Designing Outdoor Learning Spaces With iBeacons: Combining Place-Based Learning With the Internet of Learning Things

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Abstract: This paper presents a collective case study of learners using mobile technology to engage in place-based science learning in an Arboretum. Our work investigates how proximity-based computing mediates youth's engagement in scientific observations and conversations in their Appalachian community. We draw upon theory from informal learning, place-based learning, and context-sensitive educational technologies to inform the research. Data from 26 children in a summer camp program include log files, field notes, and video-records. Our findings illustrate how an iBeacon system supported children's playful and scientific engagement (including in observational practices). We provide insights into designing for learner-centered mobile computing that moves beyond presenting just-in-time information to creating digital-physical spaces where learners engage each other and natural objects to support their interests in science.

Keywords: informal learning, mobile computing, pedagogical design, science education, gardens

Introduction

As mobile technologies become ubiquitous tools in educational settings, new opportunities have been created for everyday objects to become connected to mobile devices. These connected devices have resulted in digitally-augmented learning environments, which are referred to as the Internet of Things (IoT) (Trappeniers, Feki, Kawsar, & Boussard, 2013) or Internet of Learning Things (IoLT) (Selinger, Sepulveda, & Buchan, 2013). In the IoLT, designers connect computers to objects to bring together digital resources and physical places. Our research and development agenda seeks to inform science learning experiences with design principles for technology-enhanced pedagogies. Specifically, we are investigating how informal learning institutions (ILIs), such as zoos, gardens, and science centers, can adopt iBeacon technologies to augment exhibits to engage visitors in interactive learning activities within and about their community. As such, our work conceptualizes how proximity-based technologies, informed by an IoLT perspective, can support youth to learn about biology, geology, hydrology, and ecology in the places that matter to their daily lives.

Theoretical framework

Conceptually, our research and design efforts use an IoLT paradigm to make visible the scientific phenomena present (Eberbach & Crowley, 2009) in an ILI in ways that align with instrumental and social disciplinary practices. Through this work, we transform object-oriented institutions into child-centered learning spaces as we draw upon three literatures: *informal learning, context-sensitive technologies*, and *place-based learning.*

The *informal learning* perspective (Bell, Lewenstein, Shouse, & Feder, 2009) acknowledges that people's sociocultural experiences, prior knowledge, and purposes/agendas for engaging in activities need to be honored in the design of learning experiences. Informal learning processes that we support with our design work include (a) meaning-making through talk where learners understand new phenomena through social interactions (Leinhardt, Crowley, & Knutson, 2002) and (b) making, drawing, or developing artifacts in order to elaborate, share information, and connect and build ideas (Kafai & Resnick, 1996).

The learning with mobile technology literature considers the learner's interactions with their physical location, others, and the technology as part of *context-sensitivity*. Context-sensitivity is often associated with types of augmented reality (AR) (Dunleavy, & Dede, 2014). Sharples (2013) asserted that context in a learning environment is more than just the setting, instead context is negotiated moment-by-moment through learners' interactions with the physical location, technology, material resources, and other people. We also drew heavily on research on science learning with mobile computers (Chen, Kao, & Sheu, 2005; Huang, Lin, & Cheng, 2010; Kamarainen, et al., 2013; Land & Zimmerman, 2015; Looi, et al., 2010; Rogers, et al., 2005).

Place-based learning (Smith, 2002) aims to ground learning experiences in community perspectives to illustrate how global and abstract concepts manifest in local places and spaces. Place-based activities recognize learners' everyday experiences as assets to future learning. When place-based learning is combined with context-sensitive technologies, mobile computers become tools for learners that mediate connections between a local setting and the broader disciplinary perspectives (Zimmerman & Land, 2014).

Technological setting: The *Places* iBeacon system

The iBeacons development platform (*Places)* includes a content management system (CMS), the *Places* app deployed on iPad™ tablet computers, a server that hosts the CMS and data analytics, and iBeacons placed at biological, geological, ecological, and hydrological exhibits within the Arboretum. We used Gimbal™ iBeacons that were battery-operated Bluetooth Low Energy (BLE) transmitters. iBeacons transmit signals to a user's mobile device in ways that allow the device to detect a learner's proximity to the iBeacon. With the fine-grained proximity information, the *Places* app pushes relevant content and learning activities to children and families.

The research team developed a CMS to communicate to the *Places* app via the Internet. In the CMS, the researchers loaded customized maps of the Arboretum exhibits, diagrams, photographs, and text (written at a 3rd-grade reading level for children ages 8-9) as well as unique codes found on each iBeacon. The CMS was designed so that a learning designer could connect unique educational resources to each iBeacon in its database. When in the Arboretum, the *Places* app launches the appropriate exhibit map when it detected an iBeacon that was identified on that map. The iBeacons allow the *Places* app to push information to learners at the proximity level of a specific tree specimen or exhibit component (at a precision that other location-aware technologies such as GPS nor QR codes cannot easily accomplish). This specificity of proximity enables the IoLT perspective in ILIs, because iBeacons can support a visitor to compare and contrast relevant features of two trees or two sculptures that are just meters apart.

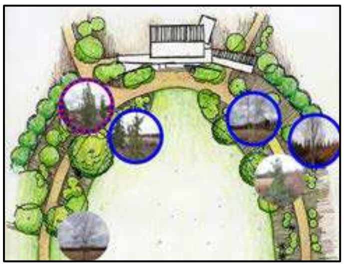

Figure 1. When iBeacons are detected, the *Places* app launches a map for children, which highlights the trees with additional learning activities.

For the two case studies presented here, learners were given iPads to use with *Places* in the Arboretum. (Note: After the *Places* app is downloaded, the Internet is not needed). As the children reached a proximity threshold specified by an algorithm set by researchers in the CMS, the iBeacon triggered the display of content on the iPad that included a learning activity and scientific information. During the learners' visit to an ILI, the *Places* app used the iPad's hard drive to store data about the learners' interactions with and proximity to each iBeacon. The data captured by the *Places* app contained an iPad-specific ID, iBeacon ID, content ID attached to the iBeacon, first access time, number of total access points, and last access time. When the *Places* app next accessed the Internet, *Places* transmitted non-personally identifiable log file data back to the *Places* server with the users' consent (and assent).

Methods

The overarching methodology is a collective case study to consider the unique features of a case (i.e., each iBeacon-enabled learning experience) as well as to compare and contrast two cases. We selected the Arboretum at Penn State as our study site as it is a prototypical outdoor ILI. The Arboretum has a pollination garden, a model cave, children's garden, live specimens, sculptures, and various scientific representations. Learners in Case A include 26 summer camp youth aged 6-10 learning about caves, and learners in Case B include 24 youth (from the same summer camp) learning about fruit. Learners worked in small groups with the teachers from the camp to use the *Places* app and iBeacon system.

In order to investigate how an iBeacon mobile computer system can be designed to support learners' science learning in ILIs, this study asks the following two questions:

- What types of conversations do learners have while using the materials? What types of engagement patterns can be observed related to playful and/or scientific learning?

Data collected include: (a) observations of small groups of children using the *Places* app and iBeacons at the Arboretum, (b) learning analytics of small groups' actions based on iBeacon proximity; (c) small groups' photographs and drawings, and (d) recording from digital video-cameras and GoPro® point-of-view cameras.

Observations of children at the Arboretum at Penn State

Each researcher followed one small group of children on-site. Researchers did not ask questions of the children but assisted with technical issues as needed. Field notes were compiled into a database, and episodes were identified related to (a) learner experiences with wayfinding and usability of the app and (b) learners' discourse related to their observations of trees, the technologies, and science concepts. The episodes identified on the field notes were coded from our theoretical framework as well as by emergent codes. Multiple researchers worked together on transcripts during team meetings to confirm themes and patterns related to the research questions.

Learning analytics of children using the *Places* app

From the *Places* app, the research team collected detailed logfiles at the level of each small group, rather than individual learners. These logfiles from small groups were coordinated to the fieldnotes so that we could align the online data with on-site observations. We collected data that included the mobile device ID, content set accessed, iBeacon accessed, timestamp, and learners' digital photographs. Logfiles were exported into Excel for analysis. From these data, we determined the time spent at each plant specimen, the learning pathway taken across the Arboretum, and breadth and depth of the science content that each group accessed.

Video-recordings of the learners at the Arboretum

We collected video-recordings of the children at the Arboretum. Team members made content logs where key actions were identified. Researchers noted connections to prior knowledge, connection to concepts presented, use of representational forms, and talk that described or explained relevant scientific phenomena. The team held interaction analysis sessions where researchers described, documented, and interpreted the learners' activities in the Arboretum. Narrative accounts of each group of learners were developed as were analytical memos related to themes of place-based learning, informal science learning, play, and technical use issues.

Findings

Case A: iBeacons assisted learners to coordinate ILI exhibits' content to their local community, its history, and the learners' playful interests

In Case A, we developed a 60-minute tour that showed learners models of phenomena that were of geological, hydrological, and biological importance to their community. An important theme on the tour was the way that water transformed the landscape and how the land transformed the water. All 26 children were observed to engage in playful and scientific discussion around the iBeacon content. The first excerpt illustrates how four children were able to connect *Places* app science content to a life-sized model of a cave:

- At the iBeacon trigger for the cave, the *Places* text read: "Do you see where the water may have dissolved the rocks?" Cora pointed up to the stalactites. Then, Alex, Zoey, and Sawyer also pointed at the stalactites. Sawyer said, "see the white rock". Alex and Zoey added, "and the white stalagmites".

The excerpt with Cora, Alex, Zoey and Sawyer illustrate how the text triggered by an iBeacon could act as a prompt to support observations of small (less than 10 cm) stalactites that grew on the ceiling of the model cave.

Even while observing in the garden, learners added imaginative role-play elements to the iBeacon content. In this second excerpt, Sebastian added a time machine element to iBeacons activity, pretending that he could go back in time when his local community was covered by ocean to explore the prehistory of his community:

- Sebastian: Oh yeah! This is our next destination. This has to be. Is this real coral? Ohhhh, the trannsssmittter! Look! I'm putting this in here. Locked coordinates with black rock. ((He puts a rock in the hole in the coral model.)) Locked in coordinates. Look this fits in here perfectly! I'm going to the beach . . . ((singing)) yeah!

We interpret Sebastian's time-travel interactions to be consistent with expectation for play (and fun) in an ILI setting. While we designed structure in our iBeacon program for *Places,* we took care not to over-structure the program — we left space for learners' interests (and personal agendas and aims) alongside the scientific aims.

Case B: iBeacons supported observational practices across a large exhibition

In Case B, we created a 60-minute observationally-focused tour that applied one concept — the biodiversity of fruit. We placed iBeacons on trees that had visible evidence of fruit in the Arboretum, but we encouraged the groups of learners to find other plants or trees with fruit. The 24 summer camp children engaged in observations that resulted in playful, descriptive, and conceptual discussion of plants, as shown by these three excerpts:

- Playful talk: After investigating a tree and observing its many pinecones, Sebastian raised his hands above his head to imagine that he was a pinecone similar to those he saw: "I'm a very small pinecone".
- Descriptive talk: A teacher asked if the children observed any differences between two crabapples trees. The children described differences in tree size, tree shape, bloom color, and branching pattern.
- Conceptual talk: While looking at a tree, Sawyer and Violet observed strawberry plants at its base. Violet connected the berry plants to others she had seen: ". . . they usually bloom in the early spring".

These three examples from our dataset learners engaged in scientific observations of the selected iBeacon-ed trees as well as other content that piqued their interests. These three excerpts were typical of others' scientific and playful interactions related to observing plants at the Arboretum.

Cross-case discussion and implications to learning with mobile technologies

Across the two cases, we found that both play and science learning — especially related to observational practices (Eberbach & Crowley, 2009) — were supported when we integrated an iBeacon system into a summer camp program. In keeping with the goal to design an IoLT experience (Selinger, et al., 2013) for youth, the *Places* iBeacon system delivered content, question prompts, and activities to children in the Arboretum in a manner that supported them to look deeply at plants. We also found that social interactions occurred in the form of science-related learning conversations (Leinhardt, et al., 2002) of both a descriptive and conceptual nature. This project adds to the understanding of how to blend context-sensitive technologies with place-based perspectives on learning because the design principles were supported by our case analyses to align to the orienting meta-principle of augmenting outdoor spaces to reveal scientific aspects that might not be visible to novice learners. Based on our analysis, we posit that by empowering young learners to explore ILIs with iBeacon systems (or similar context-sensitive educational technologies), youth can follow their own interests as they engage in the science practice of observation. Learners can also use iBeacon systems to control the depth and breadth of science content presented, based on their proximity to pre-selected specimens and exhibits.

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Acknowledgments

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