NatureCollections: Can a Mobile Application Trigger Children's Interest in Nature?

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Abstract: In this study, we investigate whether and how a mobile application called NatureCollections supports children's triggered situational interest in nature. Developed from an interest-centered design framework, NatureCollections allows children to build and curate their own customized photo collections of nature. We conducted a comparison study at an urban community garden with 57 sixth graders across 4 science classrooms. Students in two classrooms (n = 15 and 16) used the NatureCollections app, and students in another two classrooms (n = 13 and 13) used a basic Camera app. We found that NatureCollections succeeded in focusing students' attention–an important aspect of interest development– through sensory engagement with the natural characteristics in their surroundings. Students who used NatureCollections moved slower in space while scanning their surroundings for specific elements (e.g., flowers, birds) to photograph. In contrast, students who used the basic Camera app were more drawn to aesthetic aspects (e.g., color, shape) and tended to explore their surroundings through the device screen. NatureCollections supported other dimensions of interest development, including personal relevance, social interactions, and positive experiences for continued engagement. Our findings further showed that the NatureCollections app facilitated students' scientific discourse with their peers.

1 INTRODUCTION

Personal interest plays a vital role in learning across domains (Ainley, 2006; Azevedo, 2013; Hidi & Renninger, 2006; Krapp, 2002, 2003). When students form a personal connection to a topic, they are more likely to feel intrinsically motivated to learn about it, retain what they have learned, and enjoy the learning process itself (Ainley, 2006; Hidi & Renninger, 2006; Krapp, 2002). Prior work investigating nature-related science learning is consistent with the broader research related to interest-driven learning. When children have a personal interest in nature, their learning about nature-related topics increases (Klemmer et al., 2005; Louv, 2008; O'Brien & Murray, 2007).

To develop interest in nature, one must have positive experiences outdoors (Azevedo, 2013; Braun & Dierkes, 2017; Hidi & Renninger, 2006; Krapp, 2002, 2003). Unfortunately, children today are spending less and less time in contact with nature (Bassett et al., 2015; Holt et al., 2015; Kimbro et al., 2011; Lohr & Pearson-Mims, 2004). Although increased screen time is often blamed for decreasing children's time spent outside (Gray et al., 2015; Kimbro et al., 2011; Louv, 2008), prior work has demonstrated that mobile technologies can actually support children's positive, fun experiences outdoors and can be effective in connecting children to nature (Crawford et al., 2017; Ruiz-Ariza et al., 2018). For instance, recent research has shown that mobile-enabled activities such as games (e.g., *Pokémon GO*) can engage children and their parents in enjoyable activities, help motivate them to go outside, and even increase their overall time spent outdoors (Sobel et al., 2017).

We know less about leveraging mobile technologies for interest-driven learning about nature. Prior work has focused on using mobile technologies to engage children in science learning and guided exploration (Chipman et al., 2006; Kamarainen et al., 2013; King et al., 2014; Kuhn et al., 2011; Y. Rogers

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Figure 1: a. Student taking a close-up shot of a flower b. One student pointing nature element to her peers a c. Students walking and scanning their surroundings.

et al., 2004; Yvonne Rogers et al., 2005; Schellinger et al., 2017; Zimmerman et al., 2016). This research shows how leveraging affordances such as location awareness makes it possible to push contextually relevant content to users, thus enriching their learning experience (Kamarainen et al., 2013; Y. Rogers et al., 2004; Zimmerman et al., 2016). However, this research has not typically positioned interest development as a major and explicit consideration in designing mobile technologies for nature-based science learning. At the same time, researchers have uncovered insights that are relevant to the design of interest-driven learning experiences with mobile technologies more broadly (i.e., not specific to nature), which inform the current work. For instance, prior work shows how introducing overly structured activities limits a learner's autonomy. In addition, it can be difficult to achieve balance between guided activities and open-ended exploration—a key component of interest-driven learning (Azevedo, 2013; Hidi & Renninger, 2006)—when designing mobile learning technologies (Kamarainen et al., 2013; Kuhn et al., 2011; Lo et al., 2012; Zimmerman et al., 2016).

In their four-phase model of interest development, Hidi and Reninger describe the evolution of an externally triggered situational interest into a sustained personal interest (Hidi & Renninger, 2006). In the current work, we explore how mobile technologies can support interest-driven exploration in nature, particularly, the first phase of interest development: a *triggered situational interest*. Although typically short-lived, a triggered situational interest is central to the model because it contains characteristics that pervade it, and because it is the necessary precursor to all other phases of interest development. The characteristics that underpin all phases of the model include personally relevant experiences, focused attention accompanied by positive emotional engagements, social interactions,, and opportunities for re-engagement (Hidi & Renninger, 2006).

In prior work (Kawas et al., 2019), we presented an interest-centered design framework to promote children's interest in nature. Drawing on Hidi and Reninger's model of interest development, we derived a set of four design principles: (1) personal relevance, (2) focused attention, (3) social interactions, and (4) opportunities for continued engagement. Through co-design sessions with children, we developed design strategies to enact each of these principles (Table 1). Using this framework, we designed *NatureCollections,* a mobile application that allows children to build and curate photo collections of nature.

In the current study, we evaluate the interest-centered design principles and strategies embodied in the NatureCollections app features and the extent to which, together, they support children's interest development in nature. Our purpose in this evaluation is to assess whether the system *as a whole* supports the emergent behavior of interest, in this case, a triggered situational interest in nature. This objective stands in contrast to research that assesses individual design features or interaction techniques (Greenberg & Buxton, 2008; Olson & Kellogg, 2014).

In line with this objective, we adopted a qualitative approach in the current investigation, one that allowed us to identify and describe the emergent behavior of interest as children interacted with the system as a whole, in a real-world setting (Klasnja et al., 2011; Olson & Kellogg, 2014). The study took place at an urban garden with 57 sixth graders across 4 science classrooms at a single school. Students in two classrooms (*n* =15 and 16) used the NatureCollections app, and students in another two classrooms (*n* = 13 and 13) used a basic Camera app. We included the comparison group to ensure that any effects that we observed were not due simply to using a smartphone to take pictures of nature (Jake-Schoffman et al., 2017; Nayebi et al., 2012). Beyond ruling out a novelty effect of using a smartphone to take pictures, our comparison group was not intended to evaluate any single feature of the app.

The contribution of this work is empirical evidence showing that NatureCollections succeeded in triggering children's situational interest in their natural surroundings. This evidence supports the effectiveness of the interest-centered design framework that we used to design NatureCollections. In addition to showing how the app's features supported specific dimensions of the interest development model (e.g., focused attention), our analysis also uncovered emergent themes related to students' scientific discourse and distinct patterns of movement through nature while using the app, which complement the interest development framework.

2 RELATED WORK

2.1 A Theoretical Model of Interest Development

Hidi and Renninger describe four distinct and sequential phases of interest development that depict how a sustained, internally driven personal interest emerges from an initial external stimulus (Hidi & Renninger, 2006). The first phase is a *triggered situational interest*, which occurs from a stimulus in the environment that sparks an individual's in-the-moment, focused attention, either because it is personally relevant, unexpected, or both. The experience is also typically accompanied by positive feelings. The second phase is a *maintained situational interest*, where both focused attention and positive feelings are sustained through meaningful interactions over an extended period of time. Both a triggered and a maintained situational interest require external support to materialize. During the third phase, an *emerging individual interest* develops from recurrent engagement with a particular content that the individual values based on prior experiences. Some external support is typically needed during this phase to provide reengagement opportunities. The last and fourth phase of the model is a *well-developed individual interest,* which stems from an enduring predisposition towards re-engaging with a topic overtime. This stage is marked by an individual's accumulated knowledge, positive feelings, and supportive social interactions (Hidi & Renninger, 2006).

All four phases share common characteristics that underpin interest development: focused attention on personally relevant content accompanied by positive emotions, supportive social interactions, and opportunities for continued engagement. We drew on these characteristics to form the foundational principles in the interest-centered design framework (Kawas et al., 2019). In the current evaluation study, we focus on the first phase of interest development, a triggered situational interest, as it contains the core characteristics that pervade the entire model. It is also a necessary precursor to all other phases of interest development.

2.2 Insights from Mobile Learning Technologies Research

In addition to being theoretically guided by the interest development model, our work is informed by prior empirical research on mobile learning technologies that aim to support learners' science inquiry and nature-based explorations. Projects like *Ambient Wood* (Y. Rogers et al., 2004), *Tree Investigators* (Zimmerman et al., 2015), *Zydeco* (Kuhn et al., 2011), *GeoTagger* (Fails et al., 2014), *iBeacons* (Zimmerman et al., 2016) and *EcoMOBILE* (Kamarainen et al., 2013) harness location awareness capabilities and just-in-time prompts to deliver relevant content based on the learner's location to engage them with their surroundings. For instance, both EcoMOBILE and Tree Investigators leverage augmented reality to overlay images of biodiversity and background information to amplify learners' observations in their surroundings. Similarly, Zydeco and iBeacons push relevant information to the mobile device to connect learners with their surroundings. All these projects also allow learners to collect and/or annotate their observations to guide their science inquiry.

Commercial location-based mobile games have also engaged children with outdoor exploration using similar features (Ruiz-Ariza et al., 2018; Sobel et al., 2017). For example, Pokémon Go uses augmented reality features to overlay co-located game characters onto the physical surrounding. The game also makes use of just-in-time, location-based prompts to deliver relevant content, such as the existence of a nearby raid battle. Research has shown that such games are highly engaging for children, support social interaction, and promote positive feelings (Sobel et al., 2017).

There exists a tension between the engaging quality of mobile learning and game applications, on the one hand (Kamarainen et al., 2013; Sobel et al., 2017; Zimmerman et al., 2015), and their tendency to focus children's attention on the device screens rather than their surroundings, on the other (Ruiz-Ariza et al., 2018; Sobel et al., 2017). Researchers have documented parents' and teachers' concerns about children being preoccupied with the mobile devices during outdoor science inquiry (Ayers et al., 2016; Cahill et al., 2010; Kamarainen et al., 2013). Similarly, parents have worried about their children's safety while playing Pokémon Go due to their absorption in the game world seen through their screen rather than the physical world through which they are moving (Ayers et al., 2016; Ruiz-Ariza et al., 2018;

Sobel et al., 2017). In designing NatureCollections, our goal was to design a system that avoids the problem of focusing on one's device for extended periods of time to the exclusion of experiencing one's natural surroundings directly.

3 INTEREST-CENTERED DESIGN FRAMEWORK

In prior work (Kawas et al., 2019), we presented a design framework comprising a set of design principles and strategies to guide the design of mobile technologies to promote children's interest development in nature. Development of the framework was guided by both theoretical and empirical insights. We identified four design principles by drawing on the core dimensions of the interest development model (Hidi & Renninger, 2006): (1) personal relevance, (2) focused attention, (3) social interactions, and (4) opportunities for continued engagement.

Next, we conducted co-design sessions with children aged 7–12 years to generate design strategies to implement each of the four design principles (See Table 1) (Kawas et al., 2019). Throughout this process, we took into consideration insights and challenges identified in prior research on designing mobile learning technologies.

Table 1: *(adapted from prior work):* Interest-Centered design principles and strategies.

Mobile Design Principles	Design Strategies to Support Personal Interest Development
1. Engage Children in Personally Relevant Activities	1.1 Support children's pre-existing personal interests through customizable activities
	1.2 Provide opportunities to extend activities by unlocking new content
	1.3 Create a personalized user interface
2. Support Children's Focused Attention on Their Surroundings	2.1 Draw attention to specific elements in the child's physical surroundings
	2.2 Encourage self-directed, sensory interactions with natural elements
3. Encourage Children to Engage in Social Interactions	3.1 Connect users with each other and provide conversational prompts around topics of interest
	3.2 Create activities that involve two or more users to complete
4. Provide Opportunities for Continued Engagement	4.1 Display children's accumulated progress over time
	4.2 Promote app engagement across settings

3.1 Nature Go App Feature Design

Guided by our interested-centered design framework, we designed the features of the NatureCollections app to promote children's interest in nature. NatureCollections allows children to photograph things they see in nature, classify plants and animals in their photographs, and organize them into themed albums such as *birds, insects,* and *trees*. Here, we briefly describe key app features, along with their connection to the four design principles and associated design strategies in parentheses () shown in Table 1. (See (Kawas et al., 2019) for an expanded discussion.)

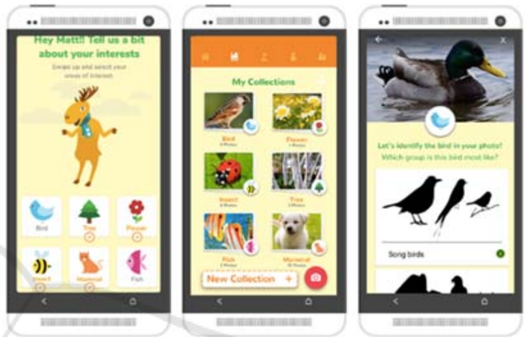

Figure 2: Screens of the NatureCollections app 1: Onboarding "What are your interests?" 2: My Collections. 3: Photo Classification.

3.1.1 Design Principle 1: Engage Children in Personally Relevant Activities

During the NatureCollections onboarding process, a friendly moose character addresses child by their name, introduces himself as their guide through the app experience, and prompts them to enter their interests (design strategies 1.1, 1.2, 1.3) (see Fig 2.1). The app includes a personalized "Profile Page" where children can track their accomplishments, including photos taken, badges earned, and challenges completed. In addition, children can create and organize their photographs into customized "My Collections" that reflect their specific blend of interests (design strategy 1.1) (Fig 2.2).

3.1.2 Design Principle 2: Support Children's Focused Attention on Their Surroundings

The "Add Details" feature allows children to enter descriptive information about their photo into text fields using conversational prompts (e.g., "How would you describe this photo?"). This feature encourages children to examine the subject of their photograph carefully and reflect on specific elements (design strategies 2.1, 2.2). The "Photo Classification" feature similarly encourages children to focus on a nature element by providing simple classification schemes for each preset photo collection. These schemes direct users through a series of stepped prompts containing visual silhouettes to facilitate classification (design strategy 2.1) (Fig 2.3).

3.1.3 Design Principle 3: Encourage Children to Engage in Social Interactions

Children can see their friends on a "My Friends" screen, including their photos and badges earned (design strategy 3.1). New friends can be added through a unique username. Several "Challenges" are designed to be social. Friends can collaborate on a team scavenger hunt (earning a team badge), or challenge each other to match a photo they have already taken (design strategy 3.2).

3.1.4 Design Principle 4: Provide Opportunities for Continued Engagement

NatureCollections features such as "My Profile," "My Friends," and "Challenges" track children's accumulated progress over time by displaying their photo count, badges earned, and friends list (design strategy 4.1). Challenges span multiple locations to promote app engagement across settings, providing opportunities for continued engagement (design strategy 4.2). Progress toward a particular goal is shown through a "Progress Bar" (design strategy 4.1).

3.2 Basic Camera App

For the current study, we developed a second, basic Camera app (also titled NatureCollections with the same app icon) to test whether the behaviors we observed as children used NatureCollections were due to the app and its collective features, or whether they were instead attributable to the effect of using a smartphone to photograph one's natural surroundings (Jake-Schoffman et al., 2017; Nayebi et al., 2012). This app consisted of two main features: (1) a camera feature with only a single shot (no other photo capture modes, filters, or video capabilities), and (2) a photo gallery displaying a grid of all photos taken.

4 METHOD

Our goal in the current study was to understand if and how the NatureCollections app design succeeds in-triggering children's situational interest in nature. Although the design framework used to develop NatureCollections addresses all four phases of interest development, we chose to focus this initial evaluation study on the first phase, a triggered situational interest. A necessary precursor to the other three phases of interest development, a triggered situational interest incorporates the core dimensions of interest development that pervade the entire model. Moreover, a triggered situational interest can be witnessed over the short-term, which was a practical consideration for this study. We operationalized interest by focusing on behavioral indicators of the four core dimensions of a triggered situational interest. This strategy is consistent with other work that uses proximal behavioral indicators as evidence of complex constructs (such as interest) (Moller et al., 2017).
We conducted an observational in-situ study comparing two groups of students in a community garden. One group used the NG app and the other used a basic Camera app (both presented to participants as the NatureCollections app). Prior research has shown that in-situ studies capture context of use when evaluating a new mobile technology and often uncover a range of design and usability issues that lab-based evaluations are likely to miss (Klasnja et al., 2011).

4.1 Participants

Participants were 57 sixth graders aged 11-13 years (M = 11.5 years) attending a private middle school located in an affluent suburb of a city in the Northwest United States. Students were predominantly White/Caucasian (73.5%) and lived in households with a high annual income (see Table 2 for complete demographic details). In a pre-survey, 100% of parents reported that their children use a tablet or phone on a daily basis, and 98% of parents reported their children own their own device. Prior to the study, we asked students about their general interests, hobbies, and favorite outdoor and nature-based activities and found no notable differences between the NG app and the Camera app groups. Students in both groups were far more likely to identify organized sports as a favorite activity than a nature-foregrounded activity.

Table 2: Demographic characteristics of participants, who shared their data (n = 49, across all classrooms).

Gender	Female (51%), Male (49%)
Age	Mean (SD) = 11.5 (0.54) | Age 11 (n=26), Age 12 (n =22) Age 13 (n =1)
Race	White (73.5%), Asian/Pacific Islander (16.5%), Hispanic (4%), African American (2%), Middle Eastern (2%), Mixed (2%)
Household Income (US$)	Less than 25K (2%), 25k-49K (2%), 50k-74k (4%), 75K-99K (4%), 100K-125K (14.5%), Over 150K (73.5%)

4.2 Procedures

We conducted the study with four different classrooms over a two-day period during their regular science class period. Since the study took place over two consecutive days and to account for weather and time of day effects (e.g., energy levels may vary before and after breaks), we used controlled random cluster assignments to assign the NatureCollections app and the Camera app to classrooms on both days. Two classrooms used the NG app (15, 16 students in each classroom, total = 31), and two classrooms used the basic Camera app (13 in each classroom, total = 26) (see Table 3). All four classrooms were told they were using a beta version of the NatureCollections app. Beyond introducing the researchers to the students, classroom teachers did not help the researchers run the study. They did, however, stay to observe their students and direct their questions to a researcher.

After explaining the study purpose, we divided the students randomly into small groups (4–5 students, 1 researcher per group). We obtained student assent, gathered parental consent forms, and administered a pre-activity questionnaire (described above). Researchers then led students in an outdoor icebreaker activity before introducing them to the photo-taking activity and handing out the phones with the app.

Table 3: App Class Assignment.

App	Camera App	NG App
Day-1 Students Class Time	Class **1** **13** Afternoon	Class **2** **15** Afternoon
Day-2 Students Class Time	Class **3** **13** Morning	Class **4** **16** Morning

The photo-taking activity took place at a nearby urban community garden. Students in both groups were invited to explore their surroundings and take photos using the app for approximately 25 minutes. Researchers were careful not to prime children by discussing details of the research project; rather, we asked them to help us try and give feedback on the nature app and reinforced that there were no right or wrong ways to use the app. In addition to videotaping the students' activity using chest-mounted GoPro cameras, researchers followed small groups of students to take observational field notes and ask them questions about their photo choices and app functionality. Following the activity, students returned to the classroom to participate in a semi-structured focus group discussion led by the researcher within their small groups. In this debrief discussion, we asked students about what pictures they took and their rationale for taking them, what they liked and disliked, and if they had suggestions for additional features.

4.3 Data Analysis

We used the video recordings of the sessions to examine triggered situational interest "moments" in detail across the two groups. The video recordings were central to our analysis; they included 18 total videos of the outdoor activity ranging from 25 to 29 minutes each. The recordings of the post-activity small-group discussions were secondary in our analysis; they included 18 debrief videos lasting approximately 15 minutes each. We analyzed our data thematically using both etic and emic codes (Boyatzis, 1998; Maxwell, 1996). Etic codes represented behavioral evidence of the core dimensions associated with a triggered situational interest: (1) personal relevance, (2) focused attention, (3) social interactions, and (4) opportunities for continued engagement. Due to the short-term nature of a triggered situational interest (and of our study), we did not expect to see robust evidence relating to continued engagement. Instead, we considered indicators that students were open to re-engage with the NG app if given future opportunities. Although we focused centrally on these etic coding categories, we also used a grounded theory approach to coding (Glaser & Strauss, 1967) that allowed for emic themes to emerge directly from the data (Maxwell, 1996).

We used interactional analysis and video research techniques to analyze the video data (Derry et al., 2010; Jordan & Henderson, 1995). The 6 researchers who led the analysis were not involved with the NG app design process. Researchers individually created a content log for the GoPro video they captured, and conducted an initial coding based on the four design principles contained in the design framework. While logging, researchers flagged segments for more intense analysis and other salient emergent themes based on alignment with the interest development model (Hidi & Renninger, 2006). After indexing the video data, the research team collectively viewedeach video alongside its respective content log, stopping for group discussion at the identified flagged segments. Researchers resolved disagreements and came to consensus on the appropriate coding before moving to the next segment (Derry et al., 2010; Jordan & Henderson, 1995). During this process, researchers highlighted "hotspots" representing triggered situational interest moments and examples of the emergent salient themes (Jordan & Henderson, 1995). After the group viewing, three researchers repeatedly viewed the identified hotspots to document the triggered situational interest moments in detail.

We used the codes from the community garden activity analysis to code the video data of the post-activity focus group discussions. Two researchers viewed one video from each app assignment and coded it together to establish agreement. One researcher then coded the remaining videos and transcribed students' responses for each small group.

We chose not to analyze the content of children's photos, as photo content itself does not offer deep insight into students' attention, intent, or experience. Instead, we focused on qualitative observational and interview methods to gauge children's interactions with the app and their interest in nature.

5 RESULTS

We present results from our analysis exploring the relationships between our etically derived interest development themes: *Personal Relevance, Focused Attention, Social Interactions, and Opportunities for Continued Engagement* and the students' interactions with the assigned app and their natural surroundings. In addition, we discuss two related themes that emerged emically: *Science Discourse* and *Mobility*. We include vignettes from the video data (outdoor activity and focus group debriefs) to illustrate how NatureCollections features supported specific dimensions of a triggered situational interest, followed by our observations of the Camera app group.

5.1 Personal Relevance

We observed several instances where the students verbally indicated a connection between the NG app and their existing interests. NG features allowed students to choose the nature photos they wanted to collect, as one student expressed aloud while selecting her interests on the onboarding screen, *"Oh my god, I forgot about rocks, rocks are like my favorite things. I had so many rock pets when I was younger"*. We also noticed that the NG app features, such as "My Collections," prompted students to notice and take interest in unexpected and unsought elements in their surroundings. One student described to a researcher the pictures he was taking, *"I'm just finding insects for my collection, that's all."* He then said, "I lost it!" and pointed his phone up in the air and said, *"Oh, there! I see it"* while another student crouched down next to him and lifted his phone up higher and exclaimed, *"They're too small"* (referring to the insects). The first student pointed to the insects area and said, *"Yeah most of them, they're right there."*

During the small group debriefs, several students mentioned that their choice of photos was driven, in part, by things they were already interested in, such as rocks and flowers. For example, one of the students explained, *"I took photos of flowers because I like flowers,"* and she continued saying, *"I got excited when I found flowers to take pictures of."* Another student said "*I took a photo of Winston*" When the researcher asked, "*Who is Winston?*" she replied, *"It's my pet rock, I named it"* showing the researcher and her peers the photo of the rock.

Students across the small groups noted that they liked the Collections feature. They observed that it helped them to organize their photos based on their interests, as this student explained, *"I took pictures because it was a collection of photos, so I was not just taking random photos…and I like small plants, so I took photos of them."* Students indicated they liked being able to create their own custom collections.

5.2 Focused Attention

5.2.1 Direction of Attention

Students in the NG app sessions appeared considerably more focused on their surroundings than their device. The teacher in attendance remarked to a researcher, *"For a person who experiences them daily, this is what 'focused' is."* When students did look at their device, their gaze alternated between the app and the nature element. This typically happened when they were photographing, entering captions, or completing a classification for a nature element.

We observed that specific app features prompted students to focus on their surroundings. For instance, the "Challenges" encouraged students to search for specific nature elements, which led them to focus much of their gaze on scanning the community garden as opposed to observing objects through their device screen. One student mumbled while looking closely at garden plots, *"I need two more photos of flowers."*

5.2.2 Sense-making

When students classified a photo using the "Classification" feature, the prompts encouraged them to focus on specific characteristics of a nature element. In one instance, three students looked at the ground, having finished photographing a pale spaghetti squash and now trying to classify it. Moving their gaze between the ground and their app, these students discussed which details and classification to assign to the photo. One said, *"That's an egg,"* another responded, *"I know it's an egg,"* and a third student said, *"No it isn't, it's a plant, it's a squash, can't you see the stem?"* The second replied, *"Oh yeah, it is,"* and the third continued, *"That has to be like an ostrich egg."*

5.2.3 Tactile Interactions

Students also interacted tactilely with particular elements while photographing them. We observed students, while adding details or classifying their photos, move closer to plants to touch leaves or kneel to feel the grass. For instance, one student, when trying to determine whether a plant was cabbage, moved closer to touch its large leaves. Several other students knelt to get closer to the ground to touch and take photos of an insect they had spotted. (See Fig 2 for the classification screen).

5.3 Social Interaction

5.3.1 Peer Engagement

Social interaction started immediately upon engaging with the NG app, with students helping peers discover new app features. Throughout the activity, students engaged in robust social interactions that involved not only showing each other their photos and earned badges, but also copying each other by photographing nature elements that their peers showed interest in or had photographed. They also provided suggestions to each other on which nature elements would be interesting to photograph, and helped each other find photos to complete challenges. In one instance, a student ran up to her friend, who was crouched down taking a photo of a plant, and excitedly told her, *"I found a purple flower!"* Her friend asked where, and she gestured for her friend to follow her. They both walked quickly to a garden bed where she pointed to a flower close to the ground. Her friend immediately crouched down to take a close-up photo of the flower and then she checked her friend's progress with the flower challenge.

NG app students were often exploring together and engaged in collaborative discussions about what they found and how to name or categorize their photos as with the example of the "*ostrich egg, spaghetti squash"* above. In another instance, a student took a photo of the same shrub as his friend and asked, *"Oh, what should I put in here?* [*referring to the Detail screen*]," to which his friend responded *"shrub, I guess."* The first student exclaimed, *"Oh snap! Yeah, I earned a new badge!"* and his friend replied, *"It looks like I earned a badge, too."*

We also observed more competitive interactions between students, such as comparing their total number of photos, completed challenges, and earned badges. One girl remarked, *"You made it a competition,"* while another responded, *"If it is a competition that means I won [referring to their badge counts]."*Students seemed to find competing to earn badges motivating to find new things to photograph in nature.

5.3.2 Playful Interactions

Students seemed to be having fun with each other when they were using the NG app, showing excitement when they were sharing what they noticed. In one instance, a student excitedly called to his friends, *"Oh come here! Come here! I wonder what this is!"* kneeling to get close to a plant, *"this is so cool!"* His friend responded, *"It's a spiky broccoli"* following his friend to take a photo of it as well. Students had fun exchanging ideas about what captions to add to their photos. While photographing a stone figure, for instance, one student referred to it as a *"fat snail"* and both giggled. The other said, *"Put it in the* Stones and Amphibians *collections"* and continued to laugh. Students also celebrated with each other when they earned a badge; for example, we observed three students high fiving each other when they earned a badge for taking a photo of a rock.

5.4 Opportunities for Continued Engagement

Due to the short duration of the study, we did not anticipate that our analysis would uncover substantial evidence relating to opportunities for continued engagement with the app. Nevertheless, we did identify several indicators that we believe increase the chances of students' re-engagement with the NG app (Fig. 3, bottom right). For example, students' evident engagement in the activity and their positive emotions—both described above—suggest they would be inclined to use the app again in the future.

Students expressed verbally in the post-activity discussion that they would use the app if they had it on their own devices. Several students said they were motivated by the challenges and desired to earn badges. One student in the NG app session explained, "*Getting [the]* Aspiring Botanist *badge makes me want to earn more badges."* He continued *"I'll probably do the challenges…I think this would get me outside more...like Facebook draws you in."* This positive desire for continued engagement frequently manifested in the post-activity discussions, as students talked about the many ways they were interested in continuing to use the app beyond the session to document nature on hikes, while camping, and even in their own home gardens.

5.5 Science Discourse

Certain features of the NG app appeared to facilitate discussions between students about the natural elements in the surrounding area of the activity. Students engaged in science discourse as they collaborated to categorize their photos in collections and when choosing the classification options (Fig. 3, top right). For instance, one student asked his friend, *"Are humans mammals?"* while trying to classify the photo he took of his friend. Another student pointed out to his friend, *"Did you see the hummingbird?"* then added as he was trying to classify the photo he took, "*Is it a songbird?"*

Several other students asked their science teacher repeatedly about the plants they did not recognize. At one point, two students were asking the teacher questions about plants when a student, crouching on the ground, exclaimed to get his teacher's attention, *"Wooo! Is it a broccoli?"* At the same time, another student moved close to touch a plant and asked the teacher, *"Is it a cabbage?"* The teacher pointed to the plants in sequence and explained, *"We got kale, chard, and this, I don't know what this is, but I have seen it at the grocery store."* Then another student said *"Is it rainbow choy?"*

Students also discussed the influence of seasons and geographical location on the nature elements they observed, noticing that some plants grow in certain seasons, as illustrated by the earlier example of one student who wondered how she could find a flower in winter. Students also discussed animal behavior. As one student searched for an animal to complete the mammals challenge, another student said to him, *"There's no animals out in the rain."*

5.6 Mobility

Across all of the NG app sessions, we observed students moving at a slower speed and scanning their surroundings more carefully as they searched for natural elements to photograph in the community garden (Fig. 3, top right). We hypothesize that this intentionality of movement supported their focused attention on nature. Students were also more likely to kneel down and position themselves closer to the natural elements they saw while using the NG app.

In addition, we noticed that students in the NG sessions showed distinct patterns of movement in small groups as they explored their natural surroundings together. Compared to the Camera app groups, NG app students were more likely to move in clusters and stay closer to friends, whether to compete or collaborate on completing challenges and identifying the elements in the community garden (Fig. 3, bottom left). We suggest that this spatial mobility was also critical to how students influenced each other's photo choices, as they were more likely to point out and discuss natural elements in their surroundings when they moved together.

5.7 Basic Camera App Group

Compared to students using the NG app, students in the Camera app group displayed notably different patterns of behavior in each of our four etic and two emic themes, as described below.

5.7.1 Personal Relevance

Overall, we documented less evidence of students forming a personal connection to the activity when using the Camera app. When we did see a personal connection, it tended to be around photography rather than nature. In one of the sessions, for example, a student uttered, *"I love photography,"* and a fellow student responded, *"I know, same"* while they were both capturing photos using the Camera app. This finding is not surprising when one considers that the two main features of the Camera app were the photo capture and photo gallery; nothing in the app prompted students to connect personally with nature beyond the name of the app (NatureCollections) and the researcher's initial prompt to take pictures of nature during the activity.

5.7.2 Focused Attention

In the Camera app sessions, students' interactions with their surroundings appeared to be mediated primarily through the device. The majority of the students looked through their phone screens to frame potential elements they considered photographing. For instance, one student mumbled while focusing the camera on a specific shrub, *"Let's take some more pictures of this."* Throughout the interaction, his gaze remained on the screen; he never looked directly at the bush. Students' attention seemed to be focused on the aesthetic aspects of nature elements when deciding what to photograph. When asked in the post-activity focus group sessions, students explained that vivid colors, light patterns, and unique shapes were things they were interested in capturing. One student explained, *"Anything that's brightly colored or seems unique,"* and another replied, *"Really colorful stuff, colorful plants, colorful step stones, or yeah, like plants."* Students also mentioned the composition of elements, experimenting with different camera angles when framing photos. For instance, one student showed a researcher a photo he had taken of a small plant, noting, "*Look, I sorta make it look like a tree… I took it from underneath*." We did not observe students articulating observations of specific non-aesthetic characteristics (e.g., identifying the type of plant), as we did in the NG groups. We also did not observe students in this group move closer to or touch the different nature elements they photographed.

5.7.3 Social Interactions

Students in the Camera app groups displayed notably different patterns of peer interaction, engaging in fewer app-related, nature-focused interactions with their peers. The interactions were more likely to be mediated through the phone screen as students took photos of one another and played offline games. For instance, we observed a group of students walking around the community garden together. They slowed down together in three different areas and spent no more than 5 seconds in each area. They had little interaction with each other while taking photos, which were often of different things. There was little discussion among them about their photos. The playful interactions we observed in this group typically consisted of posing for or taking photos of and with their peers rather than nature. During the post-activity debrief, students were excited to share with researchers the photos they had taken of themselves and their peers.

5.7.4 Opportunities for Continued Engagement

Overall during the Camera app session, we did not observe the same level of excitement among students using the app. On the contrary, many students appeared to be disengaged from the photo-taking activity. Nearly two-thirds of the students in one session turned to an offline game on the device's default browser (the phones had no data plans and were not connected to WiFi) out of self-reported boredom.

5.7.5 Science Discourse

Similar to the NG app groups, we did observe some students discussing what counts as nature. However, these conversations appeared to be prompted primarily by the title of the app (NatureCollections). For instance, one student yelled when his friend tried to take a picture of a garden trellis grid, *"That's not nature enough!"* In fact, one group of students thought that the Camera app could only take photos of nature. They quickly abandoned this idea (and their focus on their natural surroundings) when they tried to take a selfie and the photo appeared in their gallery.

5.7.6 Mobility

During the Camera app sessions, students appeared to be more aimless and wandering in their movements. We observed students move faster through different parts of the environment, snapping pictures in a seemingly haphazard way. In these sessions, students displayed a tendency to search alone for things to photograph, and they gave photos only momentary focus before moving on. This led to students being scattered and spread out in different directions during the activity.

6 DISCUSSION

In the current work, we investigated whether and how the NatureCollections app as a whole succeeded in triggering children's situational interest in nature. Our analysis of sixth-grade students' interactions with NatureCollections showed that the app's features collectively supported the four behavioral elements of personal interest that we investigated: *personal relevance, focused attention, social interaction*, and *positive experiences for continued*. In addition, we documented two emergent themes in our analysis: children's distinct patterns of *mobility* around the community garden and their engagement in *science discourse* with peers. Both of these behaviors related to and supported the four dimensions of interest development. Our findings point to the effectiveness of the interest-centered design framework used to design NatureCollections (Kawas et al., 2019). We conclude that, collectively, the design strategies embodied in the NatureCollections app hold promise for solving the problem of children's decreased time spent and interest in nature (Clements, 2004; Holt et al., 2015; Lohr & Pearson-Mims, 2004), with implications for supporting interest-driven learning about nature (Klemmer et al., 2005; Louv, 2008).

Our video analysis revealed how the design features of NatureCollections supported specific dimensions of interest development model (Hidi & Renninger, 2006). Moreover, our analysis of the students in the comparison Camera app group showed that the *absence* of these design features produced notably different behaviors in children. For instance, the NG app succeeded in supporting children's *focused attention* on the natural elements in their surroundings through features such as "Challenges," which prompt children to search for specific elements in nature, and "Photo Classification," which requires children to focus on specific characteristics of an element in order to identify it. Although children in the basic Camera app group also focused their attention on natural elements in their environment, the Camera app's limited palette of features, both of which emphasized taking pictures rather than exploring nature, resulted in focusing children's attention on the act of setting up and taking aesthetically pleasing photographs rather than on the characteristics of the nature element they were photographing. In this way, the Camera app functioned much like prior outdoor mobile learning technologies, which have consistently faced challenges associated with focusing children's attention on their device at the expense of engaging with their surroundings (Cahill et al., 2010; Kamarainen et al., 2013; Sobel et al., 2017).

Similarly, the "Onboarding" and "My Profile" features, among others, supported children's self-directed, *personalized exploration* of nature. Lacking such features, children in the Camera app group tended to connect personally to the act of photography, if they formed a personal connection at all. Self-guided, personalized exploration also had the effect of drawing children's attention to surprising elements in their surroundings, which they experienced as enjoyable, particularly when they shared them with their friends. Children using the NatureCollections app displayed excitement engaging with their environment and with their peers, and they conveyed their interest in *continued engagement* with the app beyond the study session. In contrast, children using the basic Camera app quickly lost interest in both the app and the activity. These differences suggest that it was the NatureCollections app and its unique set of design features, rather than the mere novelty effect of using a smartphone to take photographs of nature, that succeeded in triggering children's situational interest in nature.

Although our analysis focused on teasing out individual design features and tying them to specific behavioral indicators of interest development, we underscore that it is the system *as a whole* that supported the emergent behavior of a triggered situational interest in nature. To help make this point, consider the findings related to *social interaction*. Children in both the NatureCollections sessions and the Camera app sessions engaged in social interactions with their peers during the activity. However, features such as "My Friends," "Challenges," and "Badges" shaped children's social interactions in distinct ways compared to the basic Camera app group. Importantly, the distinct quality of social interactions we observed in the NatureCollections sessions appeared to support other key dimensions of Hidi and Reninger's interest development model. For example, children helped each other discover the app's various features, such as how to use the "Photo Classification" and "Challenges" features to tailor a *personally relevant* and meaningful app experience that involved *focused attention* on nature. They further supported each other's focused attention by exploring their environment together, giving each other suggestions about what to photograph, and helping each other to classify the nature elements in their pictures. In addition, their playful interactions around collecting, classifying, and earning badges contributed to their engagement in and enjoyment of the activity, which we interpret as increasing their likelihood to *re-engage in the activity in the future* (Azevedo, 2013; Hidi & Renninger, 2006). By contrast, the social interactions we documented among children in the Camera app sessions were centered to a greater degree on taking photos of each other rather than exploring and taking photos of their natural surroundings. These social interactions were neither nature-oriented nor were they supportive of the other dimensions of interest development. This example highlights the novel contribution of this work: we have provided empirical evidence that embodying the design strategies of the interest-centered design framework in NatureCollections can support children's interest development in nature.

7 LIMITATIONS AND FUTURE WORK

Our study included students from an affluent school, limiting the generalizability of our results. Moreover, although the participants' racial diversity was reflective of the city in which the study was conducted, it is not representative of the broader US population. As prior research has shown, attitudes with nature are influenced by demographic variables (Lohr & Pearson-Mims, 2004; Louv, 2008). Therefore, it would be useful to evaluate NatureCollections with students from diverse backgrounds to determine whether they respond differently to the app. Further, the current study was conducted as part of a school-based science class and took place in a natural setting (i.e. community garden). Students' behaviors with the app and the outdoor activity might be different in other contexts (e.g. urban settings) when they are not surrounded by nature and when they are not being observed by their teacher. We also had a camera crew with videography equipment, which might have altered students' behaviors. However, because these limitations apply to both groups across sessions, we are optimistic that distinctions in behavior between app groups remain meaningful. In future work, we will deploy the NatureCollections app in the field over a longer period of time to evaluate whether it succeeds in triggering children's interest in nature over the long-term.

8 CONCLUSIONS

We presented a comparative, in-situ study examining the extent to which the features of the NatureCollections app, developed from an interest-centered design framework, supported children's triggered situational interest in nature. We found that, in the short-term, NatureCollections succeeded in triggering situational interest by connecting to students' personal interests, focusing their attention on the natural elements in their surroundings, encouraging social interactions among their peers, and promoting positive feelings–evidence we interpret as a likelihood to re-engage with the app. Compared to the basic Camera app group, students using the NatureCollections app also displayed different patterns of movement and science discourse with their peers that further supported their engagement with nature. This study contributes empirical evidence that the interest-centered design framework can be used successfully to develop mobile applications that support children's interest-centered engagement in nature.

REFERENCES

Ainley, M. (2006). Connecting with Learning: Motivation, Affect and Cognition in Interest Processes. *Educational Psychology Review*, *18*(4), 391–405. https://doi.org/10.1007/s10648-006-9033-0

Ayers, J. W., Leas, E. C., Dredze, M., Allem, J.-P., Grabowski, J. G., & Hill, L. (2016). Pokémon GO—A New Distraction for Drivers and Pedestrians. *JAMA Internal Medicine*, *176*– 12. https://doi.org/10.1001/jamainternmed.2016.6274

Azevedo, F. S. (2013). The Tailored Practice of Hobbies and Its Implication for the Design of Interest-Driven Learning Environments. *Journal of the Learning Sciences*, *22*(3), 462–510. https://doi.org/10.1080/10508406.2012.730082

Bassett, D. R., John, D., Conger, S. A., Fitzhugh, E. C., & Coe, D. P. (2015). Trends in Physical Activity and Sedentary Behaviors of United States Youth. *Journal of Physical Activity and Health*. https://doi.org/10.1123/jpah.2014-0050

Boyatzis, R. E. (1998). *Transforming qualitative information: Thematic analysis and code development*. SAGE.

Braun, T., & Dierkes, P. (2017). Connecting students to nature – how intensity of nature experience and student age influence the success of outdoor education programs. *Environmental Education Research*, *23*(7), 937–949. https://doi.org/10.1080/13504622.2016.1214866

Cahill, C., Kuhn, A., Schmoll, S., Pompe, A., & Quintana, C. (2010). Zydeco: Using Mobile and Web Technologies to Support Seamless Inquiry Between Museum and School Contexts. *Proceedings of the 9th International Conference on Interaction Design and Children*, 174–177. https://doi.org/10.1145/1810543.1810564

Chipman, G., Druin, A., Beer, D., Fails, J. A., Guha, M. L., & Simms, S. (2006). A Case Study of Tangible Flags: A Collaborative Technology to Enhance Field Trips. *Proceedings of the 2006 Conference on Interaction Design and Children*, 1–8. https://doi.org/10.1145/1139073.1139081

Clements, R. (2004). An Investigation of the Status of Outdoor Play. *Contemporary Issues in Early Childhood*, *5*(1), 68–80. https://doi.org/10.2304/ciec.2004.5.1.10

Crawford, M. R., Holder, M. D., & O'Connor, B. P. (2017). Using Mobile Technology to Engage Children with Nature. *Environment and Behavior*, *49*(9), 959–984. https://doi.org/10.1177/0013916516673870

Derry, S. J., Pea, R. D., Barron, B., Engle, R. A., Erickson, F., Goldman, R., Hall, R., Koschmann, T., Lemke, J. L., Sherin, M. G., & Sherin, B. L. (2010). Conducting Video Research in the Learning Sciences: Guidance on Selection, Analysis, Technology, and Ethics. *Journal of the Learning Sciences*,*19*. https://doi.org/10.1080/10508400903452884

Fails, J. A., Herbert, K. G., Hill, E., Loeschorn, C., Kordecki, S., Dymko, D., DeStefano, A., & Christian, Z. (2014). GeoTagger: A Collaborative and Participatory Environmental Inquiry System. *Proceedings of the Companion Publication of the 17th ACM Conference on Computer Supported Cooperative Work & Social Computing*, 157–160. https://doi.org/10.1145/2556420.2556481

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Aldine Publishing.

Gray, C., Gibbons, R., Larouche, R., Sandseter, E., Bienenstock, A., Brussoni, M., Chabot, G., Herrington, S., Janssen, I., Pickett, W., Power, M., Stanger, N., Sampson, M., Tremblay, M., Gray, C., Gibbons, R., Larouche, R., Sandseter, E. B. H., Bienenstock, A., … Tremblay, M. S. (2015). What Is the Relationship between Outdoor Time and Physical Activity, Sedentary Behaviour, and Physical Fitness in Children? A Systematic Review. *International Journal of Environmental Research and Public Health*, *12*(6). https://doi.org/10.3390/ijerph120606455

Greenberg, S., & Buxton, B. (2008). Usability Evaluation Considered Harmful (Some of the Time). *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 111–120. https://doi.org/10.1145/1357054.1357074

Hidi, S., & Renninger, K. A. (2006). The Four-Phase Model of Interest Development. *Educational Psychologist*, *41*(2), 111–127. https://doi.org/10.1207/s15326985ep4102_4

Holt, N. L., Lee, H., Millar, C. A., & Spence, J. C. (2015). 'Eyes on where children play': A retrospective study of active free play. *Children's Geographies*, *13*(1), 73–88. https://doi.org/10.1080/14733285.2013.828449

Jake-Schoffman, D. E., Silfee, V. J., Waring, M. E., Boudreaux, E. D., Sadasivam, R. S., Mullen, S. P., Carey, J. L., Hayes, R. B., Ding, E. Y., Bennett, G. G., & Pagoto, S. L. (2017). Methods for Evaluating the Content, Usability, and Efficacy of Commercial Mobile Health Apps. *JMIR MHealth and UHealth*, *5*(12). https://doi.org/10.2196/mhealth.8758

Jordan, B., & Henderson, A. (1995). Interaction Analysis: Foundations and Practice. *The Journal of the Learning Sciences*, *4*(1), 39–103.

Kamarainen, A. M., Metcalf, S., Grotzer, T., Browne, A., Mazzuca, D., Tutwiler, M. S., & Dede, C. (2013). EcoMOBILE: Integrating augmented reality and probeware with environmental education field trips. *Computers & Education*, *68*, 545–556. https://doi.org/10.1016/j.compedu.2013.02.018

Kawas, S., Chase, S., Yip, J., Lawler, J., & Katie, D. (2019). Sparking Interest: A Design Framework for Mobile Technologies to Promote Children's Interest in Nature. *International Journal of Child-Computer Interaction*.

Kimbro, R. T., Brooks-Gunn, J., & McLanahan, S. (2011). Young children in urban areas: Links among neighborhood characteristics, weight status, outdoor play, and television watching. *Social Science & Medicine*, *72*(5), 668–676. https://doi.org/10.1016/j.socscimed.2010.12.015

King, C., Dordel, J., Krzic, M., & Simard, S. W. (2014). Integrating a Mobile-Based Gaming Application into a Postsecondary Forest Ecology Course. *Natural Sciences Education*. https://doi.org/10.4195/nse2014.02.0004

Klasnja, P., Consolvo, S., & Pratt, W. (2011). How to Evaluate Technologies for Health Behavior Change in HCI Research. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 3063–3072. https://doi.org/10.1145/1978942.1979396

Klemmer, C. D., Waliczek, T. M., & Zajicek, J. M. (2005). Growing Minds: The Effect of a School Gardening Program on the Science Achievement of Elementary Students. *HortTechnology*, *15*(3), 448–452.

Krapp, A. (2002). Structural and dynamic aspects of interest development: Theoretical considerations from an ontogenetic perspective. *Learning and Instruction*, *12*(4), 383–409. https://doi.org/10.1016/S0959-4752(01)00011-1

Krapp, A. (2003). Interest and human development: An educational psychological perspective. In *Development and motivation* (pp. 57–84). British Psychological Society.

Kuhn, A., Cahill, C., Quintana, C., & Schmoll, S. (2011). Using Tags to Encourage Reflection and Annotation on Data During Nomadic Inquiry. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 667–670. https://doi.org/10.1145/1978942.1979038

Lo, W. T., Delen, I., Cahill, C., Kuhn, A., Schmoll, S., & Quintana, C. (2012). A New Type of Learning Experience in Nomadic Inquiry: Use of Zydeco in the Science Center. *2012 IEEE Seventh International Conference on Wireless, Mobile and Ubiquitous Technology in Education (WMUTE)*. https://doi.org/10.1109/WMUTE.2012.16

Lohr, V. I., & Pearson-Mims, C. H. (2004). The Relative Influence of Childhood Activities and Demographics On Adult Appreciation For The Role Of Trees In Human Well-Being. *Acta Horticulturae*, 253–259. https://doi.org/10.17660/ActaHortic.2004.639.33

Louv, R. (2008). *Last Child in the Woods: Saving Our Children from Nature-deficit Disorder*. Algonquin Books.

Maxwell, J. A. (1996). *Qualitative research design: An interactive approach*. Sage Publications.

Moller, A. C., Merchant, G., Conroy, D. E., West, R., Hekler, E. B., Kugler, K. C., & Michie, S. (2017). Applying and advancing behavior change theories and techniques in the context of a digital health revolution: Proposals for more effectively realizing untapped potential. *Journal of Behavioral Medicine*.https://doi.org/10.1007/s10865-016-9818-7

Nayebi, F., Desharnais, J., & Abran, A. (2012). The state of the art of mobile application usability evaluation. *2012 25th IEEE Canadian Conference on Electrical and Computer Engineering (CCECE)*, 1–4. https://doi.org/10.1109/CCECE.2012.6334930

O'Brien, L., & Murray, R. (2007). Forest School and its impacts on young children: Case studies in Britain. *Urban Forestry & Urban Greening*, *6*(4), 249–265. https://doi.org/10.1016/j.ufug.2007.03.006

Olson, J. S., & Kellogg, W. (2014). *Ways of knowing in HCI*. Springer.

Rogers, Y., Price, S., Fitzpatrick, G., Fleck, R., Harris, E., Smith, H., Randell, C., Muller, H., O'Malley, C., Stanton, D., Thompson, M., & Weal, M. (2004). Ambient Wood: Designing New Forms of Digital Augmentation for Learning Outdoors. *Proceedings of the 2004 Conference on Interaction Design and Children: Building a Community*, 3–10. https://doi.org/10.1145/1017833.1017834

Rogers, Yvonne, Price, S., Randell, C., Fraser, D. S., Weal, M., & Fitzpatrick, G. (2005). Ubi-learning Integrates Indoor and Outdoor Experiences. *Commun. ACM*, *48*(1), 55–59. https://doi.org/10.1145/1039539.1039570

Ruiz-Ariza, A., Casuso, R. A., Suarez-Manzano, S., & Martínez-López, E. J. (2018). Effect of augmented reality game Pokémon GO on cognitive performance and emotional intelligence in adolescent young. *Computers & Education*, *116*. https://doi.org/10.1016/j.compedu.2017.09.002

Schellinger, J., Mendenhall, A., Alemanne, N. D., Southerland, S. A., Sampson, V., Douglas, I., Kazmer, M. M., & Marty, P. F. (2017). “Doing Science” in Elementary School: Using Digital Technology to Foster the Development of Elementary Students' Understandings of Scientific Inquiry. *Eurasia Journal of Mathematics, Science and Technology Education*. https://doi.org/10.12973/eurasia.2017.00955a

Sobel, K., Bhattacharya, A., Hiniker, A., Lee, J. H., Kientz, J. A., & Yip, J. C. (2017). It wasn't really about the Pokémon: Parents' Perspectives on a Location-Based Mobile Game. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI '17*, 1483–1496. https://doi.org/10.1145/3025453.3025761

Zimmerman, H. T., Land, S. M., Maggiore, C., Ashley, R. W., & Millet, C. (2016). *Designing Outdoor Learning Spaces With iBeacons: Combining Place-Based Learning With the Internet of Learning Things.*

Zimmerman, H. T., Land, S. M., McClain, L. R., Mohney, M. R., Choi, G. W., & Salman, F. H. (2015). Tree Investigators: Supporting families' scientific talk in an arboretum with mobile computers. *International Journal of Science Education, Part B*, *5*(1), 44–67. https://doi.org/10.1080/21548455.2013.832437