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Using immersive augmented reality to guide families' observations and visualizations of pollinator habitats in outdoor spaces

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Abstract: Immersive AR technologies can support students' learning processes and deep engagement with outdoor science pursuits, yet few studies explore these technologies with out-of-school learners. We analyze how immersive AR features built into an outdoor-based mobile app shaped nine families' learning experiences as they explored pollinator habitats. Preliminary findings revealed that immersive AR scanning tools built into the *Pollinator Explorers* app guided families' observational practices of real-world objects through virtual overlays representing pollinator habitats.

Introduction and conceptual framework

Prior work on the use of immersive augmented reality (AR) technologies in outdoor spaces (i.e., hiking trails, schoolyards), posits that when designed using situated learning pedagogies, apps can support students' engagement, learning processes, and problem-solving skills (e.g., Georgiou & Kyza, 2017). Whereas this prior work has mainly focused on student populations, we aim to better understand how family learning processes (Ellenbogen, Luke, & Dierking, 2004) are shaped by outdoor-based immersive mobile AR (MAR) technologies, particularly because family groups comprise the majority of visitors to informal learning sites (Bell et al., 2009).

Eberbach and Crowley (2017) define disciplined noticing as "a critical dimension of observational practice and involves learning to detect the signal from the noise" (p. 24). In alignment with this prior work, we aim to provide families with a mobile learning experience that guides them to pick out and scientifically observe the different components of a pollinator habitat while being physically situated within the dynamic and complex space of an outdoor learning setting. With the addition of immersive MAR technologies into our mobile app designs, we strive to elevate these observations so that families are supported to "see the unseen" through digital elements overlayed onto real-world phenomenon (Zimmerman et al., 2021). As such, we ask the following research question: *How did a learning-on-the-move app's immersive AR features shape families' learning experiences and observations of pollinators and their habitats?*

Methods: Context, participants, and data

Using a design-based research methodology (Sandoval & Bell, 2014), we explore this first iteration of a learning-on-the-move MAR app designed to foster observations of healthy pollinator habitats at a rural nature center in the northeast United States. The *Pollinator Explorers* app is focused on a specific type of pollinator—solitary bees—and what they need to thrive in a forest and meadow habitat (where this app tour was situated). Families in our study used the app to tour six different stops around the outside perimeter of the nature center and collected evidence (through photos) of what these native bees need to live and thrive in this habitat. Two of the six tour stops included digital augmentation of science phenomena (i.e., bee nests inside of logs, microscopic pollen grain) layered over real-world objects to further families' observations and immerse them in more deeply understanding bee needs and habitats. We focus here on the immersive AR design features at the log nesting tour stop.

Nine families agreed to participate in the research (29 individuals; 14 adults, 15 youths). Families' self-reported racial affiliations were White (93%) and Black or African American (10%). Children (female: 47%, male: 27%, did not report: 27%) were primarily between the ages of 5-12 (73%). Family groups individually participated in the *Pollinator Explorers* tour for an average of 43 minutes. Families were provided with an iPad pre-loaded with the app, and screen-recordings were enabled throughout the duration of each family's tour experience. Additionally, one individual per family donned a GoPro video camera attached to a baseball cap to collect audio-visual data from the perspective of the learner. We implemented video-based qualitative analysis of the GoPro data using an interaction analysis framework (Jordan & Henderson, 1995) to understand the families' talk and gestures as they related to their experience with the first design iteration of the app. The research team created detailed narrative accounts of each family's tour with the app with a focus on moments when the app facilitated families' real-world observations of pollinator habitat components around them. The first author vetted the narrative accounts and selected to analyze families' interactions at Stop 3 (Log Nesting Locations for Solitary Bees) due to the immersive nature of the AR technology embedded within the app design at this tour stop.

Findings

From an analysis of the full video dataset, 100% of families completed the immersive AR activity to visualize potential bee nests inside of real logs at Stop 3. This design feature aided families' observational practices in two ways. First, families were guided to find an example of a potential bee nest site by locating two side-by-side logs nearby on the ground. After locating this real-world object, families next used the AR scanning tool in the app to "see" what a bee nest inside the logs would look like. In several families, we noted that affective responses (e.g., apprehension about a potential bee nest site) signaled immersive moments where the digital augmentation blurred with the real-world phenomena. In Table 1, two examples from our dataset portray the ways in which two family groups interacted with the immersive AR activity (**bold font** represents family talk related to real-world observations and app use; *italicized font* denotes our analytical interpretation of the data).

Table 1

Two Families' Interactions with AR Technology to Support Real-World Observations of Bee Nests

Dad Simon and sons, Peyton (12) and James (8)	Mom Sharon, Dad Ryan, Nicholas (8) and Eli (2)
Peyton: Wait. And we will scan them to learn more. **Oh, we're here.** *[app supports location of bee nest site]* **I don't want to go there if there's a nest**. *[affective response signals an immersive learning experience: the potential for a bee's nest in the logs became real through the AR scanning tool]* Dad: Stand up here and see what it does. Scanning. Oh, that's cool. Peyton: Oh my gosh. Dad: Oh, **so that's where the nest is?** Oh, wow. *[digital AR supports connection of science content with real-world observation of bee nest site]*	Mom: Oh, that's cool. Look at that, **it's showing us what's inside**. **Here, let's go closer so we can look at the real thing.** *[digital AR supports connection of science content with real-world observation of bee nest site]* Nicholas: Is it really active right now? Mom: I don't know. Nicholas: I'm scared it's active. *[affective response signals an immersive learning experience: the potential for a bee's nest in the logs became real through the AR scanning tool]*

Discussion and implications

Our preliminary work with the *Pollinator Explorers* app suggests the potential for guiding families to be more disciplined observers within these rich authentic learning environments (Eberbach & Crowley, 2017). We posit that the immersive blending of real-world phenomena with virtual augmentations—an activity previously argued to facilitate high school students' learning (Georgious & Kyza, 2018)—deepened families' scientific observations and awareness of surrounding bee habitats and behaviors. Future iterations of our work will expand upon these immersive AR experiences in different outdoor learning spaces to broaden our understanding of outdoor family science learning with MAR technologies.

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