader than just location; context encompasses social, material, cultural, and environmental influences that shape and constrain what is possible to learn [2]. This perspective on context has influenced the design of technology-enhanced learning experiences for children in the informal education field.

Mobile technology can support context-sensitive learning by digitally augmenting learners' experiences with their surroundings to create new forms of learner–technology–setting interactions across time and space [3, 4]. Given the ubiquity and portability of mobile devices, they are well suited for creating learning spaces in everyday locations [1] such as nature centers, gardens, and community-based museums. Mobile devices also support the personalization of learning via on-demand resources and capitalize on learners' interests [5]. Learning about an area of interest can be distributed across settings, resources, people, technologies, and designed learning environments [5]. Advancing theory and design of context-sensitive informal mobile learning environments, then, entails intersecting sociotechnical considerations of the context. These sociotechnical considerations include learners' prior experiences, learners' interests, social interactions within the setting, the physical and environmental features of a setting, and available technologies [2, 3].

This chapter presents (a) theory related to context-sensitive learning, augmented reality (AR), and interest, (b) a review of empirical studies related to AR and ubiquitous computing in outdoor and community spaces, and (c) findings from our *Tree Investigators* research project that used AR tools and mobile computers in an informal learning setting to support learning about biology.

# 2 Theory Related to Context-Sensitive Learning, AR, and Supporting Children's Interest with Mobile Technologies

Learning is situated within specific social, material, and cultural contexts [6] with individual, social, and cultural components [7]. Informal learning happens through social interactions within museums, homes, and other everyday settings [8]. Context-sensitive, informal learning occurs in open learning environments [9, 10] where open learning environments include both the interactions that occur within one particular setting and the prior ideas and purposes of learners that occurred within another setting or context. In the open learning environment perspective, the learners' interpretations originate from their personal experiences. The designer using an open learning environment perspective emphasizes the mediating role of the individual in defining meanings and in establishing learning goals [9]. Open learning environments typically rely on technologies because their design requires the coordination of tools, resources, and pedagogies [10] to engage learners in the process of constructing knowledge.

## *2.1 Context-Sensitive Learning with Mobile Technologies*

When used in context-sensitive informal learning, mobile technologies support learners' meaning making through providing continuous interaction between learners and setting [11, 12]. Mobile computers also can bridge different learning settings [13], thereby meeting the requirements of open learning environments. Previous studies related to context-sensitive mobile learning have identified two approaches to informal, open learning environments: (a) providing specific content at the right time and right place and (b) reinforcing learners' choices and experiences driven by their interests.

The first approach to mobile context-sensitive learning environments has focused on providing learning resources through mobile computers that can detect learners' locations. For example, Chen and colleagues [14] designed a context-sensitive ubiquitous learning system that delivered appropriate learning content based on a learner's location within a museum setting.

The second approach to mobile context-sensitive learning environments focuses on augmenting learning experiences by supporting learners' choices and interests. In our work, we take this second approach; we use an open learning environment perspective in an informal setting to allow children to select which aspect of a science topic to explore, based on their interests and experiences. Instead of prompting different learning content based on learners' locations, the AR mobile technology supports interest-driven interactions between learners and the nature center setting. This chapter focuses on this second approach to context-sensitive mobile learning, where designers augment learning experiences to support learners' choices and interests.

## 2.2 AR for Context-Sensitive Learning

AR is a technology that combines the physical setting with virtual information [15–17]. When designing AR with mobile technology for educational purposes, the connecting of digital augmentations to the natural setting in ways that support learning is critical. AR includes a broad range of tools. Early AR technologies used immersive devices such as helmets or goggles, but more recently, AR for learning has been conceptualized to include any technology that combines real and virtual experiences [12].

AR tools can include digital photographs, images, or text that direct the learners' attention to key details of the setting. AR tools can also be used to pose questions and prompts for conversation, enhancing the interactions on-site. Across the various design approaches that use AR tools to support context-sensitive learning, two main approaches are seen in the literature. The first approach to AR in education is to use AR tools to impose narratives, simulations, or games on a setting to engage the learners in educational activities. The second approach is to use AR tools to engage e learners with the disciplinary narratives within a setting.

**AR Using Narratives, Simulations, or Games Imposed on a Setting**. In AR games and simulations, learners interact with virtual objects or digital scenes that are linked to a physical setting [18]. For example, an interactive mystery game called *Mystery at the Museum* was designed for groups of parents and children at a museum [19]. With the AR game, learners solved crimes, which required exploring diverse artifacts in the museum. This game immersed learners in a virtual simulation, which helped them to engage the museum's exhibits more deeply as they collaborated with other learners.

*Alien Contact*! is an AR game that enhances learners' math, language arts, and scientific literacies by engaging learners in collaborative, participatory activities [20]. Middle and high school students play the game based on a fictional scenario of aliens landing on Earth, and learners are asked to discover the reasons for the aliens' arrival. Mobile computers and GPS software detect locations of learners and display corresponding digital objects and virtual people (i.e., avatars). In the *Alien Contact*! game, learners interview avatars to collect clues to discover the aliens' intentions. These activities afford learners to be immersed in the AR learning environment that is a combination of virtual elements and the real setting.

**AR to Support Disciplinary Thinking within a Setting**. In contrast to the approach of adding gaming narratives onto a physical setting, AR has also been used to support disciplinary thinking in a setting through incorporating scaffolding and just-in-time information. AR can support learners' engagement in science inquiry, discourse, and observations [15] through blending the physical setting with

**Fig. 1** Two learners using *Tree Investigators* mobile AR app to engage in context-sensitive mobile computing during their summer camp experience

digital information. For example, *Musex* is a mobile AR app, which provides science-related questions to children related to the exhibits in a museum [21]. This project supported collaborative learning because pairs of learners participated in this activity together as well as communicated in real time with others.

AR tools also have been used to support engagement in science inquiry practices. For example, Looi et al. [22] developed mobile learning software called 3*Rs* to support young learners' science practices in everyday spaces, such as supermarkets. Throughout the sequence of activities (i.e., challenge, plan, experience, conclusion, and reflection), the technology tools prompted challenges that could be solved by observing scientific objects and then recording observations. Other projects have used mobile technologies to support similar inquiry processes such as ask, investigate, create, discuss, and reflect [23], tied to specific real-world locations.

Likewise, our research team has used mobile resources and AR to support learners' scientific observations in the outdoors, as shown in Fig. 1. Our focus is to use AR tools to support learners to make conceptual connections about scientific cycles they observe in their community, based on their observations of natural flora and fauna [3, 24].

### *2.3 Interest Development Within Context-Sensitive Learning*

Because interest is one critical factor to drive learners to make choices to participate in informal educational activities, context-sensitive learning holds promise as a design theory for mobile learning experiences that support learners' interest development. Unlike developed long-term interests, situational interests are generated by specific characteristics of something that the learner observes or notices (i.e., a stimulus) [25]. In other words, situational interests are evoked by the environment surrounding learners [26, 27], which provides designers an opportunity to influence learners' situational interest. Thus, when designing context-sensitive mobile learning, we posit that AR can be added to mobile computer apps to support the emergence of situational interests through supporting learners to observe and notice something that will capture their curiosity.

According to the four-phase model of interest development [27], interests develop through stages over time—as long as learners maintain their involvement in the activities related to their interest. First, learners' situational interests are triggered by environmental stimuli. Second, learners' interests are maintained through meaningful involvement in activities. Third, maintained situational interests can emerge into individuals' interests, and then in the final stage, people have created well developed and stable long-term interests.

The first phase of the Hidi and Renninger model [27] has unique potential for AR technology to support children's interests. AR tools can enhance the triggering of children's situational interests, by focusing the children's attention to environmental and social elements that they may find intriguing or curious. In addition, AR tools can highlight a setting's environmental features with incongruous or surprising information, which may also trigger the situational interests of learners. Finally, AR technologies can facilitate positive emotional reactions toward a particular situation as well as support sustained cognitive engagement, which are both seen as the evidence of situational interests [27, 28].

Studies of informal science learning have examined the role of out-of-school settings in interest development. Zimmerman and Bell [29] used cross-setting ethnographic fieldwork to find that children were interested in participating in scientific practices (including observing) when these practices were related to children's interests found in their everyday activities. Other research confirms that multiple informal settings can trigger and support interest related to science including in homes [30], zoos and aquaria [28], and afterschool clubs [31]. Triggering and maintaining interests has been shown to be important in relation to academic achievement, identification toward science, and eventual participation in STEM careers [32–34]. In this regard, our work importantly brings together informal science learning with context-sensitive AR to enhance outdoor education in ways that situational interests can be triggered and maintained along with science knowledge and practices.

## 3 Tree Investigators: AR and Ubiquitous Computing Supporting Science Learning in an Outdoor, Community Setting

Building on theory from educational technology, informal learning, and situational interest, we developed design considerations to guide the development of *Tree Investigators* as a context-sensitive informal mobile learning experience. We first describe these design considerations and how they guided our design decisions.

Second, we describe the *Tree Investigators* project to show how these design considerations were manifest in the resulting AR mobile technology.

### 3.1 Design Considerations for Using AR for Learning in Outdoor Community Spaces

Our primary perspective is that designing mobile AR technology to support context-sensitive learning in an outdoor community space requires a localized perspective on design. A localized perspective on design can be referred to as place-based education [35]. Place-based education engages children and families in learning activities that have strong community connections [36]. Researchers and educators adopt place-based education to highlight the disciplinary information within a place, moving from abstracted knowledge to relevant, local knowledge [37] that is related to communities' histories [38]. Place-based education can be used in context-sensitive informal mobile learning so that learners connect new scientific ideas to their community-based experiences outdoors. We adopt the view that place-based learning in ILIs can connect out-of-school learners to their communities via mobile computers, as shown in Fig. 2.

Second, we consider possible technical barriers that can happen particularly in outdoor spaces when using mobile computers. For example, Internet connection is often not stable in forest settings or parks that are outside of urban centers. Consequently, designers working with parks and nature centers may need to adopt mobile technology that enables learners to access learning materials without the Internet. Given the importance of context-sensitive learning and community settings, *Tree Investigators* offers a design model that can support the use of mobile, ubiquitous technologies in parks, state forestlands, and nature center settings.

**Fig. 2** The *Tree Investigators* app showing place-based images connecting learners in summer camp to their local community's trees


**Fig. 3** The learners used AR to learn about a tree's life cycle, such as the seed stage

Third, AR activities should be designed to support learners' interactions with environmental settings, in support of disciplinary practices such as observation. For example, at museums or nature centers, learners may have difficulty distinguishing what is scientifically relevant to observe among the numerous objects; therefore, AR can support learners to notice relevant disciplinary phenomena [41]. When supporting disciplinary practices within informal settings, designers should avoid fostering "heads-down" engagement [39, 40] with screens, where learners engage with devices rather than the setting around them. In our work, we used digital photography, such as Fig. 3, to accomplish this observational support so that learners remained engaged with the outdoors on the nature trail setting.

Fourth, AR can be designed to contain some elements that can evoke situational interests. For example, strategies for stimulating situational interests [28, 42], include using original materials; channeling learners' attention to surprising, curious, or novel phenomenon; using a pedagogy with hands-on activities; and developing materials that provide individual choice and engaging social interactions. Importantly, in keeping with our third design consideration, the AR tools used for simulating situational interests should focus the learner to attend to the unique aspects of the informal setting, rather than only the device's screen.

## *3.2 The Technological Innovation of Tree Investigators Project*

Our research team developed *Tree Investigators* as a design-based research project for tablet-mediated collaborative science learning in outdoor learning environments [3, 17]. Our first iteration focused on supporting engagement in science practices [24]. We later added perspectives of digital making to support science knowledge generation in iterations two and three [3]. In the fourth iteration of the project that

**Fig. 4** Two children use the *Tree Investigators* iPad app's AR viewfinder and checklist to support their observation of trees

we describe here, we implemented AR technology to support children to identify trees at various stages of their life cycles at a nature center summer camp. One goal of iteration four was to apply design considerations for supporting situational interest and engagement in science practices via AR tools.

In iteration four, we developed an AR-enhanced mobile app with resources optimized for iPads that allowed for real-time viewing of the physical environment with overlays of digital photographs, text, conceptual models, and supports for scientific observation practices. Science content was organized by the use of a graphic organizer of tree life cycles where learners touched part of an image to learn more. Images and text directed learners look around them at the natural setting for evidence of their claims, supporting both multisensory and multimodal context-sensitive learning experiences. Led by a naturalist, groups of learners initially explored the nature center as a large group. Then, in small groups of dyads or triads, they used the AR tool we developed to identify evidence of tree life cycles (Fig. 4).

The AR tool supported observation through superimposing criteria (in the form of check boxes) for identifying trees at all stages of their life cycle. These criteria were viewable as AR supports within the camera viewfinder. Thus, when learners viewed a tree specimen through the AR viewfinder and took a photo of this tree, the photo saved the criteria that learners checked on the photograph.

Learners then compiled their photographs into a personalized tree life cycle digital artifact while they were at the nature center, as shown in Fig. 5. The criteria the learners applied through the AR viewfinder were also visible in the digital artifact (see Fig. 5). Through engaging in digital making of a personalized tree life cycle, children enacted the place-based [35–38] goals of the project by turning abstracted tree life cycle knowledge into local knowledge in their community.


**Fig. 5** A tree life cycle photo collage

# 4 Project Findings Related to the Connection Between a Context-Sensitive AR Approach and Learners' Interests

The overarching research methodology driving the *Tree Investigators* project is design-based research [43–45], which informs theory and practice through iterative implementations of an intervention in a real-world educational setting. For the past 5 years, our team worked in partnership with Shaver's Creek Environmental Center and the Arboretum at Penn State on educational programming for children and families [3, 24]. Across our research design, our goal is to design mobile technologies to augment scientifically meaningful experiences for out-of-school time in outdoor informal learning institutions (ILIs) [8, 46].

## *4.1 Methodology*

Our fourth design-based research iteration was based on data collected from seven, 1-h sessions during a nature summer camp over two weeks at Shaver's Creek Environmental Center. As described in the previous section, the sessions were designed to support children to learn about tree life cycles with AR and iPad mini tablets. The mobile app included a conceptual organizer to learn about the life cycle of trees and AR tools for capturing evidence of tree life cycles and making a digital collage with the pictures taken by learners. The sessions included three phases of learning activities: (a) a naturalist's structured exploration of tree life cycles with a mobile app and preselected trees; (b) learner-centered exploration and identification of trees for each stage of the life cycle, and (c) digital artifact-making in small groups with the photographs collect during the camp.

**Setting and Participants**. The participants were 42 children (18 females, 24 males), who signed up for a weeklong nature summer camp as part of normal summer leisure activities and to meet parent's childcare needs. The children were nine to 12-years old (which typically corresponds to entering fourth through six grades in the United States). All 42 children consented to participate in the activity and the pre- and post-test. A subset of the children ($n$ = 35) provided their assent to be video recorded during the 1-h program.

**Data Collection**. Data were collected during normal camp activities. Children first answered a five-question assessment about tree life cycle concepts, which lasted approximately 4 min. Children then were video recorded as they participated in an informal education program that lasted approximately 45–50 min. Children next participated in a short interview with the researchers about their experience. Finally, learners completed the same tree life cycle concept assessment as a post-test. Although collaborative team activities comprised the main focus of the camp workshop, the pre- and post-tests were administered and scored individually.

**Data Analysis**. To answer the research question, *How can learners' knowledge of tree life cycle concepts be supported along with their situational interests related to nature* via *an AR mobile app?*, we employed multiple analytical tools. As noted previously, our first analytical strategy was to administer and score the tree life cycle concept assessment. Five open-ended questions were used identically for the pre- and post-test. The questions asked about facts regarding the life cycle for trees (e.g., 'List the stages of the life cycle for trees') or characteristics for some of the stages of trees (e.g., "What are some of the differences between sapling and mature trees?"). Learners' answers were assessed out of a total possible score of 19. Because we focused on their knowledge of the life cycle, simple misspelled words were scored as correct (i.e., "moture" tree was scored the same as was the correct spelling of "mature" tree).

Our second analytical technique was a microethnographic [47] line-by-line investigation of video data to investigate how and when situational interests were triggered with support of AR in the outdoor nature center. To identify how and when situational interests were triggered in the dataset, theory guided our coding. Episodes were strategically sampled when the participants' emotional exclamation, feeling of enjoyment, focused attention and engagement, and committed talk [28] were identified. This chapter focuses on the case of one group of two boys who participated in the camp, Jacob and Pavel. These two boys were strategically sampled because their behaviors were typical of those of others in the dataset. They were chosen from other typical cases because their talk was more suitable for excerpting segments for publication because their talk was less interrupted by other children, included more direct references to the site in ways that made their talk transparent without the video, and their talk included humorous elements.

### 4.2 Findings from the Tree Investigators Mobile AR Outdoor Education Program: Knowledge Gains About Trees Across 42 Summer Camp Participants

To answer the first part of our research question related to science learning, the 42 participating children were given a five-item assessment of tree life cycle knowledge and concepts, before and after the *Tree Investigators* intervention. The mean score for pretest was 5.07 (SD = 2.91) out of 19. The mean score for post-test was 11.14 (SD = 2.94) out of 19. The learners, on average, increased their understanding of the tree life cycle by 6.5 points (see Table 1).

Due to the small number of participants drawn from a specific summer camp, we could not assume a normal distribution of participants, requiring nonparametric statistics. Hence, the Wilcoxon signed-rank test was conducted in lieu of a paired $t$-test. The Wilcoxon signed-rank test results show that the post-test scores are significantly higher (Mdn = 12.00) than the pretest scores (Mdn = 5.50), $z = -5.64$, $p < 0.001$, $r = -0.62$, suggesting improvements in the children's understandings of concepts about the tree life cycle (see Fig. 6). Cohen's $d = 2.22$ and the effect-size correlation was $r = 0.743$, suggesting that a 6.5 increase demonstrates a large effect size.

**Table 1** The results of the 5-item (19 points) assessment ($n$ = 42 children) of tree life cycle concepts

| | *N* | Median | Mean | Std. deviation | Min | Max |
|---|---|---|---|---|---|---|
| Pre-test | 42 | 5.50 | 5.07 | 2.91 | 0 | 11 |
| Post-test | 42 | 12.00 | 11.14 | 2.94 | 1 | 16 |

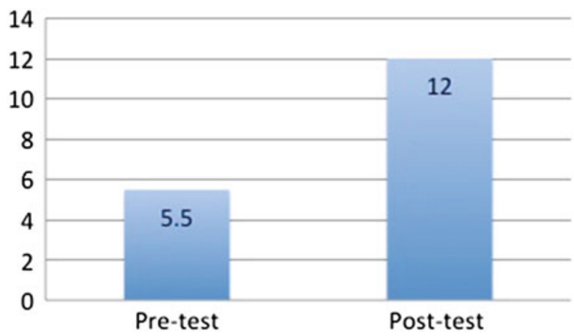


**Fig. 6** The differences between the pre- and post-test were significant statistically, with a large effect size

### 4.3 Qualitative Case Study Findings: Triggering Situational Interests with AR in an Outdoor Space

To answer the second part of our research question related to situational interest, we examined all episodes that were coded based on prior studies of interest [27, 28]. We examined episodes that included emotional exclamations, focused attention, and committed talk. Across the dataset, three situations emerged as patterns that contributed to trigger situational interests during the learning activities: (a) discoveries in the environment related to nature that were sparked by *Tree Investigators* AR tools, (b) prior experiences that led to anticipation or expectations about what would happen, and (c) hands-on experiences with natural phenomenon that were generated by the prompts given in *Tree Investigators* AR tools. To illustrate these three findings, we present a case study of Jacob and Pavel as they worked with the *Tree Investigators* AR mobile app.

**Discoveries in the Environment Supported by the AR Tool Triggered Interest**. Across the dataset, situational interests were triggered when the children discovered something on the trails that was related to the disciplinary content of the *Tree Investigators* AR and mobile materials, such as descriptions and photographs of specific trees. Most children expressed their excitement verbally or with gestures and physical movements such as pointing or jumping up and down. Because the learning activity supported by the *Tree Investigators* AR tools required the participants to find specific examples of each stage of the tree life cycle, interest-related events connected to tree life cycle discoveries were the most common. Jacob and Pavel illustrate this finding in two separate episodes below, when the two boys discovered a pinecone and a seedling.

*Jacob and Pavel's interest was triggered when they found a pinecone*:
Jacob: ((reads the text from the mobile app)) "Seed or fruit or berry or cone or nut…"
Pavel: Oh, berries are easy! ((keeps looking around with Jacob)) Where is it? I am looking for a pinecone. Somebody give me a pinecone. Gimme gimme a pinecone.
Pavel: Pinecone! ((grabs one from the ground))
Jacob: Oh good!
((Pavel picks up the pinecone))

*Jacob and Pavel's interest was triggered when they found a seedling*:
Pavel: Okay so we got the seeds, right?
Jacob: Yeah ((looking down the mobile app)) now we have to get a seedling.
Pavel: Seedling! Well, right over here! ((gesturing digging in dirt)) Neeerrnerr nee nee nee!

The boys' interest in pinecones was initiated when they read the text from the mobile app about the types of seeds and seed containers on trees (e.g., fruits, cones). After rejecting berries, Pavel began a search for a pinecone ("gimme a pinecone"). The mobile app supported them to explore the nature center's trails and find the scientific phenomenon that the children were interested in identifying through providing digital photographs of possible specimens to find. In this way, the mobile app reinforced the interaction between the local setting (i.e., pinecones on the nature trail) and the learners. When they found the appropriate species throughout the *Tree Investigators* learning experiences, their situational interests were explicitly expressed with positive exclamation toward the pinecones.

Similarly in the second seedling example, the mobile app guided the boys to find something that was both scientifically relevant and interesting to them—a seedling. And when they found the seedling after searching and observing, their situational interests were evoked with the verbal and gestural expression of exclamation and pleasure ("Seedling! Well, right over here!" and digging gesture) as well as a sense of satisfaction from completing the task ("Neeerrnerr nee nee nee!").

**Anticipation and Expectations about Nature-Triggered Interest** We also found evidence in our dataset that the learners expressed interest about a natural object based on the prior knowledge that they anticipated or expected to find, and then they set out to find the anticipated object. When this occurred, the learners expressed interests related to seeing on the nature trails based on what they knew related to their participation in the context-sensitive informal mobile learning activity.

To illustrate this finding, we return to the first excerpt, when Pavel and Jacob set out to find a type of seed. Pavel showed confidence in his ability based on his prior experiences with certain seed types ("Oh, berries are easy!"), and then participated with his partner in finding a pinecone with eager excitement. This excerpt showed the anticipation that the learners developed from their prior experiences. Pavel and Jacob expected that they could easily perform the activity, which triggered situational interests in the activity—especially to complete the activity quickly ("Gimme gimme a pinecone"). This episode ended with picking up the pinecone and in many cases in our dataset, the learners touched or picked up the object of interest as we discuss below.

**Hands-on, Sensory Experiences with Natural Phenomenon that were Supported by AR-Tools Triggered Learners' Interest**. The intention of our *Tree Investigators* design was to connect interactions between the natural setting and learners, in ways that enhanced the children's situational interest and science learning. In some cases, learners' science learning was supported by the app; but, hands-on experiences with the trees, which the app discussed, were often the triggers for situational interest. The following excerpt is an exemplar of this finding as Pavel's situational interest was triggered when he touched leaves and experienced the leaves' texture.

*Pavel became interested in leaves' texture*:
Pavel: Can I touch these [leaves]? Jacob, come feel this!
Jacob: Yeah. ((Walks to Pavel but looking at the content on the tablet)) Hey, this is the same. That doesn't…that doesn't make any sense!
Pavel: Jacob! Feel this! ((Gestures to leaves))
Jacob: Oh. ((Maintains focus on tablet)) I will just take picture of it…
Pavel: So soft!

In this example, Pavel's interest was triggered about this tree based on the texture of the leaf ("So soft!"), as evidenced by his emotional exclamation. Because his situational interest was evoked, he sustained lengthy engagement at the tree and tried to engage his peer Jacob in the same activity. Given that AR and app material encouraged visual and tactile observation (i.e., learners tested if they could put their hands around a tree trunk to check its girth to estimate its age), many learners began to explore the trees around them with multiple senses. Most children in our dataset made tactile observations as well as visual observations.

# 5 Implications for Context-Sensitive Informal Mobile Learning to Foster Situational Interest and Science Learning

This chapter illustrated how ubiquitous mobile technology supported context-sensitive science learning and the early stages of interest development of learners. Within the *Tree Investigators* project, we found that learners showed an increased understanding of the tree life cycle as illustrated by significant gains in pre- and post-test scores. Also, the video-based microethnographic analysis showed that learners' situational interests were triggered and supported within the 1-h informal mobile learning program during summer camp. In our analysis, we found that the AR checklist and the photographic artifacts were the two technological tools within our app that helped learners focus their observations in ways that were consistent with the four design considerations for context-sensitive mobile informal learning of outlined in Sect. 4.1. We discuss these two tools below, and then we end with a discussion of other sociotechnical interactions that triggered the children's situational interests.

## *5.1 The AR Checklist Supported Learning and Interest Development*

The checklist served for most groups of learners as a just-in-time, in-the-moment reminder of the key criteria for distinguishing different stages of a tree's life cycle. In peer interactions, the checklist served various roles to support science learning and interest development. The checklist encouraged children to test criteria shown on the checklist on actual trees—encouraging sensory engagement with nature and social engagement with each other, as shown in Sect. 5.3 when Jacob and Pavel focused on the pinecone.

We found these interactions as evidence that our "heads-up" interaction goals with the site were achieved [39, 40]. The criteria on the checklist allowed the children to check and double-check each others' understandings and have an authority to fall back on to develop final categorization of the tree life cycle stages. It also support the young people to look close at trees, creating curiosities and wonderings that we found to be aligned with the triggering of situational interests.

## 5.2 Photography and the Digital Making of Photo Artifacts

Digital photography functionality was most relevant to support science learning as shown through the science talk and observational practices of the children. Taking digital photos was a shared task in *Tree Investigators*, and taking the photos was a highly enjoyable activity for all groups. The photography was closely tied to our goal of supporting children to learn to see like a scientist through supporting the youth to discern the different stages of the life cycle. Importantly, the photographs served as a shared knowledge artifact around which learners oriented their conversations and observational practices.

In order to take pictures, the children had to describe the location and type of tree that they saw. This observationally focused talk was eventually used as evidence (by most groups) to support descriptions and emerging claims about a tree's life cycle stages. While our prior work has demonstrated it is useful to connect parents to children's summer camp experiences in order to support learning [17], the findings of *Tree Investigators* iteration four here show that it is important to support peer interactions around the ecology content in the outdoors as well.

Near the end of the summer camp program, the learners worked in teams to engage in a short digital making activity on the iPads. The learners' task was to use multiple digital photographs their team had taken on the trails to make a customized and personalized tree life cycle image. Through engaging in digital making of a tree life cycle, we found that the children connected what they experienced in their local nature center related to the themes of the discipline of biology.

## 5.3 Sociotechnical Interactions that Contributed to Trigger Situational Interests

Our analysis revealed three sociotechnical interactions that contributed to trigger situational interests during the learning activities with the mobile technology: (a) discoveries in the environment related to nature were supported by the AR tool, (b) prior experiences led to anticipation or expectations about what would happen or what they would find, and (c) hands-on experiences with natural phenomenon were prompted by the AR tool and other app content. Taken together, these three findings suggest that our approach to context-sensitive ubiquitous learning, which included prompting location-specific science content and supporting learner-driven experiences within the setting, can trigger situational interests and support science learning.

Derived from these three findings, we suggest three strategies for designers and researchers seeking similar approaches to foster situational interest and informal science learning. First, given that the AR tool supported the learners' discoveries in the environment related to nature, we suggest that AR can be used for more than gamification and simulations—learners' interests in and observations of the natural world can be triggered and supported via AR.

Second, we found that learners had prior experiences in the outdoors that led to anticipation or expectations about what they would find or what would happen. Our results suggest an iterative process to design can help developers create prompts and digital materials that elicit prior knowledge in order to bridge the learners' past experiences to the new informal science learning experience.

Finally, given that the AR tool prompted sensory exploration and hands-on experiences, we argue that multisensory engagement in the outdoors can be supported by ubiquitous technologies [48]. Children's engagement in nature and with mobile computers can work together to support outdoor exploration and enjoyment. This last strategy of using AR to support tactile and visual observation of the natural setting is apt given recent calls for children to spend more time outdoors [49]. In short, our context-sensitive informal mobile learning technology supported the children to engage in multimodal sensory observations during summer camp, with time spent away from the iPad screen. We found that *Tree Investigators* allowed learners to engage with the natural world around them.

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