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Using QR-Triggered Mobile Learning Experiences to Support Collaborative Sense-Making and Observation

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Abstract: We investigate how design elements can support sensory engagement and sense-making through discussion and place-based activities offered via a QR code triggered, web-based mobile learning experience. 31 families (116 individuals; 54 adults, 62 youths) were recruited at a nature center to participate in learning activities related to pollinators and native plants. From the learning-on-the-move and science education literatures, two design conjectures guide our work a) sensory engagement via tactile and visual observation of objects and specimens on-site support scientific noticing and b) discussion prompts and place-based activities support sense-making and knowledge integration via focusing conversation on scientific phenomena and big ideas. Families were observed seamlessly engaging in discussions beyond intended geographic boundaries as they observed and engaged in discussions of phenomena across space. This analysis contributes to literature on informal learning environments and the role that QR-triggered web-based science content can provide in outdoor learning settings.

Conceptual framework

This analysis focuses on how to support families' scientific talk and observations in outdoor informal learning environments with the use of mobile web-based experiences that prompt scientific observation about pollinators. The study expands on the theoretical learning sciences scaffolding theory. In scaffolding, a learner may complete a task that may be too difficult to complete on their own through another's assisted efforts (Wood et al., 1976). Learners share work with "some more knowledgeable other" to complete tasks that may be too complex for the learner to complete on their own (Reiser & Tabak, p. 45, 2014). By scaffolding instruction, learners may be prompted to engage in learning tasks in unique ways that help to maintain their interests across learning activities and prompt them to engage in meaningful discussions and reflections (Reiser & Tabak, 2014). To support families' learning, we incorporated scaffolding into a QR-triggered mobile learning experience to utilize the concepts of learning-on-the-move (LOTM) (Marin et al., 2020, Taylor, 2017, Zimmerman & Land, 2022) and learning to observe more scientifically (Eberbach & Crowley, 2009). LOTM considers the importance of place and time in meaning-making as individuals move through spaces while learning (Marin et al., 2020). Previous studies have shown how LOTM can incorporate new technologies to empower youth to learn from and express their experiences as they journey through and portray the world, such as with GPS technology (Taylor, 2017). Additionally, studies have shown that when collaboration scripts are designed within mobile computing interventions, the learners' movement can influence sense-making while engaging in an outdoor community-based learning experience (Zimmerman & Land, 2022).

Eberbach and Crowley (2009) highlight the power of children's observations but discuss how supports and scaffolds could impact the types of scientific observations children make as they make sense of the world. Children often notice phenomena on their own, however, they may need guidance to engage in meaningful sensemaking whereby their everyday noticings transition to become scientific observations. Eberbach and Crowley (2009) also note that supports for scientific observations may be lacking in non-school settings (i.e., outdoor or everyday activities). To make this transition from the everyday to the scientific, Eberbach and Crowley (2009) suggest that children may transition into more intermediate scientific observers if they engage in more sustained engagement and conversation that supports the youths to notice more relevant scientific features.

In response to the research on supports needed in observational practices, our design work provides opportunities for families and children to LOTM and engage in more scientific observational practices and conversations through scaffolds, collaboration scripts, and performance supports. Mobile learning provides opportunities to create an overlay of digital information on mobile devices in conjunction with the user's environment (Ryokai & Agogino, 2013), allowing users to view and interact with the physical world together with digital information represented on a mobile device in real time (Olsson et al., 2012). Specifically, we designed QR-triggered mobile websites to provide families with science content and discussion prompts to engage with as they traverse across informal learning spaces in their communities. The nature of QR codes provides

efficient scaffolding opportunities as web-based information is accessed after a user scans the provided code. QR codes have been shown to be effective as tools to provide digital media to learners through mobile devices (Dunleavy & Dede, 2014) while also being cost-effective and more easily deployable across various spaces to provide users with better understanding and guidance (Kuru Gönen & Zeybek, 2022). While previous designs in our research have utilized GPS triggers to launch access to AR or mobile content, a constraint for GPS is the accuracy and distance in which it can be deployed (approximately 2-5 meters away from an intended location). QR code-triggers are advantageous for outdoor education as they can provide instantaneous access to engaging science content. Wayfinding with QR-code triggers can be more spontaneous and varying, allowing users to journey along unique paths as they engage with provided content which can personalize their learning experiences (Zimmerman & Land, 2013). Additionally, instructional designers and educators may find QR code-triggers efficient as tools for swiftly providing users access to content, as they can be deployed and updated remotely via web access. This provides a more accessible opportunity for many informal learning professionals who may wish to provide regularly updated content for visitors to engage with their learning spaces. This can be particularly important for STEM education professionals who may wish to bring attention to specific outdoor phenomenon that may be relevant at specific times of the year. This is an increasingly valuable element of QR code-triggers in informal learning settings, especially across scientific learning, as changes in the environment can impact where observation may be best focused to increase scientific observation. As mobile technology continues to evolve, the capabilities to implement highly engaging and creative content via web-based QR code-triggers greatly expand.

In this paper, we address the following research question: *How does science content provided by scaffolds embedded in a QR-triggered, mobile design influence family observations and collaborative sense-making while learning-on-the-move?*

Methods

This research study took place at Shaver's Creek Environmental Center, a rural, outdoor learning center spanning over 7,000 acres of land. Shaver's Creek Environmental Center is home to a diverse environment, allowing families to explore both recreational and educational opportunities to observe nature, wildlife, and more. The design of our project focuses on two design conjectures that guided the development of our scaffolded learning materials, which build on our LOTM and observational conceptual framework:

1. Sensory engagement via tactile and visual observation of objects or specimens on-site can support scientific noticing.
2. Discussion prompts and place-based activities can support sense-making and knowledge integration via focusing conversation on scientific phenomena and big ideas.

Families in our study used an iPad™ with mobile internet access to scan four QR-triggered micro-learning sites (Figures 1a and 1b) to learn about a specific pollinator in this habitat, the solitary bee, and what these solitary bees need to survive. The QR codes used in our study provided web access to our mobile learning experiences across four micro-learning sites, focusing on solitary bees to highlight: (1) nectar for food and water, (2) nesting sites, (3) pollen as a food for young, and (4) diverse landscapes as healthy habitats. As families moved between the four micro-learning sites, they used the camera app on the tablet to scan the QR codes which triggered access to webpages that contained relevant information about solitary bees to help guide scientific observation and discussion prompts, focusing families' attention to key scientific phenomena as they moved throughout Shaver's Creek Environmental Center. Families interacted with images with 3-dimensional qualities (Figure 1c), read through relevant scientific text related to solitary bees (Figure 1d), and engaged in prompted scientific observation conversations (Figure 1e) while moving through the micro-learning sites.

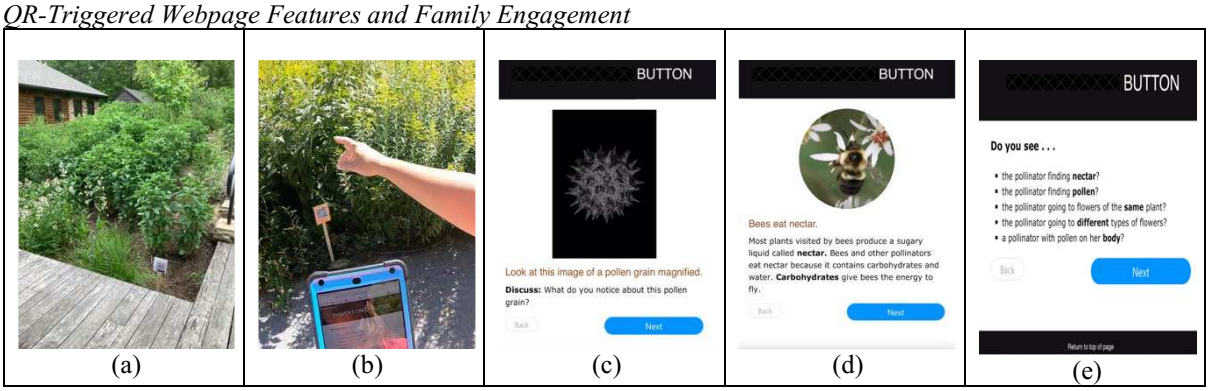
A total of 31 families (116 individuals; 54 adults, 62 youths) were recruited on-site by the research team. These families represent typical weekday and weekend visitors to Shaver's Creek Environmental Center. At least one child aged 5-12 and a parent or legal guardian was required per participating family. Written consent was obtained from each parent or legal guardian while children verbally assented to the study. Self-reported demographic data included the following adult gender and racial affiliations: 31% male, 44% female, 0% non-binary, 24% not reported, 0% Middle Eastern or North African, 4% Asian, and 11% not reported. Children demographic data was reported by the adult caregiver (42% male, 42% female, 0% non-binary, and 16% not reported) and these participants were primarily 5-12 years of age (3% ages 0-4, 87% ages 5-12, 10% ages 12 and up).

Primary data for this study consisted of video data from each family. At least one family member wore a GoPro™ mounted cap to capture video and audio data from the user's perspective while visiting the micro-learning sites. Video data were also collected from iPad™ screen recordings as users interacted with QR-triggered web pages. These videos were merged into a singular side-by-side video and transcribed professionally before being checked for accuracy again by the researchers. All family members presented in our analysis consented and assented that we could show their identifiable images in publications; however, we elected blurring their faces as an extra step in privacy for our participants.

This study presents two cases from the data set. Analysis techniques for this study included qualitative, interaction analysis (Jordan & Henderson, 1995) where interactions between family members and the environment, as well as the provided iPads and use of the provided QR code web-based content, were observed. Researchers analyzed families' interactions, activities, and discussions through co-viewing and discussions utilizing a binary (yes or no) blitz coding technique (Callanan, 2012) to review usability and interactions of the QR-triggered design. Analysis included observations of the roles in which family members took while LOTM, the types of interactions they engaged in across the micro-learning sites, and if they had engaged with the intended activity designed for each site. These co-viewing sessions and discussions amongst the research team helped in selecting cases. These cases modeled family's interactions as (1) families continued engaged observations and conversations across micro-learning sites and (2) families utilized QR code provided mobile content across micro-learning sites for new and unintended scientific conversations.

Figure 1

QR-Triggered Webpage Features and Family Engagement



(a) example QR-triggered micro-learning site, (b) family observations at a micro-learning site, (c) images with 3-dimensional qualities, (d) scientific informational text and graphics, and (e) scientific observational checklist.

Findings

Through qualitative, interaction analysis (Jordan & Henderson, 1995), the results from the 31 families showed that the QR-triggered mobile design supported families' ability to engage in meaningful sense-making about pollinators while interacting with ecological and biological content provided by the team's mobile web pages. From our blitz coding analysis, we found that families, on average, continued engaging in their observations and scientific conversations 30.5% of the time as they moved between micro-learning sites. Also, families visited our four micro-learning sites in 9 unique pathways of their own choosing. This value is of interest as families engaged with LOTM in unique ways. While many families chose to scan the QR-trigger closest to the data collection site, the next micro-learning site location they selected impacted the types of scientific observations and conversations they engaged in as they learned on-the-move.

From the interaction analysis, two main findings were identified: (1) the QR-triggered mobile design provided family members opportunities to continue scientific and observational discussions while moving between micro-learning sites and (2) families utilized content provided at previous stops as they made their scientific observations. Two vignettes highlighting families' experiences have been chosen to show the impact of our QR-triggered mobile design on families' sense-making while LOTM and their sensory engagement observations.

Vignette 1: Utilizing QR-triggered discussion prompts to continue while LOTM

While visiting the first micro-learning site, families were introduced to conceptual topics related to nectar, an important source of solitary bees' food and water supply as well as food for their young. During their experience

at this stop, Kathleen (mother), Douglas (father), Tony (12-year-old boy), Arthur (8-year-old boy), and Marie (5-year-old girl) worked together to learn about pollinators and the local milkweed as a source of nectar for carbohydrates (Figure 2). Both parents took turns reading aloud the QR-triggered mobile content, making connections to the text and images by pointing to plants like those that were displayed across the webpages (see Figure 3 for example webpage with provided mobile science content).

The vignette below begins as the father and two older siblings from the family moved quickly to the next micro-learning site, but Marie continued engaging with the provided content with her mother.

Marie (5-year-old):	Mom, so it just waves it's tongue out and then…
Kathleen (mother):	Yeah!
Marie:	And then it feels the flowers?
Kathleen:	Uh huh!
Marie:	For nectar?
Kathleen:	Yep!

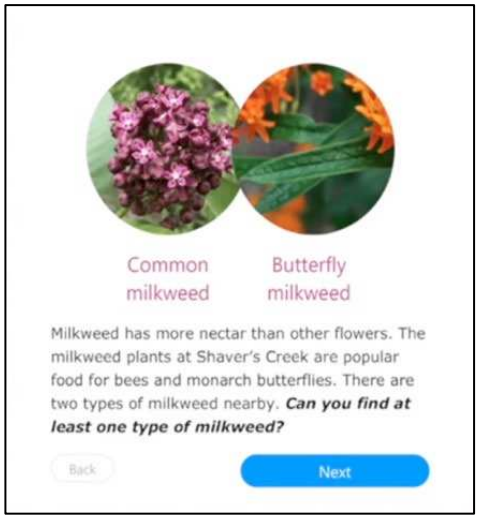
As they move towards the next micro-learning site, Kathleen continues to engage in conversation with Marie as she asks for clarification regarding the QR-triggered mobile discussion prompts and content. Marie continues to question some of the key takeaways from the content by continuing to ask questions that connect her understanding of nectar as a source of sustenance for pollinators while trying to understand the impact that a bee's proboscis has on reaching the nectar inside of flowers.

The experiences of this family highlight one way in which participants engaged with the QR-triggered mobile content to support meaningful scientific observation and conversation while LOTM. The QR-triggered content afforded Marie an opportunity to continue engaging in meaningful conversation with her mom, even as other family members had already moved to the next micro-learning site. In engaging in this conversation, Marie continues to review questions for her own understanding of how solitary bees may use their proboscis to collect nectar. As such, the QR-triggered mobile content helped support activities that led to the families' collaborative sense-making through continued conversation even while LOTM.

Figure 2

Kathleen (mother) and her Family scanning the Nectar Related QR code and Discussing their Observations.

Figure 3
Mobile Sscience Content Provided Via Scanning the Nectar Related QR Code Provided.



Vignette 2: Utilizing QR-triggered mobile content across micro-learning sites to conduct meaningful observations and engage in scientific discussions

As the activities at each micro-learning site were not required to be completed in any sequential order, families were observed reviewing science content across spaces while traveling to, and while being positioned at, micro-learning sites different from where the initial content that they viewed was intended (Figure 4). At the fourth micro-learning site, for example, families were presented with an observation checklist (Figure 1e) as they observed pollinators in a diverse habitat prompted by the QR-triggered mobile webpages. This observation checklist was initially designed to help scaffold conversations about pollinator activities and interactions with flowers during pollination. However, Wendy (an aunt) and her niece, Lindsey (a 12-year-old girl), used this checklist in a unique way when they realized that they had not yet visited all the micro-learning sites during their visit (Figure 5). This changed the types of pollinators and plants that they were able to observe as they kept the observation checklist open on a separate web tab for discussion as they moved to their final micro-learning site. Based on their choice of final micro learning site, Wendy and Lindsey engaged with content related to pollen, discussing how it sticks to bees and can be used for food for their young. During this micro learning site, families were also presented with mobile content which highlights the various spikes of a typical pollen grain. While this content was intended to be recalled via a brief discussion question at the end of the mobile webpage, Wendy and Lindsey instead engaged with this content in addition to the checklist provided at the previous stop leading to a rich and detailed discussion of the observed plants and pollinators. Wendy initially responds to the content Lindsey reads to her regarding the qualities of pollen that allow it to stick to pollinators.

Wendy (aunt): Oh, spiky. Yeah, that would be what's in these yellow ones ((points to flowers)), which are kind of starting to go too. And that's what's in those big flowers I planted at [my house]. They're really spiky pollens, if you noticed it. Okay, yeah. We saw plenty of bees. They're all over the golden rod… Look how many are over here, Lindsey.

Figure 4
Wendy (aunt) Connecting Observations about Pollen with Pollinators across Intended Micro-Learning Site Locations.

At this point, Lindsey clicks back to the webpage containing the observation checklist from the previous micro-learning site. This prompts the aunt and niece to discuss more about what they are seeing from the pollinators' behavior in the habitat, while incorporating their knowledge of pollen into the observations.

Lindsey (12-year-old): There's a wasp.

Wendy: I don't like a lot of bees… look how much pollen is on his little legs ((points)). He is so full of them. This is a honeybee. The pollinators going to the flowers of the same plant. Pollinators going to different type. Well, they're going to all of them, huh? And then there's one with, we saw her ((points)). She's got [pollen] all over her.

Figure 5
Wendy (aunt) and Lindsey (12-year-old) Reviewing the Provided Observation Cchecklist as They Make Observations of the Local Pollinators.

By completing the observation checklist after discussing pollen and engaging with the pollen grain, Wendy and Lindsey make observations based on sensory engagement that goes beyond the scientific noticing originally intended for the checklist. In this case, the family engages in discussion incorporating pollen into their observations of which plants the pollinators traveled to.

The family's interactions highlight another unique way in which families engaged with the QR-triggered mobile content as they moved across micro-learning sites to make their observations. By creating content that could be accessed via webpages, families were able to make deeper connections to science content and observations through more scientific noticing.

Discussion

While previous studies have shown that computer-supported collaborative learning can be an effective instructional tool to aid learners in their understanding of complex science principles in informal learning spaces (Yoon et al., 2017), our findings expand on the impact that scaffolded experiences can have as families engage in LOTM in outdoor learning settings. The importance of place and movement in LOTM (Marin et al., 2020) was highlighted through each families' experiences as they scanned each QR code and engaged with science content at each stop. In the first vignette, Marie was able to engage in meaningful conversation with her mother as afforded by the design of LOTM and the science content provided. By using QR codes that provided location specific content, we presumed that the types of observational conversations families would engage in would be fostered by the direct observations within the locations we specified through the placement of these QR triggers. However, the scaffolded nature of the QR-triggered design allowed for families to continue conversations across learning locations as they engaged in LOTM. Marie's conversation with her mother, Kathleen, highlighted how families utilized the provided content as they engaged in LOTM across the intended micro-learning sites. Previous studies have highlighted the power of mobility in LOTM as learners' meaning making processes are impacted (Marin et al., 2020); however, our work adds new insight as we observed families accessing prior knowledge and applying that knowledge across new spaces even though they moved from one micro-learning site to another. Additionally, these findings further expand on the concept of nomadic inquiry (Hsi, 2003), as families continued their engagement with the provided iPads™ to engage with web-based content across multiple, physical spaces, extending their inquiry beyond the intended spaces into spaces in-between. This extended inquiry transformed outdoor family time walking through a nature center into learning time as families stopped, observed, discussed, and moved through varying and diverse spaces to engage in scientific understanding. Marie was able to take part in discussion that reinforced her thinking and helped her to further understand the content that had been provided. Although other members of the family had already traveled to the next micro-learning site, the mobile webpage content allowed Marie and her mother to continue their conversation together as the two of them made their way to the next micro-learning site while continuing scientific discussions.

Our study showed strength in highlighting the practical implications of providing mobile content through scaffolded QR-triggered webpages for informal, outdoor learning settings. By providing scaffolds with QR-triggered science content, families could engage in unique observational activities that impacted their sensemaking and interactions within and across the learning space. For example, the experiences of Wendy and Lindsey in the second vignette highlight the impact that web-based mobile content can have on families' scientific conversations and observations as they can review content or checklists from previous micro-learning sites to expand upon the initially intended observational prompts provided. This may increase the level of sensory engagement and noticing families conduct, thus helping them to further transition towards observing more scientifically as they move away from everyday observations (Eberbach & Crowley, 2009).

Future work can continue expanding on the design conjectures of this study to provide scientific content to families in informal learning environments while focusing on fostering LOTM experiences through mobile content provided by QR codes. Future studies may expand upon a weakness of this study in exploring a wider variety of interactive learning items that may be provided through scaffolded, QR-triggered designs. Families' conversations exceeded expectations beyond what had been provided through our geolocation-based science content as families continued their observations and conversations as they engaged with LOTM, influencing the types of observations and discussions families had as they conversed between micro-learning sites. New features that expand upon those that were presented in this study may be easily implemented into a QR code-triggered design as web pages provide access for embedding and interacting with a multitude of multimedia tools. These expanded designs may shed light on the impact that QR-provided mobile learning can have on families' sensory engagement across space and time. Additionally, these studies may focus on elements that prompt the types of discussion observed in this study, influencing the types of observations and discussions families have as they continue scientific observations and conversations between micro-learning sites.

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