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Mobile Augmented Reality in the Backyard: Families' Outdoor Spaces as Sites of Exploration about Pollinators

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Abstract: From the first iteration of a design-based research study with 16 families, we investigated at-home intergenerational exploration of pollinators and plants. The team developed a mobile augmented reality app focused on plant-pollinator interactions. We investigated how AR elements influence families' learning in their backyards. This analysis informs the design of mobile augmented reality apps that are site-independent for families' collaborative learning opportunities in outdoor, home-based settings.

Keywords: Informal learning, science learning, mobile technologies, augmented reality, family learning

Mobile augmented reality apps supporting learning at home

Sharples and Pea (2014) theorized a sociocultural view of mobile learning as "context-sensitive learning," where learning is embedded within interacting contexts of social, material, environmental, and individual resources. Mobile devices, with their range of affordances, enable designers to reimagine configurations for how and where learning takes place (e.g., Kawas, et al., 2019). Mobile augmented reality (MAR) expands opportunities for learning within real-world places through a virtual layering of digital material that can be viewed on devices in outdoor spaces (Ryokai & Agogino, 2013). MAR uses digital resources to reveal disciplinary meanings of a place that may not be visible to learners directly (Dunleavy & Dede, 2014). Our place-based MAR concept focuses on designing "micro sites" (Sharples & Pea, 2014) for families' science learning that draws upon both planned and emergent experiences within a setting to create out-of-school learning opportunities.

We conceptualize MAR as a cultural tool mediating science learning while people move through their community. MAR has been designed to augment science learning in the natural world in places such as parks, gardens, ponds, and woodland settings (e.g., Georgiou & Kyza, 2017). We add to the MAR designs the concept of learning-on-the-move, (Silvis et al., 2018; Taylor, 2017) where movement through familiar spaces supports people as they make sense of new information. Silvis et al. (2018) investigated families' technology practices within an ethnographic study and found that mobile computers and other technologies were integrated as learning tools in homes and communities. Similarly, Taylor (2017) used ethnographic methods to explore how youths came to understand their community as a designed, complex system.

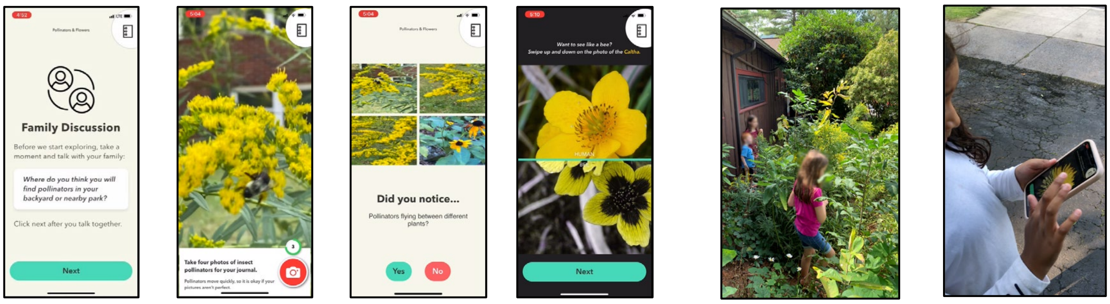
Learning scientists argue that to engage in scientific observations, people must be facilitated to notice scientifically through joint attention and guided participation (Eberbach & Crowley, 2017). Eberbach and Crowley found that parent-child conversation during their shared focus on insects and plants was an essential mechanism for understanding pollination. Using *wh-* questions is one of Eberbach and Crowley's elaborative conversational strategies to direct attention and elicit meaning-making conversations. Marin (2020) investigated observing-on-the-move in families with children as they walked together in forests; she explained how people's talk and movement across landforms work together to shape the families' field for observing and story-telling. We build from these findings to explore how MAR can engage and support families as they move and talk together to notice scientific phenomena in their backyards. As such, we ask the following research question: *How does a mobile augmented reality app support families to notice key features of pollinators and plants in their backyard?*

Methodology: Iteration one of a design-based research project

Using a sociocultural theoretical framework, we adopt cultural psychology-informed DBR (Bell, 2004), relying primarily on qualitative analyses of talk and action to understand how the MAR app could serve as a cultural tool. Our work here is the first iteration of an app on pollinator-plant interactions.

The *Backyard Explorers* MAR app features and technology

The *Backyard Explorers* experience was approximately 15-20 minutes. The app was divided into three sections: (a) Pollinators and flowers; (b) Seeing what we can't; and (c) Be a pollinator friend. Families were prompted to discuss where they think they will find pollinators in their yard (Figure 1a). Then, they were encouraged to locate flowers in their yard to observe pollinators. Families were offered a list of behaviors to attend to and were prompted to take four photos of pollinators (Figure 1b). Once complete, the photos are displayed on the screen as they answer five yes/no "Did you notice…" questions, which serve as a checklist (Figure 1c). This sequence of noticing key scientific features, photo-taking, and yes/no questions was repeated for flowers. After, the families were prompted to observe one pollinator closely and take a 10-second video. The next section of the app, *Seeing what we can't*, used AR to illustrate scientific phenomena that are difficult to see in one's backyard. One activity called 'See like a bee' illustrated through AR filters how some pollinators can see the colors from the light spectrum in ways that humans cannot (Figure 1d). The last section, *Be a pollinator friend*, prompted families to select from a list of activities they could engage in stewardship actions to promote pollinator wellbeing. All families completed the pollinator and flower activities; however, only five families completed the last activities.



(a) (b) (c) (d) (e) (f)

Figure 1: Images a) – d): our screenshots from the *Backyard Explorers* app: a) family discussion activity (left), b) photo-taking activity (middle left), c) one screenshot of the yes/no questions that make up the pollinator observation checklist (middle right), and d) the bee vision slider. Images e) and f) are families using the app.

Data collection and analysis

Data were collected via an online social distancing protocol due to the COVID-19 pandemic. Sixteen families living in rural counties completed the MAR app experience (18 adults, 28 youths). Participants reported themselves mostly as White (White: 85%, Hispanic or Latinx: 6.5%, No answer: 8.7%, Other: 2.2%). Children (female: 46%, male 54%, non-binary: 0%) were primarily between the ages of 5-12 (89%). Seven guardians were educators (39%) (e.g., teachers, professors); four were homemakers (22%); and other occupations were farmer, camp director, and self-employed. Six families (37.5%) homeschooled their children. Due to COVID-19, all families had to have internet access and an iPad or iPhone to participate (normally, families can borrow equipment). Lack of broadband access and high unemployment during COVID-19 stay-at-home orders limited our research; unfortunately, we only reached rural families with their own technological resources during this study period.

Primary data sources are *Backyard Explorers* screen recordings, which captured 15 families' voices, app interactions, and video from the AR browser of the families' yards. Five recordings were not fully captured. Additional data include (a) photographs and videos from four families, (b) online demographic surveys through Qualtrics, which included zip code, race/ethnicity, occupation, and age, and (c) pre- and post-experience interviews via the Zoom platform. In the post-interview, families were asked about their overall experience.

We conducted a qualitative analysis of the screen recordings via interaction analysis (IA) (Jordan & Henderson, 1995). The videos were professionally transcribed and confirmed for accuracy by two researchers. The authors held four co-viewing IA sessions to watch the 15 recordings. The team took notes on how the families: (a) talked about pollinator and plants, (b) used AR, photography, and checklist questions, and (c) made connections to their local community, home, and neighbors. Next, the IA notes were developed into codes to understand the families' experiences with our MAR app. Three authors coded the videos to compare and contrast the families' experiences, and then the code segments were placed in a shared spreadsheet. Based on the IA session notes and coding spreadsheet, themes were selected for this paper on how the MAR app worked as a cultural tool to support people to notice key scientific elements in their backyards. The first author selected two families' talk and actions to include in this analysis because these families clearly illustrated the phenomena of interest: noticing plants and pollinators in their backyard while engaging with the MAR elements of the app. Discussions were used to ensure confirming and disconfirming episodes were considered in the development of final analyses.

Findings

From the 15 families' screen recordings, we found that the pollinator MAR app supported talk that indicated they were noticing key concepts related to pollinators — including the presence of insects, insects on flowers, the color of flowers, and the types of plants in their yards. All families self-reported during the post-experience interview that the MAR app supported the way they saw pollinators and plants in their backyards.

Noticing key scientific phenomenon with the MAR app photo-taking and checklist

All families used the app and its checklist and prompts (in the form of yes/no questions) to notice scientific aspects of plants and pollinators. For example, a father and three children (Ava and Jillie, two 7-year-old girls, and Liam, a 3-year-old boy) used the app to observe pollinators on milkweeds, goldenrods, and daisies. The father used the app to ask questions to guide the children to notice aspects of the pollinator's behaviors:

Dad: So, what do you see? What are the bugs doing? Or what are the insects doing that we see?

Ava: They're landing on the flowers and then flying to other flowers. ***[noticing]***

Dad: Yeah, they really are. They're going from flower to flower. ***[noticing]***

Jillie: Oh daddy! I see a bee. ***[identification]***

Ava: A bumble bee. ***[identification]***

Dad: Yeah. I don't even know if that's a bumblebee. I think that might just be it. Oh, Oh, that big one. Oh yeah. That is a bumblebee. ***[identification]***

Liam: Where?

Dad: I think there's one on the, on this, on the golden rod over here. ***[identification]*** Liam, look straight ahead. ((crosstalk)) Yeah. It's just crawling all over the flower. ***[noticing]***

The excerpt shows the father started prompting the children to talk about the pollinator they saw, as suggested by the app. A conversation between Ava, Jillie, Liam and their father ensues where the family alternates between noticing key pollinator behaviors from the app and identifying plants and insects.

The family next walked to the plants alongside the wooden fences on the path in front of their house to find more pollinators such as bumblebees, honey bees, yellow jackets, and monarch caterpillars on plants. After taking photographs, the father read aloud the pollinators' observation checklist in the app (Figure 1c) to recall their children's observation about the pollinators and facilitate their ability to notice essential details.

Dad: Okay. Did you, have you seen pollinators sitting on one type of plant? ***[reads checklist]***

Ava & Jillie: //Yeah.

Dad: Yeah. Like that bumblebee. Just really did not want to leave. ***[recalls previous noticing]***

Jillie: It was just curling up ***[recalls the previous noticing]***

In this family case, similar to others in our dataset, the father used questions and content in the app, such as the checklist, to support the children's observation of pollinators. As the children observed the pollinators on the move in the garden, they attended to the physical environment and phenomena and engaged in the app's activities and content at the same time.

Using AR to connect backyard plants to the scientific phenomenon

In addition to using the app to support noticing insects and plants, five of the fifteen families used the MAR elements to make visible scientific phenomena in their backyards that they could not see without additional digital augments. An example of this comes from one family (Mother and Sofía, 7-year-old daughter) using the Bee Vision MAR (Figure 1d) to help further understand how bees could find the pollen and nectar in flowers.

Mom: Look. What do you see? Want to see like a bee? Swipe up and down from the photo. Okay, look, this is how a human sees it. And that's, that's how a human sees it and that's how a bee sees it.

Sofía: They see as black and brown? I mean, black and yellow?

Mom: Here, you can swipe it up and down to see. That's the human. And then, when you go up, that's how the bee sees it.

Sofía: Whoa... How, how does this help, how does this help them see the nectar.

Mom: Maybe they can like [inaudible] if they're more attracted to that color.

Sofía: Maybe they are.

Sofía engaged with the bee vision interface, swiping the AR representation back and forth (Figure 1f) while commenting on how people see the flowers versus how bees see them. Sofía said, referring to a flower in her backyard based on what she learned in the app about how insects see different aspects of light spectrum: "*This is a dry, dry land with just black and purple flowers. Mmm, that's pretty. That's the one we saw in the backyard. And there's a bunch of little ants in there.* [inaudible] *That's how they see it [the black and purple flowers]? That's terrible."* Sofia did not appreciate how the flowers looked through the ultraviolet light simulated visualization (i.e., terrible). While she and her mother did not use scientific language like wavelength, they noted that insects could see flowers differently than humans and that helped pollinators found flowers. This case shows the utility of visualization of the bee vision to teach families about science in their backyard gardens.

Discussion

Our work informs the learning-on-the-move (LOM) theory by building on prior findings about LOM with technology (Silvis et al., 2018; Taylor, 2017) and without (Marin, 2020). Similar to Taylor's (2017) findings that mobile technologies can guide youth to create meaning in their own neighborhoods, our study shows promise for the potential of site-independent, mobile AR to support science learning in people's backyards. In regard to advancing the design of MAR technology for use in communities, our findings suggest that the *Backyard Explorers* app supported noticing, and the MAR features helped families to understand ideas that they could not easily see otherwise. To design such immersive experiences, researchers must consider the interactional, cultural context that people bring and create as they use mobile computers in situ (Georgiou & Kyza, 2017).

Regarding design implications from our findings, the summary of the fifteen screen recordings demonstrates that the yes/no checklists and discussion prompts supported families' observing-on-the-move in each of their different backyards. Ava, Jillie, Liam, and their father exemplified how these two elements were integrating into noticing, identification, and recall. From the five families that used all of the MAR elements, these were supportive of family talk around science that was not visible in the garden without enhanced visualization. The case of Sofia and her mother illustrates one example of how a family was able to look at the bee vision visualization and apply it to the flowers in their own garden. Future design and analyses will look more closely at how families use familiar referents, objects, and stories (Marin, 2020) to talk about pollinators' behaviors, plant diversity, and other flora and fauna in their backyard.

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