Exploring Student Engagement in an Augmented Reality Game

Nicolaas VanMeerten, University of Minnesota, vanm0034@umn.edu
Keisha Varma, University of Minnesota, keisha@umn.edu

Abstract: It has been argued that approaches to education should embed learning in activities that reflect the social and physical environments in which the knowledge is relevant. Over the past ten years it has become possible to situate learning in a variety of novel contexts using augmented reality (AR) games. This study investigates the behaviors of middle school students during their participation in an AR game called *Play the Past*. The findings of this study show that engagement differed during discrete activities in the game environment and that there was a relationship between the roles that students were assigned and their engagement.

Situated cognition and augmented reality

In order to study how individuals learn it is necessary to consider how they interact with an activity, environment, and social processes to affect learning outcomes. Researchers studying situated cognition claim that these factors are integral to the learning process (Brown, Collins, & Duguid, 1989), and have the capability to enhance or depress a person's ability to learn (Hendricks, 2001). Based on these studies, it is clear that education should embed learning in activities that reflect the real-world social and physical environments in which the knowledge is relevant. Today more than ever, it is possible to situate learning in meaningful ways by using new technologies, such as, augmented reality (AR) games. AR is defined as a view of the physical environment that has been enhanced by virtually overlaying information onto it that can apply to all senses (smell, touch, hearing, visual, etc). Thanks to these affordances, AR has the potential to significantly enhance learning environments, especially when combined with the engaging qualities of digital games.

Design principles for AR games

AR games make it possible to situate learning in a relevant and engaging environment, leverage social processes, and create engaging activities. For example, Dunleavy, Dede, and Mitchell (2009) created an AR game that allowed students to investigate the crash landing of an alien spacecraft, while learning a variety of math and science concepts. Although there were some caveats and limitations to the implementation of this game, students who went through this experience were highly engaged and wanted to learn more to solve the mystery. Klopfer, Perry, Squire, and Jan's (2005) study found that the types of roles that students took on in the AR environment affected their level of engagement. Specifically, they found that higher interdependence and interaction between distinct roles increased collaboration and engagement.

Recently, three additional design principles for learning in AR games were established by Dunleavy (2014). He established these principles in order to enhance the unique capabilities of AR and minimize the weaknesses of the technology. The first design principle offered by Dunleavy (2014), is that AR learning experiences should "enable and then challenge", which means that users in these environments should be acclimated to the experience and then challenged with more complex tasks. For example, in the AR game, Dino Dig (http://www. playfreshair.com/), players are given tasks of increasing complexity starting with navigating to a location, then gathering information, and finally completing a challenge or interacting with another player. Second, Dunleavy (2014) advocates for AR learning experiences to be, "driven by gamified story". For instance, *Alien Contact!* provides a compelling narrative, where "aliens have crash landed near the students' middle school", and the students must investigate why the aliens have come to their planet (O'Shea, Mitchell, Johnston, & Dede, 2009). Third, Dunleavy (2014) recommends that learning experiences in AR should allow the users to, "see the unseen", which is an inherent capability of AR, because information can be overlaid on the physical world. This design principle is exemplified by an exhibit at the *San Diego Zoo*, where students learn about the anatomical composition of animals at the zoo, through the virtual presentation of 3D models of the animals represented on the sign.

Current study

Play the Past guides students to explore history in an engaging and fun way while on a field trip to the Minnesota History Center. The game is divided up into three hubs (Sod House, Fur Trade, and Iron Mine), that are located within specific areas of the *Then Now Wow* exhibit where students must master different roles (Hunter, Clerk, Iron Miner, Farmer), and interact with other students to master tasks and complete levels.

The majority of the design principles mentioned above are stable across the hubs in *Play the Past*, including the need to scaffold the learning experience, the use of narrators as guides, and the AR game providing the user with the ability to "see the unseen" (Dunleavy, 2014). However, students take on very different types of roles in each of the hubs within *Play the Past* that promote different levels of interdependence and collaboration. The Sod House and Iron Mine are primarily single-player narrative games, where students interact with a narrator to complete different tasks that were relevant to someone living in that historic scenario. The Fur Trade is the only multi-player game that requires interdependence and collaboration between students, because each student is assigned to one of two distinct roles (Clerk or Hunter) that must trade goods with each other to complete the hub.

Hypothesis 1. Based on the design principle proposed by Klopfer and colleagues (2005), we hypothesize that students will be more engaged with the Fur Trade, than the Iron Mine or the Sod House.

Each of the distinct roles (Hunter or Clerk) that students are assigned to within the Fur Trade also vary in difficulty. This will allow us to compare and contrast engagement levels across two different difficulty scales, and investigate this design principle in detail proposed by multiple studies in the past (Klopfer & Squire, 2008; Dunleavy, 2014).

Hypothesis 2. Thus, we hypothesize that students who are assigned to be a hunter will have a higher level of engagement with the game than students who are assigned to be clerks, because of the difference in the level of difficulty between the two roles.

Methods

This study investigates the behaviors of middle school students during their participation in an AR game called *Play the Past*. The study primarily employs an observational design to draw inferences about how subjects are affected by exposure to an environment or intervention (Carlson & Morrison, 2009).

The sample for this study consists of 7,129 4th to 6th grade students from 95 urban elementary schools in the upper Midwest. These students participated in *Play the Past* between September 1, 2014 and June 3, 2015.

AR environment

Play the Past is embedded in the Minnesota History Center's *Then Now* Wow exhibit, which is focused on several different periods of Minnesota history. It is divided up into hubs (Sod House, Fur Trade, and Iron Mine), that are located within specific areas of the exhibit, where students must master different roles (Hunter, Clerk, Iron Miner, Farmer) and tasks to complete levels. Each hub includes QR (Quick Response) codes on artifact surfaces, which students scan with their iPods (Figure 1) to progress through levels in each hub. The *Play the Past* application collected data from each student through their iPod. All data was sent to a secure Structured Query Language (SQL) database.

Figure 1. Image of a student scanning a QR code in the Fur Trade.

Procedure

All of the students who participated in *Play the Past* were on a field trip at the Minnesota History Center with their class. Each class included between ten and forty students. Students spent 38.3 (SD = 7.17) minutes in the game. During their participation, students had access to peers, chaperones, teachers, and staff for help navigating the simulated environment. Upon arrival at the museum, students were introduced to the iPod and how to use it to participate in the game. Afterwards, students were allowed to explore and complete the different hubs and levels as they pleased.

In the Fur Trade hub, students are challenged to help Monsomanain an Ojibwe hunter to gather beaver pelts that they can trade for goods, or John Sayer a company clerk that must make a profit off of trading their

goods for beaver pelts. Once students are assigned roles and have gathered their supplies they negotiate trades with each other. Once a pair has negotiated and agreed on a trade both parties must confirm the trade of goods through the game. The Fur Trade hub is divided into two levels that are described in detail below:

Level 1: Students are assigned different roles where they help a hunter or a store clerk. In order to complete the first level, students helping the hunter must "trap" eight beaver pelts by scanning QR codes on beaver floor tiles to prepare for trading. Students helping the clerk must use ten beaver pelts provided on credit from the Fur Company in Montreal to stock their store. These are independent tasks that do not require collaboration between students.

Level 2: Students use the goods they obtained in Level 1 to trade with each other - negotiating their trades in real time using their iPods. Hunters complete Level 2 by successfully negotiating fur trades for at least five European goods. Clerks finish Level 2 by successfully completing fur trades for at least 15 beaver pelts, which results in a profit of five beaver pelts.

Results

Hypothesis 1. Levels of engagement

To determine whether students were equally engaged with each of the hubs in *Play the Past*, we computed completion rates for Level 2 in each hub (Table 1). We hypothesized that the Fur Trade would have the highest level of engagement, because it has roles that promote positive interdependence, collaboration, and individual accountability. Based on this data visualization it is clear that students were more engaged with the Sod House and Iron Mine, but did not fully engage with the Fur Trade hub, which provides evidence against the hypothesis. However, this trend is not present at earlier levels in each hub (Start, Level 1), which means that students have similar levels of engagement across hubs until they reach Level 2.

Table 1. Table of student completion numbers across levels and hubs in Play the Past

	Fur Trade	**Iron Mine**	**Sod House**
Start	6,640	6,968	6,840
Level One	5,772	5,751	5,453
Level Two	3,049	3,916	4,248

Hypothesis 2. Effect of role on engagement

We were able to examine how student roles (Clerk and Hunter) affected engagement levels by further analyzing student behaviors in the Fur Trade hub. Among the 5,772 students who completed Level 1, 3,038 students were assigned to be hunters and 2,734 students were clerks, which is a significantly smaller number of clerks (χ^2 = 16.01, df = 1, p = <.001). Unfortunately, this trend continues where only 1,208 clerks complete Level 2 in comparison to 1,842 hunters (χ^2 = 131.78, df = 1, p = <.001). These findings suggest that there may be an imbalance in the design of the game between roles.

To investigate this trend further, we focused on specific behaviors of students in the Fur Trade. In particular, we focused on their interactions with the trading mechanic. This is the core activity that students must use to complete Level 2. To operationalize trading efficacy, we calculated a trade ratio for each student to reflect their skill at negotiating trades. For example, if a hunter paid 1 beaver pelt for an item that was worth three beaver pelts, the hunter would receive a trade ratio score of 3 for this trade. In contrast, if a clerk were to sell an item that was worth 4 beaver pelts for 1 beaver pelt, they would receive a score of ¼ for this trade. An average of the trade ratio scores was calculated for each player and used as a reflection of their trading skill in the analysis below.

A mixed-effects logistic regression was used to explore the relationship between role, trade ratio, and Level 2 completion rate. There was a significant interaction effect in Model C between Role and Trade Ratio when predicting completion of the levels within the Fur Trade, because Model C had the lowest corrected Akaike Information Criterion (AICc) in comparison to Model A and B (*AICc*: A = 6,301.45, *AICc*: B = 6,025.26, *AICc*: C = 5,968.04). To help interpret these findings, we plotted the predicted probability of completing Level 2 of the Fur Trade (Figure 2). This figure shows that the largest discrepancy in probability of Level 2 completion occurs when students have an average trade ratio between 0 and 2, which results in clerks having roughly 15% lower probability of Level 2 completion than hunters.

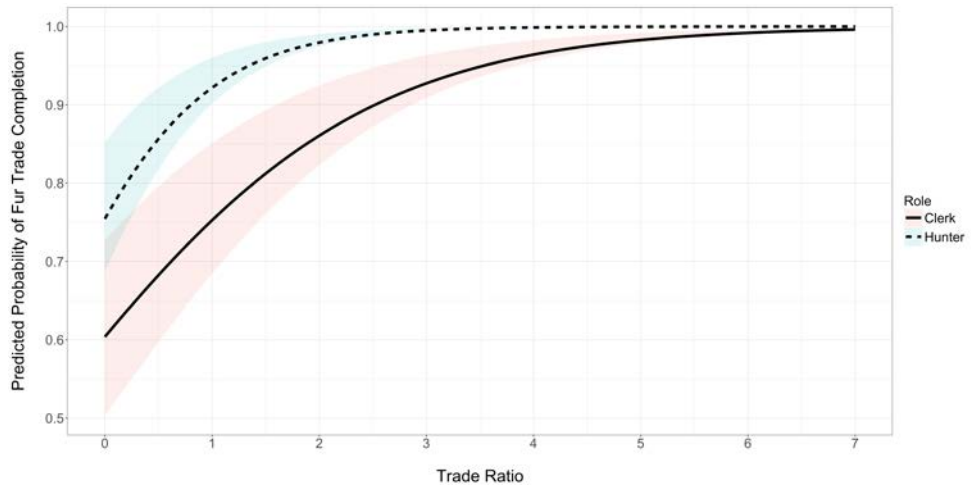

Figure 2. Predicted probability of fur trade completion based on trade ratio by role in *Play the Past*.

Discussion

Based on the findings of this study, it is clear that engagement levels differed between the hubs and levels in *Play the Past*. Students were more engaged with the Iron Mine and Sod House hubs, despite the Fur Trade's design to that had distinct roles that promoted positive interdependence and collaboration. Additionally, our results suggest that the design of the roles employed in the Fur Trade (Clerk and Hunter) do not pose equally difficult challenges. Specifically, the students assigned to be a clerk must trade at a much higher profit margin than students who are assigned to be a hunter, which may impede them from finishing Level 2 or encourage them to quit the Fur Trade and move to the Sod House or Iron Mine. Conversely, students who were assigned the role of hunter, were more likely to complete the Fur Trade than students who were assigned to be clerks. Based on this trend, it is clear that students who had distinct roles were not equally engaged in the game, despite the roles being designed to support collaborative learning by promoting positive interdependence and collaboration, as suggested by Klopfer and colleagues (2005). In addition, these findings suggest that the inclusion of interdependent roles may interact with other game design elements, such as difficulty in ways that are not beneficial to the student experience, and impede collaborative learning within the environment.

Although the findings presented here are rigorous and thorough, there are several limitations. Due to an unfortunate limit on the data that could be collected, there is no information regarding the individual students age, gender, or socioeconomic status. Additionally, conclusions drawn from this work should be modest, because of the use of only telemetry data for this study.

References

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational researcher*, *18*(1), 32-42.

Carlson, M. D., & Morrison, R. S. (2009). Study design, precision, and validity in observational studies. *Journal of palliative medicine*, *12*(1), 77-82.

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of Science Education and Technology*, *18*(1), 7-22.

Hendricks, C. C. (2001). Teaching causal reasoning through cognitive apprenticeship: What are results from situated learning?. *The Journal of Educational Research*, *94*(5), 302-311.

Klopfer, E., Perry, J., Squire, K., & Jan, M. F. (2005, May). Collaborative learning through augmented reality role playing. In *Proceedings of The 2005 Conference on Computer Support for Collaborative Learning: learning 2005: The next 10 years!* (pp. 311-315). International Society of the Learning Sciences.

Klopfer, E., & Squire, K. (2008). Environmental Detectives—the development of an augmented reality platform for environmental simulations. *Educational Technology Research and Development*, *56*(2), 203-228.

O'Shea, P., Mitchell, R., Johnston, C., & Dede, C. (2009). Lessons learned about designing augmented realities. *International Journal of Gaming and Computer-Mediated Simulations (IJGCMS)*, *1*(1), 1-15.