Analyzing the Effects of a Culturally Relevant Augmented Reality Math Board Game on Lakota Students’ Arithmetic Performances: A Case Study

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Abstract

This study aims to explore the affordances of augmented reality and game-based learning in training students’ arithmetic fluency and adaptive number knowledge. Math is a highly challenging subject due to its abstract nature, a lot of efforts have been devoted to look for better approaches to math education (U.S. G.P.O., 2005). Game-based learning is promoted as an effective alternative to traditional classroom math teaching (Devlin, 2011). Educational games can better engage and motivate students through situated contexts, storytelling, animation, and reward systems; they can provide cognitive apprenticeship through immediate feedback and scaffolds (Gee, 2004; Whitton, 2014). Despite the popularity of game-based learning, the implementation of augmented reality in math educational games has seldom been explored in game-based learning literature. In this study, A culturally relevant augmented reality math board game, the Nomads, is designed and developed through Unity game engine. The game combines the benefits of both digital games and table top games, making the learning experience engaging, immersive, embodied, and social at the same time. A case study will be conducted to investigate the effects of the game on students’ arithmetic fluency and adaptive number knowledge. Furthermore, the rich qualitative data from video recordings and interviews will be analyzed to better understand the affordances of the augmented reality features and game features.

Introduction

Math is a challenging subject for a lot of students due to its abstract nature and lack of practical correlation (U.S. G.P.O., 2005). Educational games are especially effective at tackling this problem – the multimodal feedback provided in game-based learning can adeptly translate the abstract concepts in math into more situated, embodied, and relatable formats (Devlin, 2011).

Game-based learning has garnered a great deal of attention in recent decades. Researchers have investigated both the affordances and limitations of implementing educational games within formal and informal learning settings (Gee, 2004; Jabbar & Felicia, 2015; Read, 2015; Smith, Blackmore, & Nesbitt, 2015; Whitton, 2014). Educational games can better engage and motivate students through well designed game mechanics and absorbing storytelling (Whitton, 2014). Some other affordances of game-based learning include features that provide immediate feedback and scaffolds, systems that reward failure and exploration, simulations that offer cognitive apprenticeship (Gee, 2004; Whitton, 2014).

Augmented reality is an umbrella term that defines a series of technological innovations that superimpose computer-generated content over real-world entities (Azuma, 1997). Research shows that augmented reality technology can increase learner motivation, engagement, and understanding of the content; it can facilitate 21st century learning skills by promoting collaborative learning, self-learning, and situated learning; furthermore, it and facilitate the understanding of abstract concepts (Wang, Callaghan, Bernhardt, White, & Peña-Rios, 2017).
Despite the popularity of research in both game-based learning and augmented reality, the implementation of augmented reality in game-based learning is rarely explored (Tobar, Baldiris & Fabregat, 2017). Furthermore, there is a lack of conversation in culturally relevant pedagogy in game-based learning literature. Culturally relevant pedagogy has been proven to be effective among students of all racial and cultural backgrounds (Ladson-Billings, 1994). It is especially concerned with helping culturally diverse students excel in education (Castagno & Brayboy, 2008). Gay (2010) proposes that culturally relevant pedagogy can empower students and enable them to translate it into personal confidence, courage, will to act, and academic performance. It can validate and affirm their identities by acknowledging their diverse cultural heritages.

In this study, a culturally relevant augmented reality math board game, the Nomads, is designed and developed. The game combines the benefits of both digital games and table top games, making the play experience entertaining, embodied, and social at the same time. In the game, players can practice the knowledge and skills needed to be proficient in arithmetic fluency and adaptive number knowledge. The stimulating multisensory experience enabled by the augmented reality technology can create a highly engaging and immersive learning experience for the players. The scaffolding and adaptive features built into the game allow the players to progress at their own pace, which can help alleviate the cognitive loads and anxiety commonly associated with problem-solving in mathematics. Moreover, the game can cultivate students’ 21st century learning skills by training students’ capacities in collaboration, critical thinking, and communication. Although augmented by mobile technology, the game is rooted in the physical world because students need to constantly communicate and collaborate with each other in the gameplay.

To play the game, players assume the role of a tribal leader who is responsible for leading their people through the mountains, plains, and desserts by collecting resources along the way. The players need to use arithmetic and adaptive number knowledge to solve the puzzles in the game as they travel across the land. They will also need to collaborate with players of the same tribe to conduct trading and bartering with players of different tribes.

Each player requires access to a smartphone or tablet, the 2D game board, and a game token. The game token will be augmented into 3D and dynamic models once the players view it through the mobile device’s front facing camera. The cards they collect during gameplay will also be displayed via the augmented game features.

Sequences of QR codes are printed on the squares of the map. At each turn, players are to scan the QR code on the square of their destination, which will allow them to either collect resources or play a mini cognitive training game. Points collected in those mini games can later be used as currency to exchange for goods. The game is situated within a fantasy nomadic culture. Figure 1 shows the game interface. The game can also automatically generate a computer opponent so that a student can play it by him- or herself. There will also be a standalone app version of the game in which no physical board is needed.

Two research questions are investigated in this study:

1. How does a culturally relevant augmented reality math board game affect Lakota 3rd to 7th graders’ arithmetic fluency and adaptive number knowledge?
2. How do the augmented reality features and the game mechanics of the board game affect Lakota students’ play and learning experience in the game?

![Game Interface](image)

**Figure 1. Game Interface**

**Research Method**

This research is framed as a case study. Several conditions in this research comply with Yin’s (2018) proposal of a case study research. First of all, the two main research questions are explanatory “how” questions that deal with the tracing of operational processes over time. Secondly, the case of the study is a multiplayer board game. It is hard to control or manipulate the behaviors of the participants in such a setting, researchers have to rely heavily on direct observation and video recordings. An explorative approach needs to be implemented to better understand the multi-layered effects of the board game on the participants. Thirdly, the researcher needs to collect data from several different sources – direct observation, pre- and post-game tests, surveys, and video recordings. Finally, the research design of the study is inherently informed by the theoretical propositions in this study. An observational approach is commonly used to study phenomena within the theoretical frameworks of collaborative learning and situated learning.

**Participants**

The study will be conducted at a math and culture summer camp at Pine Ridge Reservation, South Dakota. Thirty-five Lakota students from grade 3 to 7 will be sampled to participate in the study. All the students are currently living at Pine Ridge reservation, and they are consistently exposed to the traditional Lakota way of life through folklores, schools’ language classes, elders’ teachings, and communal activities like sun dance and powwow gatherings. The participants’ shared prior knowledge, the frames of reference, and analogies are believed to be highly beneficial in the collaborative learning process of the gameplay (Dunbar, 1997).

It is worth pointing out that most of the participants live a westernized lifestyle within individual properties with a nuclear or expanded family. Their daily experience is not much different from a standard student in the rest of America and they receive an education that is centered around western culture. This culturally situated board game aims to reenact the embodied and communal practice of learning in traditional Lakota culture. The game features a special learning process in which different age/grade groups are encouraged to help each other out to solve problems, which further justifies the relatively wide age group of the participants selected for the study.

**Procedure**
A pre-test is to be administered for all the participants before the gameplay. The participants are to be separated into two groups. One group will play only the physical board game and one group will play the augmented reality version of the game.

At each session, 2-3 participants will be randomly selected from the sample to play the board game. First of all, the researcher will explain the basic game rules to the players. The researcher will also facilitate the game in the process. Each group will play for 1 hour and their actions will be recorded by a video camera. In the process, the researcher will assume the role of facilitator and instructor, guiding them forward in the gameplay and helping them if they get stuck. After the game, the participants will take post-tests and conduct survey questionnaires about their game experience. Focus group interviews will also be conducted to further investigate participants’ play and learning experience.

**Results**

At this point, only observational data from the video recording from a pilot study is available for analysis. The study actual will start on July 12th this year. The data from the pilot study showed that the culturally situated game elements did provide the participants with a lot of interests, familiarity, and ease while playing the game. Once participants familiarized themselves with the game rules and started to enjoy the game itself, they started to engage in culturally relevant casual conversations. For example, some participants would give their teammates orders for fun such as “Feed your tribe!”, “NO! You forgot to feed your tribe, they are gonna starve!”, “I need more berries, go pick up more berries at the Black Hills.” Some of them even created their own narratives and storytelling of the gameplay and built upon the character of their choice by integrating their own personalities. One girl portrayed the character of her choice as a bossy and assertive leader who liked to order the men of her tribe around. After the gameplay, quite a few participants expressed to the researcher how much they have enjoyed the game, “You made learning math fun!”, as one of the participants claimed.

The video data also provided some insights into how students navigated themselves within the gameplay. Although the basic rules of the board game were provided before the gameplay, demonstrations and instructions were still needed for the first several rounds before the players could play the game themselves. Since the game mechanics are closely tied to the conduction of arithmetic calculation, students with better arithmetic skills tended to perform better than the others. Those participants also learned to navigate the game rules faster than their peers, possibly because they might have more cognitive resources to spare to learn the game rules aside from conducting the calculation.

The video data and observational field notes also confirmed the theoretical propositions in game-based learning research (Devlin, 2011; Gee, 2004; Whitton, 2014). It can be observed from the video that participants expressed a great deal of interest in the game mechanic, artifacts, and cultural context of the board game, which contributed to their continued engagement in the gameplay. Participants also found the abstract mathematical procedures more meaningful within the culturally situated context of the board game, the cultural elements also encouraged them to participate in narrative and character creation activities.

It is also observed that a lot of the participants still rely on the physical scaffolds (game pieces and fingers) to interpret the symbolic system used in arithmetic. However, improvements can be observed in the game process as participants get more adept and efficient at the exchange procedures. It is worth investigating how the improvements take place and if the results are maintainable and transferable to math skills in the long run.
References


