

The Island of Pi – Facilitating Math Learning through a Virtual-Reality-Based Game Intervention

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Abstract: This study is part of an ongoing design-based research project to investigate whether an OpenSim-based virtual-reality game can promote the learning of fractions and proportions for 5th graders. In this study, the game prototype was tested with pre-service teachers and math students to investigate its usability, playability, and learning integration. An adventure-themed storyline was created on a virtual world named as the *Island of Pi*, and the game-based intervention was carefully designed into three learning-by-making tasks with increasing difficulties. Data were collected via video recording, infield observation, experience survey, and interview. Findings of this study should inform designers and researchers on the design of game tasks and mechanics that reinforce content learning.

Introduction

Constructionists believe that learning is a process of knowledge construction, and effective learning happens when people actively make meaningful products in the real world (Papert & Harel, 1991). According to the situated cognition theory, learning should be integrated with activity, context, and culture: learners practice in a community, engage themselves, and acquire behaviors (Lave & Wenger, 1990).

Virtual-reality-based games have been applied to facilitate learning in different subject areas. Barkand and Kush (2009), and Vogel, Greenwood-Ericksen, Cannon-Bowers, and Bowers (2006) asserted that game-based learning environments possess pedagogical advantage by fostering motivation via play, interactivity, and challenge. When people play, they are likely to spend more time and efforts, which may lead to increased learning. The level of interactivity between the user and the game determines the depth of user involvement in the activity, and appropriate level of challenge encourages students to make attempts and motivates them to a higher level of learning (Vogel et al., 2006).

This exploratory study, as part of a design-based research project on the learning effectiveness of the virtual-reality-based math game, investigated the usability, playability, and learning integration of the game prototype for the math learning of 5th graders. Specifically, our research questions are: (1) How do users interact with the design features of the Island of Pi? and (2) How do they perceive their play and learning experience on the Island of Pi?

Intervention

We create an OpenSim-based, immersive 3D game environment, the Island of Pi (π), for 5th graders. It consists of three scenarios embedded in an adventure-themed storyline. Our goal is to help learners develop conceptual understanding and acquire calculation skills of fractions and proportions through artifact making and problem solving.

On the Island of π , Wizard Lin predicts that the island will vanish in a disaster. It is the learners' mission to seek help from the outside world and assist islanders to escape from the island by completing tasks. These tasks require increasing levels of conceptual understanding and mathematical calculations. The first scenario is paper-making, where learners calculate the right amount of paper-making ingredients to make right types of paper in order to send out a help message. The second scenario requires firework-powder making. Wizard Lin assists learners to find firework powder ingredients and calculate proportions of those ingredients so as to make and set off fireworks as SOS signals. In the third scenario – an underwater world, the ultimate task is to build an ark. Learners need to follow clues to collect wood pieces in different sizes and build the ark based on the instructions that contain fraction and proportion calculation. To make the tasks intriguing and entertaining, learners earn OpenSim dollars during game play and use them to unlock next puzzle.

Research Design

This study adopted expert review and user-testing methods to investigate the usability, playability, and learning integration of the game prototype for the math learning of 5th graders. Seven participants, comprised of 5 undergraduate and 2 graduate students majoring in math education or mathematics, aged 20-25, including 5 males and 2 females, participated in the study. They were given basic instructions on how to operate their avatars in

the OpenSim world prior to the usability test. The participants' game-play performance was observed and screen recorded. After completing all three game tasks, the participants completed a usability survey and answered semi-structured interview questions on their game play experiences and perceptions. A qualitative thematic analysis was conducted with the data collected.

Findings

The results indicated that users found the scenarios engaging and the interventions instructive. The users had opportunities to develop knowledge and apply what they have learned during game play. Feedback regarding possible improvement for game design highlighted the following aspects:

1. How to maintain engagement during the intervention

Majority of the users reported that the embedded learning content in the first scenario was overly challenging for the target learners, which exerted extra intrinsic cognitive load on the users, disrupted their engagement, made some of them rush through the task without effortful thinking. Segmenting the content into small chunks and sub-tasks may be helpful. A balanced arrangement of learning load across the three game tasks is critical. Some users felt frustrated navigating the virtual world during the treasure-hunting activity. Thus clearer clues and more scaffolding should be provided.

2. How to balance/incorporate learning and game playing parts

Content-specific learning should be better integrated into each and every major game action. For example, a lesson learned is to integrate purposeful fraction learning into treasure hunting by asking learners to locate treasures via fraction-embedded coordinates in the map, which should also reduce the time spent on random exploration in the virtual world.

3. Whether the difficulty level of content knowledge fits learners' ability level

The users were concerned about whether a diverse group of target learners would acquire knowledge for each game task. Thus they suggested the adoption of multiple versions of scaffolding or game-play instructions to be learner-adaptive. For example, during ark making, math disadvantaged learners could use more visual and verbal aids (e.g., 2D sketches as well as the 3D models, a composite of mini steps, number line as a visual guide) when performing fraction calculations to build each side of the ark. Another frequently mentioned suggestion is to use mathematical terminologies accurately and consistently for the target audience.

4. Content sequencing and presentation

The data indicated that the sequencing of the learning content should be well aligned with the storyline development of the three game tasks. Specifically, the artifact-making task in a new scenario should build on and activate the knowledge learned in previous tasks. At the micro level, users suggested that the presentation of math calculation in cut-screens or media boards should use animated visuals or visual cues to highlight the flow among major and mini steps.

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