Reaffirming the Critical Role of Transformative Research and Knowledge Production in the Age of Post-Truth

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A Developmental Study on Video Games in Helping to Educate and Improve Learning Capabilities of Students in Mathematics

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Abstract: Analyzing the positive impact of mathematical video games is a multifaceted process that extends beyond mere observation of students' gameplay. This research delved into a comprehensive exploration of requirements, objectives, target audience, and specific considerations pertaining to mathematics education. Employing a three-phase methodology, the study aimed to develop an interactive educational video game specifically tailored for mathematics learning. During Phase 1, an extensive analysis of existing educational games and relevant literature was conducted to identify the key factors necessary for designing effective and engaging educational video games. Drawing insights from Phase 1, Phase 2 focused on designing the video game module, incorporating feedback from experts in video game development and mathematics education. The design process encompassed careful consideration of game mechanics, instructional approaches, and design elements that align with effective mathematics learning. Phase 3 involved rigorous testing and evaluation of the video game module by experts and playtesters. Their invaluable feedback and insights contributed to iterative refinements of the game mechanics, design, and instructional approach. Challenges identified during testing were addressed to enhance the game's effectiveness in facilitating mathematics education. This developmental study provides valuable insights into harnessing the potential of video games for mathematics education, with particular emphasis on students' motivation, engagement, and persistence. The findings contribute to a deeper understanding of how video games can augment learning capabilities in mathematics. The outcomes have noteworthy implications for the development and implementation of educational video games, fostering positive learning experiences and promoting students' proficiency in mathematics.

Keywords: mathematical video games; education; engagement; learning capabilities; mathematics proficiency

1. INTRODUCTION

Videogames are now a staple in the entertainment industry, especially for growing children (Smith, 2016). While game developers and educators alike create games dedicated to educating the player base it is quite rare that these developers use platforms that are already quite popular among children such as the video game Roblox which enables its users the ability to develop their own games. Educators and researchers have shown interest in understanding the motivation behind children's engagement with video games as a method of learning. Video games used for educational purposes, such as Quest Atlantis, have demonstrated positive learning experiences in various content areas (Barab et al., 2005; Sandler et al., 2007; Zuiker et al., 2007; Kafai, 2010). These games have been successfully implemented in language arts, social studies (Barab et al., 2005), and science (Barab et al., 2007). Additionally, studies have explored the positive impact of video games in enhancing children's mathematical understanding (Chang et al., 2012; Habgood & Ainsworth, 2011; Ke, 2008; Pareto et al., 2012), generating a favorable attitude towards

mathematics as a subject (Ke, 2008; Pareto et al., 2012).

However, the advantage of using video games in math education presents varied findings. Analyzing the positive impact of mathematical video games is a complex process that requires more than just observing students' gameplay. Young and colleagues (2012) conducted a meta-analysis and found a limited number of referenced studies in the larger body of research related to mathematical video games. Studies focusing on math games, specifically in arithmetic and geometry for elementary school students, have been limited and yielded mixed results.

Nevertheless, Olkun, Altun, and Smith (2005) demonstrated positive results with students using geometric puzzles, suggesting a positive effect on students' geometric reasoning about two-dimensional shapes. When implementing video games for instruction and learning, caution should be exercised in academic settings. Educators, practitioners, and instructors need to consider individuals' intrinsic and extrinsic motivation to participate in the game. It is intriguing to examine how players exert varying levels of effort and persistence when engaging with educational video games. Moreover, investigating their behavior and learning processes through the lens of motivation theories, such as Ryan and Deci (1985, 2000), is crucial.

The study aimed to develop an interactive educational video game that relates to fractions which would be overseen by experts in the field of video games, specifically by reviewing and going over gameplay footage and providing necessary comments and suggestions to create an output that will be applied to classroom settings.

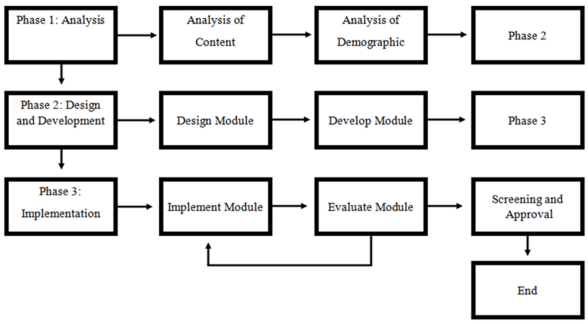
2. METHODOLOGY

2.1. Theoretical Framework

The developmental study was conducted in 3 phases to simplify and streamline the process of development. Phase 1 of the methodology included analysis of the content which involved research on the main topic of the video game as well as similar educational games to determine what factors were ideal in conceptualizing an educational video game to optimize engagement and retention with players. Phase 2 of the study involved creating the module's design with the help of preliminary information from Phase 1 of the methodology, then developing the module once all details were sorted. Finally, Phase 3 involved the implementation of the module to playtesters as well as evaluation from experts from the field of game design and development, which was a repeated process to implement all related and necessary criticisms given until the final output of the game was screened and approved for implementation in classroom settings.

Figure 1

Theoretical Framework of the Study



Note. This theoretical framework entails the basic process of developing the main module of the game.

2.2. Research Design

2.2.1 Implementation of Phase 1

The implementation of Phase 1 in game development involved the analysis of the context and environment in which the game was being developed. According to Fransen and Nijholt (2016), the analysis phase is critical in identifying the requirements and objectives of the game, as well as understanding the target audience and the existing market for similar games. During this phase, the development team collected information about educational video games and fractions, such as existing educational games and the intricacies of the topic of fractions. The collection of information included the playtesting of educational games related to fractions and judging them by user experience, depth of content, as well as content exposure, and accessibility. Regarding the context of the literature being reviewed, papers were judged with similar

criteria with the slight adjustment of reviewing the targeted ages and approach to the application of video games in a learning environment.

In line with this, Orvis and Dwyer (2021) explained that research into the aspects of the variables, including the game's mechanics, learning objectives, and design, is crucial in creating the conceptual design of the game being developed. The research helps identify the strengths and weaknesses of existing educational games, assess the feasibility of incorporating fractions in the game, and determine the appropriate instructional strategies.

Based on the findings from the analysis and research phases, recommendations on solutions to problems and the introduction of new technology can be made (Fransen & Nijholt, 2016). The recommendations may include modifications to the game's design, changes in the instructional approach, or the incorporation of new features to improve the game's effectiveness in teaching.

2.2.2 Implementation of Phase 2

In the second phase of the study, the findings of the analysis phase were utilized to guide the design of a video game for interactive learning of the 5th-grade math topic of fractions. The objective of this phase was to design a video game that effectively teaches fractions concepts based on the information gathered during the analysis phase. According to Kebritchi, Hirumi, and Bai (2010), the design phase is critical in ensuring that the game aligns with the learning objectives, engages the players, and effectively teaches the targeted concepts.

Subject matter and technology experts were consulted during the formative evaluation of the video game to provide feedback on the game's effectiveness in teaching fractions concepts and identify areas for improvement. The feedback provided by the experts was crucial in ensuring that the game aligns with the learning objectives and effectively teaches fractions concepts (Arnab et al., 2012).

During the design phase, the game's mechanics, instructional approach, and design elements were developed to ensure that the game effectively teaches fractions concepts and engages the players. According to Boyle et al. (2016), the game design elements should align with the learning objectives and be engaging to the players to enhance their motivation and facilitate learning. Moreover, the video game's instructional approach was designed to incorporate effective instructional strategies, such as scaffolding and feedback, to enhance learning (Kebritchi et al., 2010). The instructional approach was also aligned with the learning objectives and the targeted fractions concepts.

2.2.3 Implementation of Phase 3

The implementation of Phase 3 in game development involved consulting with experts in the fields of video game design, game development, and mathematics to obtain comments and criticisms about the game and make changes accordingly. According to Alqahtani (2019), expert feedback is crucial in identifying areas for improvement, validating the game's effectiveness in teaching the targeted concepts, and ensuring that the game aligns with the learning objectives.

In this phase, the participant's perceptions of the game's activities were also studied, and the difficulties faced during the implementation of the game were determined. Identifying these difficulties is critical in ensuring that the game effectively teaches the targeted concepts and engages the players (Garris et al., 2002). Once the difficulties were identified and necessary criticisms were considered, the implementation of a solution or compromise was necessary to produce the best possible output. The solution involves modifications to the game's mechanics, design, or instructional approach to address the identified difficulties and improve the game's effectiveness in teaching mathematics concepts.

Moreover, the difficulties encountered during the implementation of the game was reported to help further innovations in the study of the development or improvement of educational video games. The identification of these difficulties provided valuable insights into the challenges of creating effective educational games and helped to inform the design of future games (Gee, 2003).

3. RESULTS AND DISCUSSION

3.1 Game Concept

Fractionia is a third-person educational game developed in the game studio of Roblox. The game follows the premise of a self-insert adventure story with three

different levels. Furthermore, the game is classified as a 3D interactive quiz-type game. The player must solve fraction problems and choose the correct answer before the timer runs out.

3.1.1 Game Design Description

Fractionia takes place in the Ironbark Forest, which acts as a central hub and spawn point for all players. It is the players' job to learn about Fractions and explore the Crystal Crypt, the cave mentioned in the story, to find treasure. The protagonist will be using their knowledge of Fractions to solve problems and further progress into the cave.

3.1.2 Genre

With the game tackling Fractions and their applications, the game is classified as an Educational Adventure Game that utilizes interactive quiz-type features. The adventure element is due to the story of the game taking inspiration from an Indiana Jones Style adventure of treasure hunting in caves and ruins.

3.1.3 Platform

The game is playable on Personal Computers (PC) and Mobile devices. Furthermore, the game is only accessible through the app of Roblox, which is only available on PC and Mobile, providing accessibility to players. The game's primary platform, however, is the PC since gameplay requires a player to use the chat box, and it will be simpler to utilize that feature on PC.

3.2 Game Mechanics

3.2.1 Core Gameplay

Fractionia is an educational game developed in Roblox that uses a quiz format to teach players about Fractions. The game's core gameplay mechanic is typing in the correct answer to a given problem to progress through different levels. Each level presents the player with a set of problems. The player must type in the correct answer within a certain amount of time, and if they get the answer right, they move on to the next level. As the player progresses through the game, the problems become more complex, challenging their understanding of fractions and its subtopics. The game also includes a health bar system encouraging players to solve and obtain the correct answers to make the gameplay more engaging. Overall, Fractionia is a fun and interactive way for students to learn about fractions while improving their typing and problem-solving skills.

3.2.2 Game Flow

Fractionia follows a linear gameplay flow. Players will be given a portion of the narrative, then be given a reason in that narrative to explore a particular cave. The game is divided into three sections, constantly encountering problems involving fractions to further progress in the story. Once a section is completed, a portal will be opened that will link two sections together to facilitate a smoother transition.

After completing a level in the game, players will go through the same primary sequence again, revealing more of the story and motivating them to keep playing. In addition to the regular gameplay, unique "set pieces" transitions between two locations and include cutscenes that develop the characters and plot.

3.2.3 Characters

This game only has two non player characters (NPCs) that will help drive the story of the game forward as well as being instructors to the self inserted player character.

- Charlie: Charlie is the NPC that serves as an instructor to the player teaching them the concepts of fractions being utilized in the game on the first level which serves as a practice level.
- Arthur: Arthur is the NPC that acts as the main driver to the story. Serving as the main quest giver, Arthur accompanies the player as they proceed through the Crystal Crypt.

3.2.4 Boss Fight

The final quiz section of the game involves a boss fight against a shadowy golem named Javagon. Rather than the setup of obstacles blocking the player's path to progress, the boss fight requires players to correctly answer questions in order to deal damage to the boss as well as avoid the attacks that the creature performs when given an incorrect answer. This concept is implemented to emulate the format of a traditional platformer game and apply elements of

educational games in order to make the final output more interactive.

3.2.5 Controls

The game is playable on both PCs and mobile devices; hence, there are two sets of controls for the game. Both controls follow the default control settings of Roblox which have specific interfaces for both platforms.

The mobile controls utilize touch screen technology; hence, the interface only requires pressing on the chat icon to open the chat feature as well as a circle pad and jump button on the screen to facilitate the movement of the player.

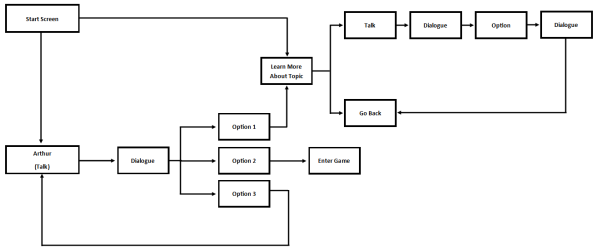
For the PC version, the controls follow the standard WASD format which uses the aforementioned letters as the keys to player movement while having the spacebar to jump and the enter key to open the chat box.

3.3 Interface

The following flowcharts are for the different screens and their individual data flow such as the start and options screen.

Figure 2

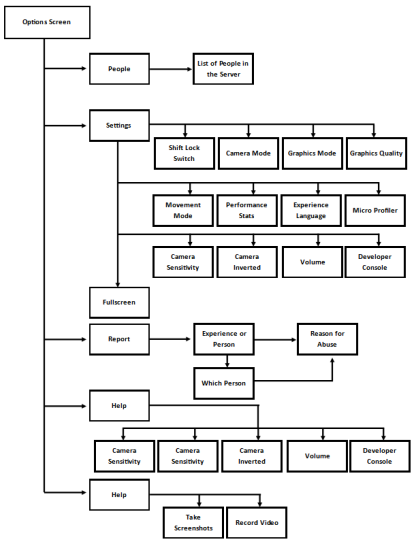
Starting Screen Flowchart



Note. This flowchart showcases the possibilities of the options presented in the main hub of the game.

Figure 3

Option Screen Flowchart



Note. This flowchart showcases the options screen that Roblox provides to allow a player to adjust certain factors in the game.

3.4 Story

The players have been tasked by the adventurers guild to help a group of archaeologists find an ancient stone mask that harnesses strong magical energy that is said to have the ability to unlock a person's full potential. The group faces challenges that the player should conquer with their own smarts and problem-solving skills. The players then meet the archaeologists Arthur and Charlie in the Ironbark forest. Arthur and Charlie have tried using most of their strengths and brains but realize that the path that they are about to take is dangerous. That's where the player comes in to help them obtain the ancient stone mask. The player must therefore learn all about fractions to navigate the cave and find the artifact they were tasked to find.

3.5 Level Overview

The game is essentially separated into 3 parts that focus on different methods. The first segment will be the tutorial portion for players as well as the lecture which introduces the topic of fractions by providing a no-consequence quiz. The second segment will be the player

going down one of two pathways answering questions related to fractions, reducing the player's health and preventing the player from advancing when an incorrect answer is given. The third and final segment will be a boss fight combining the gameplay of dodging the boss's attacks and solving questions in order to damage the boss. Once the boss's health drops to zero the player is teleported to a victory room to claim the artifact the quest informs the player about at the start of the game.

3.6 Market Analysis

According to December 2022 data from Roblox Corporation, 23 percent of Roblox games users worldwide were between the ages of nine and 12, while 22 percent were under the age of nine. Only 17 percent of Roblox users were aged 25 years and older. In the fourth quarter of 2022, players aged 13 years and older accounted for 7.3 billion hours of engagement with Roblox games, compared to 5.4 billion hours by younger players. In the United States, 21 percent of children who use Roblox spend more than ten hours per week on the platform. Additionally, a survey conducted in October 2022 found that 27 percent of U.S. gamers who play Roblox and have children who also play spent six to ten hours per week playing with or watching their child play Roblox game experiences (Clement, 2023).

4. CONCLUSIONS

Creating an educational game about fractions can have significant implications for learning. Such a game can help elementary students develop a deeper conceptual understanding of fractions by providing hands-on, interactive experiences. By engaging with visual representations and problem-solving activities, students can grasp key fraction concepts and operations more effectively. Moreover, educational games make learning fractions enjoyable and engaging, motivating students to actively participate and maintain their interest throughout the learning process. Through repetitive practice and immediate feedback, these games reinforce learning and improve long-term retention. By analyzing students' performance and offering corrective feedback, games can actively contribute to error analysis and misconception resolution. The game's accessibility and flexibility also accommodate diverse learners. As a supplement to traditional teaching, educational games can reinforce concepts, assess understanding, and provide additional support in various learning environments.

Since the research focused on developing the fundamental requirements of an interactive educational game, the researchers would like to recommend further development such as extra levels to deepen the level of understanding for players. On the other hand, the implementation of the game to an educational level is also recommended for researchers who would like to further pursue this topic.

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