AN ANALYSIS OF ENGAGEMENT IN A COMBINATION INDOOR/ OUTDOOR AUGMENTED REALITY EDUCATIONAL GAME

By

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ABSTRACT

This paper describes the results of a qualitative analysis of video captured during a dual indoor/outdoor Augmented Reality experience. Augmented Reality is the layering of virtual information on top of the physical world. This Augmented Reality experience asked students to interact with the San Diego Museum of Art and the Botanical Gardens in San Diego's Balboa Park. Pairs of students were videotaped as they progressed through the experience and the results of video analysis indicated that student engagement and collaboration was relatively high even though there were several technological difficulties – particularly present during the outdoor portion of the experience.

Keywords: Augmented Reality, Engagement, Story, Folktale, Learning.

INTRODUCTION

This paper is intended to describe videotape analysis of an Augmented Reality (AR) curriculum to determine the level of student engagement engendered by the experience. Augmented reality is defined as "games played in the real world with the support of digital devices (PDAs, cellphones) that create a fictional layer on top of the real world context" (Squire & Jan, 2007, p. 6). It has been identified in both the 2010 and 2011 Horizon's ReportsWork at Harvard, MIT and the University of Wisconsin has shown promise in exploring the academic impacts of AR, and have also started to explore the issues of engagement and student affect associated with AR curricula (see, for example, Klopfer,Yoon,& Perry, 2005; Squire & Jan, 2007; Klopfer & Squire, 2008; Dunleavy, Mitchell, & Dede, 2009; O'Shea, Mitchell, Johnston, & Dede, 2009; and O'Shea, Kaur, Amaechi, & Dede, under review). These initial efforts, however, depended upon instruments that were either leveraged from other fields or were developed internally to judge the engagement levels of students in the augmented reality gamespace.

The AR curricula designed at Harvard, MIT and the University of Wisconsin were placed in outdoor settings, and used GPS-enabled handheld computers. In these instances, students were presented with a map of their physical surroundings on the handheld device and as they moved around the physical space an avatar would move around the map. Their tasks revolved around finding and interacting with virtual characters and objects that were found on the map. Conversely, there have been indoor efforts at AR experiences that used some other means of triggering these events, such as RFID tags (see, for example, work by Papadimitriou, Komis, Tselios, & Avouris, 2006).

This paper will describe an AR curriculum that incorporates both indoor and outdoor elements. This educational experience takes place through the School in the Park (SITP), which "is an innovative program that shifts the location of 'school' from a traditional classroom setting in an inner-city school, to the resources and educational opportunities available at museums in Balboa Park. A relevant instructional environment is created as hands-on learning challenges students to become active participants in their own education" (School in the Park, 2009). Elementary students are brought from their home schools for eight weeks a semester to participate in educational experiences in the museums located in Balboa Park. The AR curriculum described in this paper took place in the San Diego Museum of Art (SDMA) and the Botanical Gardens.

The Crane Augmented Reality Curriculum

This AR experience was called The Crane, and was based on a Chinese Folktale called The Lord of the Cranes (Chen, 2000). In this folktale, a Chinese mystic decided to leave his mountaintop retreat and visit a village in the valley below. As part of his journey, he dressed as a street-beggar to learn how people would treat him. There was only one person who showed compassion to the beggar/mystic, an innkeeper who provided him with food and lodging. In response to the innkeeper's kindness, the mystic paints a magical mural of cranes on the wall of his restaurant. Whenever there was happiness in the restaurant (for example, clapping or laughter) the cranes in the mural would dance for the customers. This magical mural became very famous and drew large crowds to the restaurant, thus making the innkeeper very wealthy and famous. The mystic asked only that the innkeeper continue to show the same kindness and dignity to other people in return for his mural.

The indoor aspect of the AR experience asked students to interact with the museum's artifacts in order to prove themselves worthy of getting to the restaurant and seeing the dancing cranes. In order to do this, students selected one of four roles (a Traveler, a Potter, a Weaver, or an Emperor). Based on their role, they interacted with the artifacts differently. These interactions were triggered through QR codes (Figure 1) that were placed near the artifacts involved with the experience. Students would trigger the QR code with a QR reader on their cell phone (which ran the Google Android OS and were provided to the students for this experience), and based upon which role they had selected, they would be provided with a role-specific task to accomplish. For example, each student would be shown four images of items within the museum exhibit and be told to trigger the QR code next to the item that was must appropriate for their role (e.g. the Emperor role had to trigger a pair of decorative fingernail protectors while the traveler had to trigger a water flask). If they were unsuccessful, they would be asked to select again while successful completion of these tasks provided each student with clues to their next task. At the end, after successfully navigating through all of the tasks, they were granted access to a virtual restaurant where they could see the cranes dancing in the mural.

Figure 1. QR Code that Triggers the Beginning of the Indoor AR Portion

The outdoor aspect of the AR experience took place a couple days later and asked students to interact with the physical environment of the Botanical Garden, which is located right next door to the Museum of Art. In this case, the students would again select their role, although they did not have to take on the same role that they had for the indoor portion, and their task was to help plan a Chinese New Year celebration to take place at the innkeeper's restaurant (for example, the Weaver was asked to explore the surroundings to find inspiration for a gown that the Emperor had asked them to create for the ceremony). Students did this by interacting with virtual objects and characters through the Layar Augmented Reality app on their cell phone (Figure 2). The location and approximate distance to individual interactions was displayed on the device, and when used as a "viewfinder" the students would be able to see where they needed to go next as a virtual icon on the screen. Successful completion of each

Figure 2. Screen Shot of Layar Augmented Reality App at Botanical Gardens

individual task provided the students with clues to their next task, and at the end of the experience the students would see a video of a Chinese New Year celebration.

Methodology

In order to evaluate the engagement levels for students, evaluators shadowed several student pairings as they participated in the ARE (both indoor and outdoor) and videotaped these interactions. Researchers followed specific student parings in an effort to witness engagement throughout the entire Crane ARE. Additionally researchers randomly videotaped student pairings throughout the ARE experience (both indoor and outdoor).

A basic content analysis was then conducted on the entire video dataset (6,953 seconds). The videotape was analyzed using an a priori qualitative coding scheme that was originally developed through the Handheld Augmented Reality Project specifically for Augmented Reality implementations. This original coding scheme was adapted to align with this particular ARE project. Code adaptations were done through an iterative process including the modification of coding categories and coding descriptions. These modifications were done to provide a basic validation of the coding scheme or to show that more than one coder could use the coding scheme for measurement and get similar results.

Intercoder reliability

The goal of any content analysis is to record relatively objective (or at least intersubjective) characteristics of messages (Neuendorf, 2002). Given this goal it was essential to validate the coding scheme, establishing clarity surrounding its definitions, so that multiple coders identified the same messages within the videos being analyzed. As was stated above, the coding scheme was modified through an iterative process. Intercoder reliability was a driving force behind the code modification. Using the adapted coding scheme (see appendix A) acceptable intercoder reliability measures (Kappa values above .80) were achieved for all variables (codes) within our coding scheme. The coding scheme and the corresponding intercoder reliability measures have been included in Table 1. The full description of each of these codes, along with indicating actions can be found in Appendix A.

Code (variable)	Intercoder reliability (Kappa)
Technology issues (engagement)	.82
Technology (engagement)	.85
Curriculum issues (engagement)	.86
Collaboration (general)	.92
Non-collaborative (engagement)	.80
Disengagement	.93
Instructor Interactions	.95

Table 1. A priori coding scheme with corresponding intercoder reliability (Kappa) values

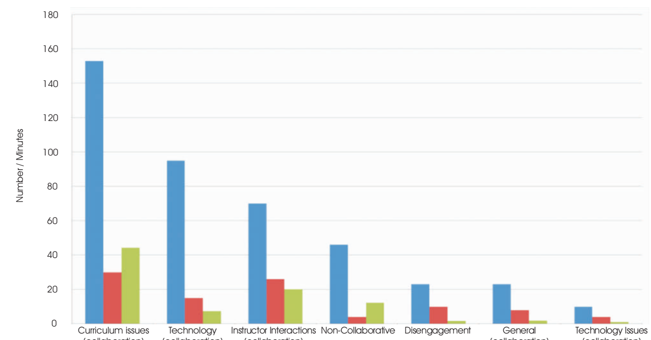
Findings

Coding was done using NVivo, which allowed for the exploration of the durations involved with each code. The following section will present data associated with the ARE implementation as a whole, and then data associated only with the outdoor and indoor portions of the ARE. As student pairings could, potentially, fall into more than one code at a time (for example, through performing actions that indicate both collaboration and engagement at the same time) or into no category at given times, the data will not add up to 100 percent of the available time.

ARE (all videos)

Overall we analyzed 6,514 minutes (one hour, 38 minutes, 34 seconds) of student activity in the Crane ARE. As a percentage of total video duration analyzed 71% of the video was shot indoors and 29% during the outdoor activity. This disparity, between indoor and outdoor video capture, was unintentional and is addressed in the analysis below.

Table 2 shows that the curriculum issues (collaboration) code was used most often (36 percent of the total coding references) and encapsulated the most time (41 percent of the overall video duration). This indicates that the



	Curriculum issues (collaboration)	Technology (collaboration)	Instructor Interactions (collaboration)	Non-Collaborative	Disengagement	General (collaboration)	Technology Issues (collaboration)
Coding references	153	95	70	46	23	23	10
Sources	30	15	26	4	10	8	4
Duration (Min.)	44.24	7.34	20.21	12.21	1.61	1.83	1.11

Table 2. Coding references, number of sources, and duration for the overall ARE (both indoor and outdoor)

students spent a considerable amount of time engaged collaboratively in solving curriculum issues will playing the Crane ARE. Furthermore, students were engaged with the technology, 23% of the overall codes were associated with technology (collaboration) indicating that the students were engaged and worked together with the technology. Although the technology seemed to be central in the experience (ranked second and referenced 95 times) the time students spent specifically engaging with the technology ranked forth (7.34 minutes), indicating that the students spent more time interacting with the curriculum (curriculum issues), instructors (instructor interactions), and engaged with the Crane ARE in non-collaborative ways (non-collaborative), such as watching videos.

Alternatively, relatively low percentages of the time indicated disengagement (1.61 minutes) and issues with the technology (1.11 minutes). It's important to point out that this particular ARE was designed to minimize competition, so it is not surprising that there would be very little action indicating this was taking place.

Indoor and outdoor ARE

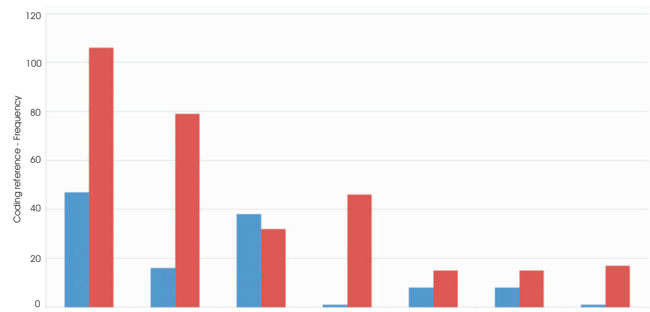
As is described above the indoor ARE was a somewhat different experience than the outdoor ARE. Therefore, the authors disaggregate the videos in this section and analyzed them separately in an attempt to understand the differences. There was considerably more video shot during the indoor ARE (76 minutes) than the outdoor ARE (32 minutes). This discrepancy occurred not out of design but from basic logistics of the researchers' availability and time *on site* to capture video. In order to make comparisons between the indoor and outdoor data two tables were generated. Table 3 compares raw coding references and Table 4 uses a weighted average based on the overall duration of video included for each separate ARE experience (indoor 76 minutes versus outdoor 32 minutes).

Table 1 indicates that students spent a considerable amount of time collaborating around curriculum issues in the indoor (106 references) versus the outdoor ARE (47 references). However, in the weighted comparison (Table 4) the coded references, normalized on duration, seem to be closer to equal. Continuing with these comparisons technology engagement was apparently greater during the indoor ARE experience, this difference is apparent even in the weighted scores (Table 4). This indicates that the students spent more time collaborating with the technology indoors than out.

Although the raw coded references indicate that instructor interactions were similar (Table 3), the weighted scores (Table 4) indicate that instructors provided more assistance and direction overall during the outdoor ARE. Furthermore, students' actions were coded as non-collaborative, walking with a purpose and watching videos, more during the indoor ARE experience. Technology issues, although relatively low, were coded as more frequent during the indoor ARE. Finally, both general collaboration and disengagement were overall relatively low and equal between the indoor and outdoor experience.

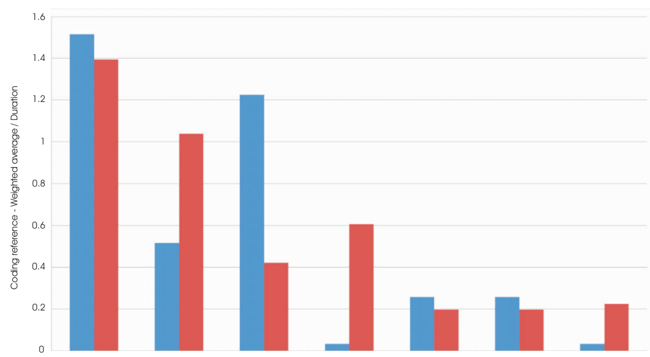
Analysis

Reflecting on the weighted scores, observed (coded) instructor interactions were proportionally higher, and technology collaboration was proportionally lower during



	Curriculum issues (collaboration)	Technology (collaboration)	Instructor Interactions (collaboration)	Non-Collaborative	Disengagement	General (collaboration)	Technology Issues (collaboration)
Outdoor	47	16	38	1	8	8	1
Indoor	106	79	32	46	15	15	17

Table 3. Coding references outdoors versus the indoors ARE experience



	Curriculum issues (collaboration)	Technology (collaboration)	Instructor Interactions (collaboration)	Non-Collaborative	Disengagement	General (collaboration)	Technology Issues (collaboration)
Outdoor	1.516129032	0.516129032	1.225806452	0.032258065	0.258064516	0.258064516	0.032258065
Indoor	1.394736842	1.039473684	0.421052632	0.605263158	0.197368421	0.197368421	0.223684211

Table 4. Weighted average by duration of video included outdoor versus the indoor ARE experience

the outdoor ARE. Observations shows that students confronted significantly more technology troubles when participating in the outdoor ARE and these troubles impact the types of instructor interactions that students had with teachers. While most of these interactions during the indoor ARE take the form of large group direction-giving, the interactions with teachers outdoors tended to be one-to-one and focused on technological issues. Furthermore, as is indicated, observed and coded technology issues were higher during the indoor ARE indicating that students also encountered technical issues indoors but were able to solve these issues alone without instructor interaction (see definition of technical issues for clarification).

Interesting, coded observations for non-collaborative activity was proportionally higher in the indoor ARE indicating that the experience required more individual actions, and disengagement was slightly higher during the outdoor ARE but less so than the researchers anticipated. Despite the technical issues encountered during the outdoor ARE on average the students spent equal time engaged with the curriculum with the outdoor ARE being slightly higher. This is encouraging, indicating that even though technical issues may be encountered students persisted and continued on with discussions and readings related to the academic content of the ARE.

There are several important findings from this analysis. First, the technology troubles that students confronted when participating in the outdoor ARE impacted the types of instructor interactions that students had with teachers. While most of the interactions during the indoor ARE took the form of large group direction-giving, the interactions with teachers outdoors tended to be one-to-one and focused on technological issues. It was observed that students became much more frustrated with the technology during the outdoor ARE, gave up because of the difficulties, and resorted to asking a teacher for help. This resulted in an increase in the frequency of *instructor interaction* coding. As well, and related, students interacting together to solve technology issues (coded as *technology issues*) or using the technology together went down considerably during the outdoor ARE. The researchers believe that this may be due to the fact that as frustrations with the technology increased students seemed to take less time troubleshooting the problems together and went directly to the teacher for assistance. Despite the technical difficulties encountered in the outdoor ARE, the weighted averages for collaboration around the curriculum (*curriculum issues* coding) were almost equal. This indicates that although students encountered technical issue they found help, persisted and engaged in the unique learning process. In a separate study, significant gains were established in a pre-test-post-test analysis indicating that students improved their overall comprehension and that their performance on the test measure improved, an indication of learning (O'Shea & Folkestad, 2010).

Stated simply, there were technological concerns with the outdoor ARE that were not necessarily seen in the indoor ARE. A series of informal "wrap-up" sessions with teachers and students indicated that these issues were well understood by the instructional staff, and mid-course corrections were taken to deal with these technical difficulties. Primarily these technical difficulties had to do with the layout of the Botanical Garden's structure and the scale at which the ARE was played. The Botanical Gardens are situated in a rectangular wooden lattice building, with entrances at the mid-point of the longest side. This meant that students had to enter the building in the middle and then progress to either end. Ideally, the triggering mechanisms in the Layar software would have activated the virtual elements of the ARE whenever a student entered a circular area around a GPS coordinate, however, the building's layout meant that the students would have had to walk through these triggering locations out of order. Figure 3 shows the dimensions and layout of the Botanical Gardens (white rectangle), and the arrangements of the

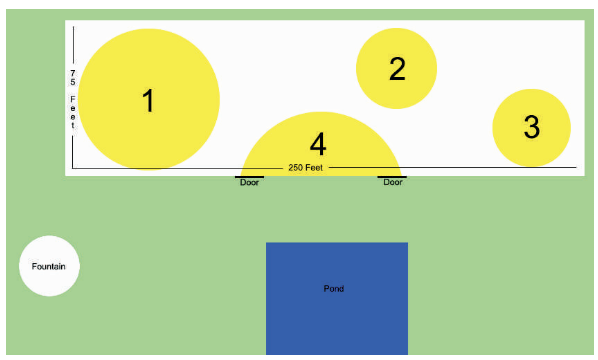


Figure 3. Triggering Map for ARE Events in the Botanical Gardens

triggering events (yellow circles). As can be seen, students would have to walk through the area for event number 4 to get to any of the earlier events. Since the Layar technology did not allow for these events to trigger each other in sequence (e.g. have event 1 provide access to event 2, etc), it was necessary to have all events available from the start of the ARE. Even if event 1 were located at the entrance to the building, the size of the circular areas around the GPS coordinates would have meant that students would have had to walk through events out of order. The linear triggering of the events would only have been possible if the entrances had been situated at either end of the building.

Secondly, the GPS accuracy on the devices was problematic based on the scale at which the ARE was played. The fact that the ARE was played within the Botanical Gardens constrained the event to an area approximately 300 by 200 feet large. At this scale, the GPS was not accurate enough to consistently provide reliable locations for individual triggering locations. After all, with a consistent GPS error of approximately 30 feet, the devices themselves could think they were actually outside the building, even though they were inside. This meant that events could be triggered outside of the Botanical Gardens rather than inside the structure. Playing the ARE with the same events but using a playing area double or triple the size would have minimized the impact of this GPS error.

Having explained these difficulties, it is important to remember that the level of engagement in the outdoor ARE was still very high. Although lower than that seen in indoor video, the analysis still showed very low levels of disengagement during both indoor and outdoor experiences.

Conclusion

In conclusion, the functionality of the ARE is highly dependent upon how the technology and curriculum interact. The video of students participating in the experiences indicated that the functionality of the indoor ARE worked more smoothly than the outdoor, but also showed that students were engaged in both settings and with the content. Also, the video indicated that students worked collaboratively, although efforts could be made to facilitate and make communication between partners more robust.

Aside from some pressing technological problems, which should mitigate as the technology becomes more robust and through curricular tweaking, the largest take away from this evaluation was the level of engagement; the researchers found that these kinds of experiences can be highly engaging for students and that commitment can provide benefits to the learner. Of course, the primary objective is to have the technology be engaging, not creating a significant hurdle that the students and teachers have to overcome, while having the students engaged in learning about their assigned topic. The results from this study indicate that even though technical difficulties were encountered, engagement with the curriculum was still very high.

In addition, the refined coding scheme itself and the established intercoder reliabilities are important outcomes of this study. In post study debriefings, the researchers acknowledge that these codes provide a significant foundation for future work and analysis. However, the codes may need to be modified and adapted based on context of the ARE under evaluation.

Looking ahead, the researchers believe that it is important to think strategically about the use of AREs. It is unclear how much of the obvious engagement is based on the inherent benefits of augmented reality and how much is based on the novelty of using GPS enabled handheld devices. This is a intriguing area for future longitudinal study. Having said that, however, the fact that the students are engaged with the content and that the entire SDMA/SITP curriculum is helping students to learn content(O'Shea & Folkestad, 2010) might indicate that an activity that engages students based on the novelty effect isn't necessarily a bad thing.

Appendix A – Engagement coding scheme

Technology issues (collaboration)

Indicate actions between students in an effort to overcome technical difficulties or to use the technology. Actions fitting this code include things such as:

- Two students talking about program not working, loading (code the duration of the discussion)

- Students asking other students for help (code the duration of the interaction)
- Students asking group members where things were on the handheld / game (code the duration of the interaction)

Technology (collaboration)

These are actions between students that indicated collaborative use of the technology

- Two students touching the handheld device at the same time (code the duration of the combined touch only)
- Two students passing the handheld device between one another (code 10 seconds only)
- One student touching or steadying the hand of the student holding the handheld device (cod the duration of the student-to-student contact)

Curriculum Issues (collaboration)

This would indicate actions between students to share or solve curriculum issues. Actions fitting this code include things such as:

- One student reading to the other student (code the duration of the reading only)
- One student point at an object within the curriculum – not pointing direction to move or go (code the duration of the pointing)
- One student asking a question about the curriculum (code the duration of the question and answer session
- Discussing what to do related to the curriculum (code the duration of the conversation)
- One student asking the other a question about what to write (code the duration of the question and answer session)

General (collaboration)

This would indicate actions between students to collaborate on other issues besides technology and curriculum. Actions fitting this code include things such as:

- One student pointing the direction to the next location (code the duration of the point only)
- One student pulling the other student by the shirt sleeve, or jacket to provide direction (code the duration of the pulling action only)
- A student taking leadership and directing other students (code the duration only)

Non-collaborative

This would indicate non collaborative actions demonstrating engagement with the content. Actions fitting this code include things such as:

- Walking with a purpose (code 10 seconds only)
- Watching the handheld device at the same time. (code the duration of the watching)

Disengagement

This would indicate actions by students demonstrating disinterest with the content or technology. Actions fitting this code would include:

- Student walking away from student with devise (code the duration of separation only)
- Student not listening to their partner or becoming distracted (code the duration of the separation only)
- Student attempting to distract partner (code the duration of action only)
- Students complaining about the activity (code the duration of the compliant only)
- Students making comments such as: "I'm so bored." (code the duration of the comments only)

Instructor Interaction (collaboration)

This would be present when the teacher or other instructional staff interacting with the students for educational or technical purposes. Actions fitting this code would include:

- Teacher giving instructions (code the duration)
- Teacher asks how group is doing (code the duration of the conversation)
- Students 'giving up' on the technology and asking an instructor for help (code the duration of the time until they get instructor assistance).

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