Using Augmented Reality (AR) to Bring the Past to Life in Informal Science Learning

Background

A key mission for science museums and science centers is to engage a large and diverse public audience in science learning (Macdonald, 1997). To that end, science museums attempt to present information in entertaining, socially oriented, and innovative ways. For instance, recent work makes use of immersive technologies in the museum experience (Radu, 2014). An example is the use of augmented reality (AR) technology that overlays virtual objects on to the real-world (Azuma, Baillot, Behringer, Feiner, Julier, & MacIntyre, 2001). This technology allows visitors the unique ability to interact with content that is both situated in the context of the exhibit and virtually generated in a way that allows hidden worlds to become visible (Salmi, Thuneberg, & Vainikainen, 2017; Wu, Lee, Chang, & Liang, 2013). AR can also be leveraged to allow interactivity with public exhibits that might otherwise be more passive experiences (e.g., outdoor features prior to entry).

Theoretical Framework

An advantage of using AR in informal learning spaces like museums is the ability to bring physical places alive with virtual additions to their setting. Researchers studying AR have combined GPS location awareness technology as a way to leverage technology to engage learners in the rich content places can offer (Dunleavy & Dede, 2014). This is an example of place-based education (Sobel, 2004), a pedagogy where curriculum or learning experiences are rooted in the communities and places that the learners populate daily. More broadly, place-based learning strives to deepen learners meaning-making through the design of activities that are within and about their communities (Smith, 2002; Sobel, 2004; Smith & Sobel, 2010). The combination of AR technology and place-based learning can be employed by museums as a way to connect visitors to their community. It can also offer transformative potential to resolve persistent science misconceptions, by creating effective conditions for both engagement and personalized interactions with science (Authors). The transformative potential of AR not only supports visitors' understanding of abstract science concepts but also long-term knowledge retention, group collaboration, and motivation (Radu, 2014).

Given the potential of AR technology in informal learning environments, the purpose of this study was to explore the utility of AR as an emerging vehicle for informal science learning and engagement. This project is situated at the La Brea Tar Pits and Museum (LBTP) a centrally located museum in one of the largest and most diverse cities in the United States (Los Angeles). The LBTP is a unique place where history, ongoing active science, and community merge on the grounds of a public park. Families gather for celebrations, dogs are walked by their owners, and other normal park activities occur daily alongside paleontologists who are actively excavating and processing fossils dating back thousands of years. On the same grounds resides a museum where those fossils are curated and transformed into exhibits about the history of LBTP. These factors make the LBTP an excellent place for an exploration into how place-based science pedagogy and AR technology can increase public understanding of science.

Methods and Data Sources

This NSF Funded collaborative project investigates two high-level design factors for mobile AR. Design Based Research (DBR) was used to iterate four design cycles for the AR technology and science learning content. In the first design iteration, AR was used to both extend and emphasize aspects of LBTP as a unique place for the purposes of learning (e.g., as per Zimmerman & Land, 2014). Along with iterations of the AR design features, we developed, tested, and refined measures of knowledge and engagement. We created multiple-choice instruments that measured two misconceptions specific to the LBTP: (1) animals fell into the tar, and (2) large animals fell into the tar pits on a regular basis. Along with content knowledge, we collected data on participants' engagement with the experience and their view of usability.

In Design Cycle #1, a sample of adult museum visitors (n=62) were recruited as they walked by to interact with the five-minute AR experience following a virtual mammoth through an initial encounter with a tar pit to its exhibit in the museum, while they listened to a narration about the scientific inquiry process (see Authors, 2021). In the second and third design iterations, a new AR exhibit designed based on the data from the first cycle was developed and tested in two iterations. In this version, 28 visitors in Design Cycle #2 and 40 museum employees in Design Cycle #3 watched a 10-minute AR experience where they virtually dig, discover, and identify fossils. Participants were surveyed and interviewed about their knowledge of the ecosystem of ice age Los Angeles (pre and post), their ease of use with the technology, any frustration or glitches with the technology, and their reactions to the experience (Venkatesh et al., 2003). Interview data were transcribed, and then open and axial coding revealed broader themes about the science at LBTP: (a) surprise as an initiator for hypothesis revision, and (b) deepening understanding of fossil evidence (Saldaña, 2013; see Table 1 for examples).

Here we report on the fourth design iteration where 240 adult visitors participated in a randomized controlled trial (RCT). The focus of this RCT was to test 6 conditions which compared two manipulation conditions (selection with physical tool versus phone touchscreen), two delivery conditions (headset versus handheld phone), and two control conditions (a typical museum informational poster present in both conditions that participants were either asked to read in Control Condition #1 or given no specific instruction to attend to in Control Condition #2).

Participants ranged from 18 to 70 years of age with a mean age of 37.79 years (*SD* = 14.17). Participants were mostly White or Caucasian; 141 (59%), 31 were Asian or Asian American (13%), 22 were Latinx or Hispanic (9%), 11 were Black or African American (5%), 4 were Native American, Alaska Native, or Pacific Islander (2%), 15 were multiracial (6%), 3 were another race or ethnicity (1%), and 13 did not share this information (5%). Eight participants (3%) were members of the Natural History Museums of Los Angeles County or the La Brea Tar Pits.

Results

To examine differences among the conditions, a one-way analysis of covariance (ANCOVA) was conducted to compare the posttest knowledge scores of participants across each of the six conditions while controlling for participants' pretest knowledge scores. We also collapsed across conditions and conducted a t-test comparing the percentage of items correct on the knowledge pretest ($M = 0.67$, $SD = 0.16$) and knowledge posttest ($M = 0.74$, $SD = 0.16$). This analysis showed significant gains from pre to post $t(239) = 7.30$, $p < 0.001$. The ANCOVA, however, revealed no significant effect of condition on posttest scores after controlling for pretest scores ($F(5,233) = 1.94$, $p > 0.05$). (See Table 2.)

Data collection was completed in July and analyses are still be conducted. Additional analysis of engagement data will be completed and included in the presentation should this proposal be accepted. In general, our results presented here highlight the promise of combining place-based science pedagogy with AR technology for supporting public understanding of science and deeper engagement with the places communities inhabit. While quantitative differences were not found among conditions in knowledge gained, significant learning gains were seen from pre to post, illustrating the potential for place-based informal science learning. Furthermore, incorporating AR technology into museum exhibits can update them with 21st learning tools to support visitor enjoyment in the learning experience.

Significance

The strategic impact of this project is in the empirical comparison of AR design choices for immersion and interactivity for visitors' engagement and understanding of science. The result of this study, once fully analyzed, could serve as a model for similar public exhibits, as well as design principles that generalize to AR experiences for a larger range of informal learning environments. This research contributes to understanding of usability and logistical issues for different AR designs for a public, outdoor informal setting.

Figure 1. Pilot Study of AR experience (Design 1)

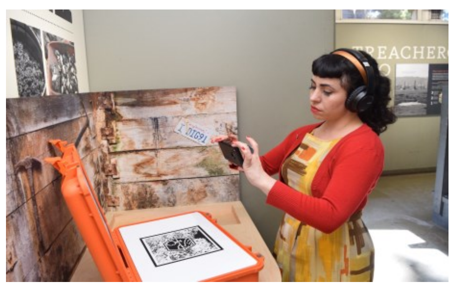

Figure 2. Participant Engages with AR Experience (Design 2)

Table 1: Evidence of learning about making hypotheses' about the past environment of La Brea

	Interview Excerpts
Surprise as an initiator for hypothesis revision	*I guess I expected it to have a look and feel more like a stereotypical ice age, but the fact that it was a lot wetter and had trees and fish was kind of a little surprising for me. I'm not a history buff. I should have known that going in.*
	I mean, what surprised me is that initially where it said this was the Ice Age and I thought, well duh, then it must be that this happened in the Ice Age and I pick Ice, and so I really learned something from this. I mean, it really had not occurred to me that during the Ice Age, the whole country wasn't covered with ice. I actually didn't know that. To find out that LA was wetter and colder, but a lot like it is now, was just fascinating to me. I don't know that just being told that would be meaningful, so I like it in the sense that it led me through that, through the process. I actually found out a very interesting way to learn,

	to think I've been here, I have Ice Age as an image in my head, but I honestly hadn't thought the fact that Ice Age differentiated across the U.S.
Deepening understanding of fossil evidence	*I think the idea that I started to learn more about how a fossil, discovering a fossil can influence my understanding of the environment. So I found out that, Oh, there's a fish, okay. So in the environment may not be so icy as I thought it was. There might've been some flowing water present. So I was able to reevaluate my hypothesis and choose something else that was more maybe more accurate to that time.*
	Yeah, so when I thought about ice age, I just thought about frozen things and cold and icy mountains. But then one of the fossils that I got was a fish, and then I learned if there was a fish fossil then there were streams and rivers. So that was really surprising, and it was cool to see how one bone really changed my thinking, and then see the change through the VR.

Table 2. Pre-and Post Test Knowledge Percent Correct by Condition in RCT

Condition	Number of Participants	Pre-Test Mean % Correct Score (SD)	Post-Test Mean % Correct Score (SD)
Control #1	30	0.658 (0.169)	0.759 (0.149)
Control #2	37	0.652 (0.176)	0.764 (0.158)
Manipulation Headset	42	0.676 (0.151)	0.706 (0.163)
Manipulation Phone	46	0.689 (0.172)	0.768 (0.175)
Selection Headset	40	0.631 (0.139)	0.732 (0.151)
Selection Phone	45	0.712 0.134)	0.737 (0.141)

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