The Effects of Game-Based Learning in an Opensim-Supported Virtual Environment for Mathematical Performance

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THE EFFECTS OF GAME-BASED LEARNING IN AN OPENSIM-SUPPORTED VIRTUAL ENVIRONMENT FOR MATHEMATICAL PERFORMANCE

By

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ABSTRACT

This experimental study was intended to examine whether game-based learning (GBL) that encompasses four particular game characteristics (challenges, a storyline, rewards, and the integration of game-play with learning content) in the OpenSimulator-supported virtual reality (VR) learning environment can improve mathematical achievement and motivation for elementary school students toward math learning. In this pre- and post-test experimental comparison study, data were collected from 132 fourth graders through an achievement test, and a Short Instructional Materials Motivational Survey (SIMMS).

The same tasks were provided to the experimental and control groups. Tasks for the experimental group involved the following four game characteristics: (1) challenges, (2) a storyline, (3) rewards, and (4) the integration of game-play with learning content. The control group was given the same tasks and learning environment setting (OpenSimulator-supported VR) that was used for the experimental group. The exception was that the control group tasks did not include the game characteristics: (1) challenges, (2) a storyline, (3) rewards, and (4) the integration of game-play with learning content.

Analysis of covariance (ANCOVA) using a treatment (treatment vs. control) on the achievement indicated a significant effect of GBL in the VR environment on math knowledge test performance. For motivation, the results indicated that there was no significant difference on the post-test scores for the perceived motivational quality of the learning activity (MQLA) between the experimental group and the control group.
CHAPTER 1

INTRODUCTION

Context of Study

Mathematics has always been an important subject in school curriculum. Mastery of mathematics is important in high-stakes testing, competitive selection, and student placement (Roman, 2004). The results of mathematical assessments by state, national, and international standards indicate that U.S. students’ proficiency in straightforward computational procedures reaches the average level of performance. Mathematics competence is fundamental in other fields such as economics, statistics, and physics (Arnold, & Straten, 2012; Ballard & Johnson, 2004; Johnson & Kuennen, 2006). Mathematics is involved during the early stages of a child’s life, and assists in making sense of his or her world both in and outside of school. The National Association for the Education of Young Children (NAEYC) also stated that the development of mathematical skills is imperative beginning in the early stages of child development. Arnold and Straten (2012) asserted a need for preparatory math education for secondary education as well. The assertion aligns with the statements from NAEYC on the significance of early age development of mathematical skills.

However, U.S. students have a below-average ability to apply appropriate mathematical skills, even for simple tasks (Vigdor, 2013). The National Commission on Mathematics and Science Teaching for the 21st Century (known as the Glenn Commission) expressed the same concern and asked, “As our children move toward the day when their decisions will be the ones shaping a new America, will they be equipped with the mathematical and scientific tools needed to meet those challenges and capitalize on those opportunities?” (p.6). This observation arose from the results of the overall low level of the U.S. students’ mathematical proficiency tests.
(Kilpatrick, Swafford, & Findell, 2001), which indicated the need for greater attention towards mathematical education in the U.S. The concern about mathematical performance has been an issue in the U.S. (Vigdor, 2013). Educators and researchers have focused on more studies that aim to identify the solutions to improve mathematical performance (Swanson, Jerman, & Zheng, 2008) in the U.S.

Our education system has focused on delivering mathematical knowledge, such as computational procedures (Vigdor, 2013), instead of helping students understand the actual connection between the importance of learning mathematics and the context of applying mathematics in real life. Because of this knowledge gap, students are less likely to appreciate the pervasive influence of mathematics in their lives (Mack, 2001). Furthermore, bridging this knowledge gap may provide insight into U.S. students’ lack of ability to apply mathematical skills in life situations.

The literature in mathematics has indicated that the performance of real-life problems, which involves fractions, is difficult for students (Chinnappan, & Desplat, 2012, p.2), but students should be able to apply math skills in real-life contexts (Mack, 2001). In addition to lacking real-life application skills, the National Assessment of Educational Progress (NAEP) in a United States report (Brown, & Quinn, 2006) showed a lack of students’ proficiency with fraction concepts as well.

According to the Common Core State Standards (2010), students begin to learn fractions in school in the third grade. However, curriculums aligned with the CCSS do not begin formal mathematical development of fractions until the fourth grade level. At the fourth grade level, students need to have a clear and functional understanding of fractions in order to complete the assigned fractional arithmetic operations successfully (Common Core State Standard, 2010).
More than just their inherent value as a number, students need to understand the values of fractions and how to work with them as part of the school curriculum. Thus, fourth grade students are required to learn how to add, subtract, multiply, and divide fractions and use these operations to solve problems.

Different methods and technologies have been used to improve student achievements in all fields. One example of that technology is virtual reality (VR), which has been used in educational settings since 1990 (Siddens, 1999). VR functions as a computer-generated 3D (dimensional) representation of a real-life learning environment (Wang & Shao, 2012). Recently, Internet access in classrooms that allowed increased VR use opens new opportunities to advance the learning and teaching environment.

In addition, the popularity of computer games among people has been increasing rapidly across varied age groups. People who play computer games are often completely engaged in problem solving and task performance (Garris, Ahlers, & Driskell, 2002). This phenomenon has captured educational professionals’ attention. Considerable scholars have shown interest towards using game characteristics (e.g., challenge, point, reward, competition) to enhance learning including math learning (Gee, 2003; Ke, 2008; Prensky, 2006; Shaffer, Squire, Halverson, & Gee, 2005; Shute, Riber, & Van Eck, 2011).

While people are fully engaged in the game, they are asked to solve given tasks (e.g., challenges), requiring persistence to continue playing the game. Problem solving skills and persistence are considered essential for the modern workplace, but those traits are not being adequately developed with students in the current educational system (Shute & Ke, 2012). Although there are studies examining the incorporation of game characteristics or game-based learning (GBL) in general in math teaching/learning (Chen, Cheng, Yeh, & Chan, 2012; Ke,
2013; Whitton, 2012) or game-based learning (GBL), there is little consensus regarding the effectiveness of GBL and the game characteristics that promote learning, particularly in math education.

Therefore, the current study attempted to examine whether some specific game characteristics (i.e., challenges, a storyline, rewards, and the integration of game-play with learning content) incorporated with the learning content can improve mathematical performance in an OpenSim-supported VR learning environment. These four game characteristics used in the study were commonly addressed among game scholars but rarely validated or examined in their use or design in a math learning context. The learning content consisted of the use of fractions that fourth graders have learned. Chapter 2 will provide more detailed information about an OpenSim-supported VR environment.

**Problem Statement**

Based on the results from the mathematical assessments, students’ mathematical performance in the U.S. showed low levels of mathematical performance (Vigdor, 2013). In particular, they cannot apply math skills in real life. A lack of real-life application of fractions has been an issue for many years (Brown & Quinn 2006; Chinnappan, & Desplat, 2012). Although 3rd graders start to learn fractions, fourth graders are required to have better comprehension of fraction concepts based on Common Core State Standards (2010). fourth graders are already required to learn the basic operations (addition, subtraction, multiplication, and division) of fractions and apply those operations to solve problems. Yet American students continue to have a difficult time applying knowledge of fractions in real-life situations. Students are also less likely to show motivation toward math learning. Thus, more research is warranted to examine intervention that promotes the real-life applications of fractions in school students.
Purpose of the Study

This study aimed to examine whether incorporating game characteristics (i.e., challenges, a storyline, rewards, and the integration of game-play with the learning content) into the learning task can improve mathematical achievement and motivation in an OpenSim-supported VR learning environment for elementary school students, specifically for fourth graders. The targeted learning process is the practice and application of fraction concepts.

Research Questions

This study examined whether GBL in the OpenSim-supported VR learning environment has a positive effect on learning achievement and the motivational quality of the learning activity used in the study. This study addressed the following questions:

1. Is the learning achievement in a knowledge test that focuses on applying knowledge of fractions in real-life situations higher for fourth graders participating in a game-based learning activity, compared to those participating in a non-game-based learning activity, in an OpenSim-supported virtual reality-learning environment?

2. Is the perceived motivational quality of the learning activity higher for fourth graders participating in a game-based learning activity, compared to those participating in a non-game-based learning activity, in an OpenSim-supported virtual reality-learning environment?

Research Hypotheses

1. The experimental group (the game-based learning group) will exhibit a higher learning achievement in a knowledge test that focuses on applying knowledge of fractions in real-life contexts than the control group (the non-game-based learning) group.

2. The experimental group (the game-based learning group) will exhibit a higher score for perceived motivational quality of the learning activity (MQLA) on the short instructional
materials motivation survey (SIMMS) than the control group (the non-game-based learning) group.

Chapter 2 will provide the literature evidence regarding the research hypotheses of the current study.
CHAPTER 2

LITERATURE REVIEW

This chapter provides an overview of game-based learning (GBL), virtual reality (VR), and how GBL within VR has affected motivation and achievement, with a focus on math education. The characteristics of games and VR are addressed. Examples of research studies that have utilized these variables are provided as well. In addition, the ARCS motivational design is introduced, as well as how the ARCS design is applied in prior research studies.

A number of books, articles, and research papers were used as sources of this review. In order to access the literature, ERIC and Google Scholar were also used. The keywords used were: game-based learning, virtual reality, the ARCS motivational design model, motivation or achievement in math education, and math achievement with game-based learning and virtual reality.

Game-Based Learning (GBL)

Emergence of Game-Based Learning

The popularity of computer games among people has been increasing rapidly across all age groups. People who play computer games find that these games can be engaging and intriguing (Garris, Ahler, & Driskell., 2002). During game-play, some of the tasks that are presented require the players to demonstrate tenacity toward finding the solutions for the task. While problem solving skills and persistence are fundamental skills to be developed by an individual for the modern workplace, but students are not likely to have an opportunity granted to acquire these skills from the current school systems (Shute & Ke, 2012).

Prior empirical evidence showed that games could be an effective learning tool to enhance learning and assist learners in comprehending a complex level of studies (Cordova &
Lepper, 1996; Ricci, Salas, & Cannon-Bower, 1996). This phenomenon has captured educational professionals’ attention. Considerable scholars have shown interest in using games to enhance learning (Gee, 2003; Prensky, 2006; Shaffer, Squire, Halverson, & Gee, 2005; Shute, Riber, & Van Eck, 2011).

GBL has permeated education (Danielsson & Wiberg, 2006) due to the increased potential of the educational benefits of games and their capability to create a better learning environment to support interactive, engaging, and immersive activities (Gunter, Kenny, & Vick, 2008, p. 511). Garris et al. (2002) referred to gaming as an activity where students play a game and return to continue playing over time due to the user’s engagement with the game.

GBL has shown promise as an effective learning pedagogy in educating new generations of learners (Prensky, 2001). Thus, numerous studies have been conducted relating to GBL in a variety of fields (Barendregt & Bekker, 2011; Liu & Chu, 2010) among scholars. However, few studies have clearly presented the definition of GBL. Based on the contexts of the previous studies regarding GBL (Chen, Cheng, Yeh, & Chan, 2012; Thomas, Thomas, Mark & Elizabeth, 2011; Whitton, 2012), it can be generally agreed that GBL is a type of instruction involving the use of game characteristics (e.g., challenge, points, reward, feedback, competition). The studies infer that those game characteristics boost learners’ motivation and improve engagement. Ultimately, GBL can enhance learning (Garris et al., 2002; Ke, 2013; Ricci et al., 1996; Whitton, 2012).

Game Characteristics

Scholars proposed varied essential game characteristics (Garris et al., 2002, p.446). Malone (1981) suggested that the four fundamental game characteristics are: challenge, fantasy, complexity, and control (Garris et al., 2002, p.441). Baranauskas, Neto, and Borger (2001) noted
that risk and challenge were essential game characteristics. The Crorkall, Oxford, and Saunders (1987) study used the term, “game features” instead of using game characteristics. They stated that game features are: rules, strategy, goals, competition/cooperation, and chance. According to the meta-analysis of computer games by Ke (2009), Prensky (2001) used the term “game feature” and noted six key structural game features: (1) rules, (2) goals, (3) outcomes and feedback, (4) challenge, competition, opposition, (5) interaction, and (6) representation or story (Ke, 2009, p. 2). Thornton & Cleveland (1990) stated that interactivity is a fundamental aspect of the games. Dynamic visuals, interaction, rules and goals (de Felix & Johnston, 1994) were described as structural elements of a game.

In spite of broad games characteristics or features proposed by many game scholars (de Felix & Johnston, 1994; Garris et al., 2002; Malone, 1981; Thornton & Cleveland, 1990), GBL has already been used in a variety of fields due to the potential benefits that may be obtained from incorporating game characteristics into instructional lessons: medicine (Salajan et al., 2009), language learning (Barendregt & Bekker, 2011; Liu & Chu, 2010), engineering (Su, & Cheng, 2013), and math education (Chen, Liao, Cheng, Yeh, & Chan, 2012; Ke, 2013; Whitton, 2012).

Based on the review of the literature, there is no clear distinctive use of terms among game features, game characteristics, and game elements. Obviously, there is little consensus regarding how essential characteristics of games are described. Garris et al. (2002) also pointed out that there is not a central understanding about which game characteristics or features can be commonly used to assist learning, or what kind of game characteristics engage learners in a specific context and produces learning outcomes through game-play (Garris et al., 2002, p.442; Whitton, 2012). Moreover, few studies described and examined particular game characteristics in
interventions. Thus, this current study examined the selected game characteristics (i.e., challenges, a storyline, rewards, and the integration of game-play with learning content) commonly used among scholars, particularly in a math learning context to examine whether these characteristics will bring a positive impact on learning performance.

**Positive Aspects of Game-Based Learning**

GBL has been considered as an effective tool to teach current generations of students (Prensky, 2001). Many studies have addressed that GBL has been more effective than traditional teaching for learning achievement and motivation (Chen, Liao, Cheng, Yeh, & Chan, 2012; Miller, Chang, Wang, Beier & Klisch, 2011; Papastergiou, 2009; Su & Cheng, 2013; Thomas, Thomas, Mark & Elizabeth, 2011), but not necessarily an efficient tool in terms of time and monetary resources for creation (Whitton, 2012).

An example of a positive learning effect by using digital games is the Gamestar Mechanic online game (Shute & Ke, 2012). This game aims to develop children’s systems thinking skills. Systems thinking helps people understand the entire scope of a topic and consider the interrelationship among the elements, instead of focusing on a single particular element of the problem. This game allows children to learn basic game design skills prompted by the actual game itself. During game-play, children have to make decisions, and the consequences of the decisions are associated with systems thinking skills (Shute & Ke, 2012).

According to a review by Shute and Ke (2012), Urban Science is another example that supports learning in a positive manner (Bagley & Shaffer, 2009). Urban Science is an online game and is categorized as an epistemic game. Epistemic games allow players to experience the life of an urban planner (Shaffer, 2006). This can lead the players from the virtual learning experience to become an actual practitioner. The game situates the players in order to act out the
urban planner role and have experiences (e.g., interviewing people, visiting a site etc.). These experiences can easily immerse a player in these types of games. A Rezaiyan, Mohammadi and Fallah (2007) study also indicated a positive result with children who require special learning needs. The students in the study showed increased motivation internally and their learning improved in comparison to not using learning games.

Lastly, there is more evidence demonstrating the positive effects of GBL in a variety of fields. For instance, when applying games in the dental field, where the learning content is difficult to comprehend, the result showed a positive perception from the students toward learning related to the challenging content (Salajan et al., 2009). Some studies (Barendregt & Bekker, 2011; Liu & Chu, 2010) presented positive outcomes of GBL in language learning settings as well.

**Game-Based Learning in Math Education**

GBL has been implemented in math education as well (Chen, Cheng, Yeh, & Chan, 2012). Some scholars asserted that GBL might be an effective instructional tool to support math learners’ engagement (Whitton, 2012). Also, GBL assists math learners’ understanding of arithmetic concepts and problem solving (Ota & Dupaul, 2002; Van Eck & Dempsey, 2002). Therefore, a knowledge domain such as math can benefit in teaching more effectively through computer gaming (Hays, 2005; Randel et al., 1992). A study by Chen et al. (2012) supported the positive impact of using GBL in math learning. They used GBL systems to increase motivation in math learning. The authors developed the game titled, “My-Pet-My-Quest” to enhance students’ math learning. This study aimed to examine how game quests influenced students’ enjoyment of learning and goal orientation. The results showed that students were more likely to enjoy tackling game quests that were embedded into learning tasks than students who were given
learning tasks directly. Students showed a tendency to undertake more tasks in the context of the
game quests as an active learner. Overall, this study showed a positive effect toward using GBL
in accordance with math learning and suggested further investigation for the long-term effects of
GBL, considering the short period of its study.

More recently, Ke and Abras (2013) examined the potential effect of computer games
when teaching math games (i.e., pre-algebra) targeting middle school children with special
learning needs, and linguistics and cultural differences. They focused on the use of appropriate
design features and learner support to promote learning while keeping learners engaged. The
results indicated that educational games could foster and promote learning for learners with
special learning needs with the emphasis of proper design in that particular context. Although Ke
and Abras (2013) study participants were learners with special learning needs and different from
the current study, the findings indicated that game-based learner support (e.g., presenting the
game introduction in multiple ways, helping to understand the game rules, and solving technical
issues during the play) and in-game learning scaffolding features (e.g., recalling and retaining the
information) should be carefully considered when designing educational games.

Another example of the positive effect of GBL is a case study by Ke (2013). Ke (2013)
implemented game-based tutoring on computer mathematics games with the assumption that
game-based tutoring can support student players. The study results showed a positive impact on
students’ state test performance through a game-based tutoring program (Ke, 2013). Even though
many studies have been conducted to examine the effects of GBL in math education, more
empirical studies are still needed that can outline common guidelines when designing,
implementing, and assessing GBL for the different types of tasks and audiences to accomplish
the ultimate goals (i.e., higher motivation and achievement) in math education (Ke, 2013).
Research by Vogel, Greenwood-Ericksen, Cannon-Bowers, and Bowers (2006) examined whether CAI with embedded game elements (motivation, reward, score, interactivity, and challenges, p. 105) versus non-game attributes embedded in the instruction had an impact on the math and language skills of children with special learning disabilities (hearing and deaf children). Although the study addressed the positive potential of GBL to support learning, the overall results were not able to support the positive effect of GBL on math skills.

Despite the inconsistent perspectives on the effectiveness of GBL (Chen et al., 2012; Ke, 2008; Vogel et al., 2006) in math education, people still consider games to be effective educational tools in that they motivate children to actively engage in learning activities and environments as part of the game-play (Amory, Naicker, Vincent, & Adams, 1999; Ke, 2013). The results of prior gaming research presented have contributed to the future directions of GBL to meet their educational purposes. Further, the results proposed appropriate design features needed to deliver the benefits of GBL into education. The suggestions are as follows:

First, in order to use computer games as an effective educational tool (von Wangenheim & Shull, 2009), it is necessary to identify the appropriate game types and elements that are aligned with the desired learning outcome for the specific subject (Amory, Naicker, Vincent, & Adams, 1999). This needs to be addressed so that practitioners can adapt and apply game elements effectively in their classes. In the same vein, a common gaming design guideline that teachers can customize on their own appropriately when tailoring GBL in a classroom setting is still needed (Ke, 2008).

Second, more empirical studies are needed on the inclusion of skill practice within game tasks, when a learner is challenged in a particular subject within a specific context. For instance, Ke (2013) attempted to embed essential skill practices for learners into the game challenges,
which the students had to interact with, while maintaining their engagement. This support one of
the concerns of the prior game research on the lack of association between the learning tasks and
the game-play challenges (Gunter et al, 2008). More empirical studies are required to study the
inclusion of skill practice into the gaming tasks in order to verify the results.

Third, prior research noted that external learner support during game-play is needed, so
learners can accomplish their given challenges in the game (Garris et al., 2002) without
interrupting the flow of the gaming experience (Brom et al, 2010; Ke, 2013). A study by Ke
(2013) indicated that learners might not feel fully comfortable asking for external assistance
during the gaming. With the results from her study, the specific role of external learner support
within the specific gaming (Ke, 2013, p.17), as well as how specified learner-support can be
embedded into game designs without interrupting engagement, still requires clarification (Shute
& Ke, 2012, p.44).

**Virtual Reality**

Virtual reality (VR) is a new medium that enables people to simulate the real world
through 3D models and initiate interactions through an avatar -- a graphical representation of the
user. Using 3D figures in VR allows a user to participate in activities and games for educational
purposes. There are mainly three benefits of using VR in comparsion with 2D CAI (Computer
Assisted Instruction). First, 3D VR allows a user to experience real-life situations. Second, using
3D figures is like “being in another body (avatar),” which can promote the sense of social
presence in the cyberspace. Third, embodiment will award a user the self of presence that
promote higher cognitive engagement with other avatars (Schwienhorst, 2002, p. 201). Thus, the
3D, interactive experiences in VR can assist a user to comprehend complex ideas or skills easier
than 2D CAI (Rossou, 2004).
VR has been used in educational settings during the past two decades (Siddens, 1999). Internet access in classrooms that allows increased VR use presents new opportunities to advance the development of authentic learning environments. VR can suggest three directions for future education: (1) a permutation of existing learning and teaching environments, (2) distance education, and (3) employment of self-directed learning via virtual reality (Siddens, 1999). However, the leap to embrace this new change in education has not yet been made due to the variety of issues and perspectives in education, such as the management and maintenance in schools, technical support, the schools’ budgets, and training to implement this new environment (Siddens, 1999).

Despite those setbacks, Second Life (SL) gained considerable attention by educational researchers and practitioners. SL is an internet-based 3D virtual world, developed by Linden Research Inc. It is considered a new learning platform through which people can interact with each other (Huvila, Holmberg, Ek, & Widén-Wulff, 2010). It functions as a computer-generated 3D representation of a real-life learning environment (Wang & Shao, 2012). For example, researchers and practitioners expect this to be a potential tool of assistance for the teaching and learning of diverse subjects such as foreign languages, business, music, and computer science (Cargill-Kipar, 2009; Greenberg, Nepkie, & Pence, 2009; Tuten, 2009). There are, however, significant difficulties. For example, SL is costly when first creating and setting up the intended learning environment. Furthermore, there are frequent connection problems such as unexpected region crashes, login hiccups and lags, among other issues (Huvila, Holmberg, Ek, & Widén-Wulff, 2010).

Recent and more advanced VR developments include an open source multi-platform and multi-user 3D application servers, such as OpenSimulator (OpenSim). OpenSim is a platform
that allows people to easily create and customize a 3D environment using technology that fits his or her comfort level. It also provides better stability because of the sophisticated hardware and high-bandwidth connections. With an avatar, people can interact with other avatars while experiencing the same space in real time. This interaction is comparable to a real world setting so teachers are able to use this platform to provide authentic experiences for students (Michelle, Parsons, & Leonard, 2007).

Kim and Song (1997) proposed guidelines for creating an effective learning environment via VR for instructional designers, thereby justifying its importance in learning. The fundamental strong assumption of the study is that VR can enrich students’ learning experience. Again, students who learn while immersed in VR can gain a deeper level of understanding of the content (Reid, & Sykes, 1999). According to the Reid and Sykes study, the implementation of VR in public schools allowed students to become more active participants in their own learning processes. Moreover, the simulated environment that provided a hands-on experience was one of the highlights of VR.

Because of its capability of enabling learners to experience the real-life situations in an optimal space, VR environments have gained educators’ attention (Huang et al., 2010). The characteristics (i.e., enriching the student learning experience, more active learning, and authentic learning experience like real-life situations) derived from VR are aligned with the aspects of constructivism, such as active learning, authentic and contextualized learning environments, and rich learning environments (Richey, Klein & Tracey, 2011, p. 133). Within VR environments, the variety of hands-on experiences will enable the learner to apply math concepts that they have learned in the classroom.
The Integration of Virtual Reality and Game-based Learning

A Potential Solution for the Game-Based Learning Environment

The advancement of new technologies has led to growth of computer game development. Educators have tried to use game characteristics to support learning. One of the major reasons that educational games are still in the contemplation stage in education is the budgetary concern. Developing computer games from scratch requires significant financing, expertise, skills, and time (Schaefer & Warren, 2004). Unfortunately, the concurrent educational systems cannot support these needs. Due to the lack of resources, GBL studies frequently employed existing educational games (Cameron & Dwyer, 2005; Ke, 2008; Ke, 2013; Miller et al., 2011) from well-known organizations (e.g., Massachusetts Institute of Technology) or popular educational resources (e.g., the EducationWorld.com). The study by Miller et al. (2011) created CSI: THE EXPERIENCE with the Fort Worth Museum of Science and History. However, they also employed three other unnamed existing games, which were stated as cases during their study (p.1427).

Recently, Whitton (2012) suggested using VR as a game-environment with the belief that games motivate learning. As an alternative solution, VR, especially that of an open-source platform, can be a potential cost-efficient solution to creating games. In the field of engineering, Su and Cheng (2013) studied the effectiveness of GBL method and have adapted VR to create game environments. In Taiwan, some studies developed a system (e.g., My-Pet-My-Quest System) where individuals have an avatar and are allowed to control their avatars in a virtual environment (Chen, Tseng, & Liao, 2009; Chen, Lian, Cheng, Yeh, & Chan, 2012). The Su and Cheng (2013) study developed a 3D game system that used a cloud-based (Three-Tier) architecture. The finding of their study showed that 3D GBL with software engineer systems
accomplished a better learning achievement and learning motivation of students than students who used traditional face-to-face teaching (p. 1). However, only a few studies have developed and examined the usage of VR-supported game environment. More research is required to examine the benefits of using VR as a game environment. Reflecting on the information from the prior studies, the current study will attempt to develop a 3D VR environment via OpenSim for the creation of a GBL environment.

**The Potential Effects on Math Education**

In math education, Vogel et al. (2006) examined whether gaming attributes (i.e., CAI with embedded game elements: motivation, reward, score, interactivity, and challenge, p.105) could improve math skills through the use of VR tools. Their study focused on improving the math and language skills of students with special learning needs.

Two reasons for employing VR in their study were described. First, unlike traditional classrooms, VR provides a 3D environment. The VR environment can make students’ experiences feel more like real-life, as well as producing a more meaningful learning experience (p.108). Second, students have control over their own learning (e.g., flexibility for students’ schedules and convenience in practicing their mistakes) in the program. These experiences are more likely to assist in developing the learners’ comprehension of complex ideas and skills. In particular, the learning experiences of students with special-learning needs can be helped through VR, as problem solving can be shown in less abstract ways (Roussou, 2004). The results showed a positive effect on math skills.

Although the results were not able to support the positive effect on math skills when incorporating GBL with VR, this study noted that the interaction between participants and GBL was at a similar level with CAI. The study implied that both conditions (treatment and control
group) showed a significant difference between the pre- and post-test scores, but the improvement of the scores in the control group showed a large significant change (p.113).

The literature indicated that many studies (Cromby, Standen, & Brown, 1996; Kandalaft, Didehbani, Krawczyk, Allen, & Chapman, 2013; Parsons, & Cobb, 2011; Vogel et al., 2006) targeted whether VR with GBL can improve learning for children with special learning needs (i.e., Autism, Asperger). However, there is a lack of studies regarding the utilization of VR incorporated with GBL for typically developing children in math education. This current study intends to concentrate on bridging this gap.

**Motivation in Math Education**

Research on students’ mathematics achievement has gained greater attention in math education (Roman, 2004). Extensive literature reviews presented various factors (e.g., learning environment, gender differences, attitude, learning experiences, and affective factors) to be associated with academic achievement (Allison, 2012; Gottfried, Marcoulides, Gottfried, Oliver, & Guerin, 2007; Lewis, Ream, Bocian, Cardullo, Hammond, & Fast, 2012). Motivation is found to be one of the predictors of academic achievement (Pajares & Kanzler, 1995). The studies by Aunola, Nurmi, Lerkkacnen, and Rasku-Puttonen (2003) and Kikas, Peets, Palu, and Afanasjev (2009) also noted that motivated children were willing to make a greater effort in learning situations, and this led to better results in mathematical skills. Arnold and Straten (2012) investigated whether motivational factors played a role in affecting mathematical skills in economics students. This study finding confirmed that motivation is one of the imperative factors (p.45) for successful learning, specifically for math-deficient students. According to the study result by Uguroglu and Walberg (1979), there was a positive correlation between motivational factors and achievement in mathematics.
Based on the findings from previous research, the major motivating factors for increasing motivation in math learning were self-efficacy (Collins, 1982; Hoffman & Schraw, 2009; Pajares & Kranzler, 1995; Pajares & Miller, 1994) and intrinsic motivation (Arnold & Straten, 2012; Paras & Bizzocchi, 2005). Self-efficacy refers to a person’s own ability to perform a task (Bandura, 1997). Intrinsic motivation refers to a person’s own desire and interest, which brings pleasure that is inherent in the activity itself (Berlyne, 1971; Deci, 1975; Eccles, Wigfield, & Schiefele, 1998). The Pajares and Graham (1999) study claimed that self-efficacy in mathematics is closely correlated with mathematical achievement (Pajares & Kranzler, 1995; Pajares & Miller, 1994) and can be a greater predictor of math performance (Pajares & Kanzler, 1995) than prior math experiences (Pajares & Miller, 1995). Many scholars also noted that students’ attitudes (Alkhateeb & Mji, 2005; Hemmings & Kay, 2010; Hoges & Kim, 2013; Ma & Kishor, 1997) could be a motivational factor related to math learning.

Prior research indicated that the reasons as to why students’ motivation toward math has decreased could vary based on the learner experience, interest, instructor ability, class size, and characteristics of the content (Croft & Ward, 2001). Pajares and Miller (1995) also noted that many students have experienced poor performance in the past that led to lack of confidence or caused math anxiety, compared to the various factors (e.g., self-efficacy, intrinsic motivation, student attitude, learner experience and learner interest) affecting math learning motivation.

Based on the results from the National Assessment of Educational Progress (NAEP), the primary reason for decreasing student motivation is that they have a difficult time understanding the relevance of mathematics in their own lives (Vigdor, 2013). In a report from the Netherlands by Case (2005, p.378) titled, “The Dutch Revolution in Secondary School Mathematics”, it showed that Germany attempted to reform their math education. Germany introduced a realistic
mathematics education nationally in 1989. Mathematics was divided into Mathematics A and Mathematics B (p. 379). Mathematics A was named “Realistic Mathematics Education.” It focused on assisting students to engage in real-world situations and applications by giving them realistic examples. The goal of realistic mathematics education (Mathematics A) was to create a new environment where students can flesh out the steps for the answers of a problem without formulas. That way, students were more likely to use mathematics to make sense of the real world around them (p.378). Mathematics B also included realistic mathematics, but it limited to provide knowledge on the rigor only for students in science major in the university. Overall, a number of students enrolled in Mathematics A have grown rapidly. The instructors focused on encouraging students in the search, in order to allocate meaningful numerical values, while connecting the underlying real-world ideas. Thus, this way led the students to discuss and think in depth (p.380).

The creation of Realistic Mathematics Education (Mathematics A) was not separate from student activities; the activities intend to develop students’ abilities to find and form mathematical elements into the real world to solve problems by themselves. Case (2005) claimed that a reform in student learning of mathematics is critical, and student activities, in turn, are required to reconstruct mathematics education (p. 378). Though the Case (2005) study did not provide the specific learning activity used, his claim referring to the emphasis of reconstituting students’ learning activities along with new curriculum (Realistic Mathematics Education) is relevant to this current study.

As of yet, there is still a lack of empirical studies targeting the motivational quality of student activities, particularly in math learning with elementary students. Based on the results of the aforementioned research studies, this current study employed the ARCS Model of
Motivational Design developed by John M. Keller to measure the motivational quality of a learning activity that the participants engaged in. The intervention encompassed four particular game characteristics (i.e., challenges, rewards, a storyline, and the integration of game-play with learning content) that hypothesize about improving achievement and increasing motivation.

The ARCS Model of Motivational Design

**Background.** An individual’s motivation can be noticed by looking at ‘a learner’s effort’ while learning. However, a learner does not always make an effort voluntarily. Keller (2008) addressed the significance of a purposeful learning process and he illustrates that motivation is equivalent with a person’s choice to approach a task or avert a task, as well as the learner’s effort in completing the task. Therefore, the interest, curiosity, value of the task, and motive can influence on a learner’s effort (Keller, 1983).

According to Keller (2008), designers, which can be instructional designers or teachers, can influence learners’ efforts by following the principles of motivational design, which is the ARCS model. The ARCS model of motivational design refers to four steps (attention, relevance, confidence, and satisfaction) for promoting and sustaining motivation during the learning process (Keller, 2008). Keller developed the ARCS model of motivational design in 1980 to help understand motivation within instruction. Since then, the ARCS model is prominent in use, and it has been widely applied to instructional design (Hodges & Kim, 2013; Paras & Bizzocchi, 2005; Richey et al., 2011; Song & Keller, 1998). The central idea of the ARCS model is about addressing learner motivation when designing instruction. This motivational design model encompasses the four components to design instruction that have a positive influence on a learner effort and satisfaction (Keller, 2008; Richey et al., 2011).
**Four Components of the ARCS.** The four main components of the ARCS model are: (1) attention (2) relevance (3) confidence, and (4) satisfaction. The model is about learners getting the appropriate intrinsic and extrinsic rewards from the instruction (Richey et al., 2011, p.123).

![ARCS Model Diagram](image)

*Figure 1. ARCS model*

**Attention.** Attention involves prompting and maintaining the interest and curiosity of the learners. A learner’s interest and curiosity can be closely associated with intrinsic motivation. Intrinsic motivation is about a learner’s own desire which brings pleasure that is inherent in the activity itself (Berlyne, 1971; Deci, 1975; Eccles et al., 1998). It means that when a learner’s interest and curiosity are stimulated toward a subject, a learner’s performance will increase (Gottfried, Fleming, & Gottfried, 2001) and will have a positive impact on learning. Intrinsic motivation is more likely to lead to a life-long learner.

**Relevance.** Relevance is about the given instructional situation, meeting with a learner’s personal needs by establishing relevancy between what learners will learn and what they are
familiar with, as well as how it can be connected with increasing motivation.

**Confidence.** Confidence is about the given instruction providing a certain level of confidence for the learner. Having an appropriate level of self-confidence or confidence in a given subject is important when motivating learners.

**Satisfaction.** Satisfaction is about learners gaining the appropriate intrinsic and extrinsic rewards from the instruction (Richey et al., 2011, p.123). When learners receive intrinsic and extrinsic reinforcement properly for their effort and performance, they will be more motivated.

Use of the ARCS model as a part of instructional design is relatively uncomplicated and straightforward. It plays a significant role as the guiding framework or guidance on how to design instruction more effectively toward the motivation of learners. Additionally, the validity of the ARCS model has been tested often (Song & Keller, 2001; Kim & Keller, 2008). With the proven educational benefits that the model can provide, some reseachers apply the ARCS model to online learning and CAI (Hodges & Kim, 2013; Song & Keller, 2001).

**Examples of Studies Applying the ARCS Model**

Due to the advancement of new technologies, technologies themselves are attractive and gaining the attention of many people. They bring novelty and this novelty stimulates people’s interest. Song and Keller (2001) studied the effects of a prototype of motivationally adaptive CAI using the ARCS model and how the ARCS model can be applied in the new delivery medium. CAI gained attention of learners due to the novelty and variety of features. Song and Keller were aware that the novelty effect might decrease over time (Keller, 1997; Keller & Suzuki, 1988) and it could be difficult to sustain motivation for students who already had high motivation before using CAI. On the other hand, students who have lower motivation in the beginning might be motivated through the entire learning process. Song and Keller primarily
focused on whether motivationally adaptive CAI can offer the optimal and appropriate motivational strategies based on a learner’s motivation level (higher motivated vs. lower motivation).

Song and Keller created three treatments in their study: (1) motivationally adaptive CAI, (2) motivationally saturated CAI, and (3) motivationally minimized CAI. Motivation was measured by a simplified version of Keller’s (1993) Instructional Materials Motivational Survey (IMMS) to measure students’ reactions towards the motivational features of instructional material. The dependent variables of the study were effectiveness, perceived motivation (both overall motivation and each of the A, R, C, and S components) efficiency, and continuing motivation (p. 5). The results indicated that motivationally adaptive CAI showed higher effectiveness, overall motivation, and attention than the other two CAI types. No significant differences among the three CAI types were found for the continuing motivation. However, there was a correlation between the overall motivation and continuing motivation across the three CAI. The end results showed that motivationally adaptive CAI could be effectively altered to increase motivation through the use of the ARCS model.

Hodges and Kim (2013) studied the use of the ARCS model to assess students’ attitudes toward mathematics throughout an online course. They examined what constitutes learners’ attitudes toward mathematics and how a learner’s attitude can be improved by increasing learners’ motivation to master mathematics. Within the study, they targeted college students’ attitudes toward an introductory algebra course. Prior research supported the fact that students’ attitudes toward mathematics affected their learning (Evan, 2004; House, 1995). For instance, emotional aspects (McLeod, 1989) and beliefs (Fennema & Peterson, 1985) are influential factors on attitudes, but these studies did not state what constitutes “attitudes.” Thus, the aim of
the Hodges and Kim study was to discover a coherent set of variables that people systematically
target to improve students’ attitudes toward mathematics (Zan & Di Martino, 2007). The
intervention of the study was an online course (i.e., instructional material) that was designed
using the ARCS model. They defined attitudes toward mathematics as a construct that influenced
the way learners react to mathematics in a specific context, such as expressing indifference to a
math class. Interest, task value, and self-efficacy were all variables that helped measure attitude
in the study (Hodges, & Kim, 2013). The study results indicated that students’ attitudes were
changed positively using the motivational treatment design within the instructional material.
The Paras and Bizzocchi (2005) study used an integration of effective learning processes with
the process of playing and an endogenous learning experience that can be interpreted as the
intrinsic motivation in a game environment. A game environment has great potential to provide
an immersive learning experience; therefore, the study revealed that intrinsic motivation had a
stronger impact on learning. Paras and Bizzochhi (2005) stated that motivation had to be
developed through the entire instructional process in contrast with the traditional instructional
design where motivation was more likely to be considered a starting step in the instructional
process. Furthermore, the authors paid extra attention to ‘a learner effort,’ which can develop and
grow during the learning process. Learner effort can assist learners in becoming motivated,
which is aligned with the idea from Keller (1983) emphasizing the importance of a learner’s
effort when completing a task.

Even in the field of chemistry, Feng and Tuan (2005) applied the ARCS model as well
when designing an acid and base unit lesson for 11th graders who displayed low interest and
motivation in learning chemistry. The intervention of this study was the instruction designed
using the ARCS model and the students’ motivation towards science learning (SMTSL)
questionnaire. Achievement was measured before and after instruction. The study results showed that the motivation and achievement increased after using the instruction employed in the ARCS model.

Although there are only few studies that applied the ARCS model in math education, the researchers stated the significance of the ARCS model when creating effective design (Feng & Tuan, 2005; Hodges, & Kim, 2013; Song & Keller, 2001). While the results when applying the ARCS model were positive in those studies, there was still a need for further investigation in math education that has seen lower motivation in comparison with other fields. This current study aims to contribute toward this need.

**ARCS-based Measure of Motivation**

**The Instructional Materials Motivation Survey (IMMS)**

The Instructional Materials Motivation Survey (IMMS) is an instrument that was developed in conjunction with the ARCS model. This instrument does not intend to measure motivation itself or motivation toward general school learning. The aim of the instrument is to measure students’ reactions toward the lesson, activity, and instructional material (Keller, 2010). The use of the instrument is flexible and situational. Keller stated that the IMMS could be used in various contexts such as computer-based instruction, online courses that are self-directed, and paper-based self-directed instruction (Keller, 2010, p. 277).

Keller also noted that this instrument could be adapted to suit specific situations. Meaning, the phrase “the lesson” above can be changed, depending on the specific situation that is being assessed, to another term, such as “this course,” “this lecture,” “this computer-based instruction,” etc. (p.277). The targeted population of this instrument is flexible as well. Students in college including graduate students, adults who are in non-academic environments, and
secondary students are apt to use the IMMS. Younger students who maintain appropriate reading ability can also use IMMS. Keller noted that the items could be paraphrased, based on the competency level of the target audience (p.277).

Keller (2006) presented that the total scale of the IMMS reliability estimates was 0.96 (Cronbach $\alpha$) for each component (attention, relevance, confidence, and satisfaction). As for the IMMS validity, the scores on the experimental lesson showed significantly higher than for the control group lesson (p. 8). Meanwhile, Keller developed the Short Instructional Materials Motivation Survey (SIMMS), which is a revised version of the IMMS (Bickford, 1989, p.47). This original IMMS consists of 36 items, while the SIMMS consists of 16 items. It is a shorter version of the original IMMS of ARCS (Bickford, 1989). A study by Bickford (1989) used the SIMMS for her 7th grade audience. Her study stated that the original IMMS would be too long for her audience to finish reading, while still giving them sufficient time to complete her study. Her study noted that using the IMMS could have affected the motivation of students’ responses as well (p.48). Under the same aspect, this current study adopted the SIMMS to measure the motivational quality of the learning activity.
CHAPTER 3

METHOD

The purpose of the current study was to (1) examine whether GBL that encompasses particular game characteristics in an OpenSim-supported VR-learning environment can improve mathematical achievement and (2) motivation for elementary school students, specifically fourth graders.

GBL in the current study was defined as an instruction incorporating game characteristics. The four game characteristics to be used in this study were: (1) challenges, (2) a storyline, (3) rewards, and (4) the integration of game-play with learning content. The game-play was expected to emerge from the interaction among the game characteristics used in the study (Rollings & Adams, 2003). The challenges, a storyline, and rewards (or feedback) used in the current study were among the key structural features of games by Prensky (2001) -- rules, goals, feedback, challenges, interaction, and story. The most recent meta-analysis of computer games by Ke (2009) addressed Presky’s key structures of games, and proposed the integration of game-play and learning content as a critical feature of computer learning games (p.2). The integration of game-play and learning content was included to stimulate players to interact with given tasks connected with real-life situations.

In this study, a challenge was defined as a mission requiring knowledge and skills to solve the given mission for further challenges. rewards were defined as a player receiving virtual money as soon as a challenge was accomplished. A storyline was referred to as the steps that a player needs to follow to successfully complete his/her tasks or missions during game-play. The storyline used was aligned with real-life events to make it naturalistic. The current study addressed the following questions:
1. Is the learning achievement in a knowledge test that focuses on applying knowledge of fractions in real-life situations higher for fourth graders participating in a game-based learning activity, compared to those participating in a non-game-based learning activity, in an OpenSim-supported virtual reality-learning environment?

2. Is the perceived motivational quality of the learning activity higher for fourth graders participating in a game-based learning activity, compared to those participating in a non-game-based learning activity, in an OpenSim-supported virtual reality-learning environment?

Participants

A total of 132 fourth graders from five schools, between the ages of nine and ten, participated in the study. The sample population of the study was fourth graders from elementary schools in northern Florida, and were all English native speakers. The descriptive demographic information for the participants is provided in Table 1:

<table>
<thead>
<tr>
<th>Description of Participants Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Ethnicity</td>
</tr>
<tr>
<td>Native American</td>
</tr>
<tr>
<td>Asian</td>
</tr>
<tr>
<td>African American</td>
</tr>
<tr>
<td>Hispanic</td>
</tr>
<tr>
<td>Caucasian</td>
</tr>
<tr>
<td>Totals (N=132)</td>
</tr>
</tbody>
</table>

30
Three criteria for exclusion were applied prior to randomly assigning the participants to minimize sampling errors: (1) known physical deficits, (2) known cognitive deficits, and (3) gifted students. This information was collected from the teachers in selected schools.

**Materials**

The materials used by the participants in the study were VR-based learning tasks (the treatment), a pre-test, post-test, a motivation survey (SIMMS), and the virtual reality environment. Preliminary instruction for participants was developed (see Appendix A).

**Treatment.** This study included four tasks used for practice with fractions. The task items were based on the Common Core State Standards (CCSS) in Mathematics. The same tasks were provided to the experimental and control groups. The given tasks for both groups were based on real-life applications and focused on basic and extending fraction concepts (e.g., fraction equivalence and ordering, extending fraction concepts, and extracting fraction concepts). The content ranges of the given tasks and the length of the intervention were determined and validated by six experienced fourth grade math teachers.

Given tasks for the experimental group included the following game characteristics: (1) challenges, (2) a storyline, (3) rewards, and (4) the integration of game-play with learning content. A participant for the experimental group read a mission card, and this mission card told the participant what missions(challenges) he/she had to complete in the OpenSim-supported VR-based environment. The mission card was written based on the storyline that would help the participants immerse themselves into the simulated scenario(Storyline). It wrote, “You are preparing a picnic for your four best friends: Joe, Wilky, Grace, and Julie. You are the team leader and in charge of getting the food for their picnic. You have to complete four challenges in order to get your best friends meals. Are you ready? Check out your first challenge!” The
participants were given four challenges (see Appendix B); first challenge was, “Wilky wants \( \frac{1}{2} \) of a sandwich. If he eats \( \frac{1}{2} \) of a sandwich every day of the week, what is the total amount he has eaten?” The second challenge was, “Joe, Wilky, Grace, and Julie all want a whole pizza for themselves. Substop has 1 \( \frac{2}{7} \) of a cheese pizza left and 2 \( \frac{6}{7} \) of a pepperoni pizza left for today. Q1: Is there enough pizza left for each person to have a whole pizza? Q2: How much pizza will be leftover? The third challenge was, “Joe wants his sandwich cut into 12 pieces. He will eat 11 out of the 12 pieces. \( \frac{1}{12} \) of the sandwich remains. Write a fraction equivalent to \( \frac{1}{12} \), and then change that fraction to a decimal.” The fourth challenge was, “Julie wants \( \frac{3}{4} \) of a chocolate chip cookie. Grace wants \( \frac{2}{3} \) of an oatmeal cookie. Who has the bigger cookie?” Each challenge required fraction knowledge application and all challenges being interrelated. At the end of each task, rewards (i.e., virtual money) were provided if a participant selects the correct answer. The tasks were designed to allow the participant to make continuous attempts if the participant was unable to solve the problem on the first attempt. Correct answers led to follow-up questions with rewards (i.e., virtual money). The rewards were accumulated throughout the game. Incorrect answers provided options for a participant to either make another attempt at answering the question or choosing an option to end the game.
Table 2. Learning Activity Difference between the Experimental Group and the Control Group in the Context

<table>
<thead>
<tr>
<th>Experimental Group (GBL Activity= Four Game Characteristics)</th>
<th>Control Group (Non-GBL Activity= Non Four Game Characteristics)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Challenges: Numbers on the table in Figure 2 indicates the level of the challenges</td>
<td>No challenges, only task given</td>
</tr>
<tr>
<td>Storyline: Mission card presented</td>
<td>No storyline</td>
</tr>
<tr>
<td>Reward: Virtual money used</td>
<td>No reward(virtual money) used</td>
</tr>
<tr>
<td>Integration of game-play with learning content</td>
<td>No game characteristics. Thus, game-play did not take place.</td>
</tr>
</tbody>
</table>

Note: *A challenge--a mission requiring math knowledge/skills to solve; multiple missions are connected and sequenced to serve the game goal. Game-play emerges from the interaction among the game characteristics.*

The control group was given the same tasks and learning environment setting that was used for the experimental group (see Figure 2). The exception was that these tasks did not include the aforementioned four game characteristics. The non-game-based learning activity for the control group involved mainly web-based word problems (e.g., selecting the correct answer by clicking on the choices). The other parts of the VR-based learning environment were the same between the experimental group and the control group. The duration of the intervention was approximately 30-40 minutes as the same as the experimental group as well.

Based on previous game studies, the lengths of the interventions typically range from a 15-minute game session for children ages 14-16 (Pillay, 2002) to one semester (Rai, Wong, & Cole, 2006; Wellington, Faria, & Nulsen, 1996). Van Eck (2006) used approximately 50 minutes sessions for 7th and 8th graders between the ages of 12-15. The average length of interventions can be inferred to be 20-45 minutes for children ages 8-14 (Cameron & Dwyer, 2005; Conati & Zhao, 2004; Ravenscroft & Matheson, 2002). Interventions targeting college students average.
approximately one semester. There is a study that used very short durations; as low as six minutes. The target audience was preadolescents to senior citizens (Johnson, 1993). Vogel et al. (2006) used two weeks with ten minutes per day for children ages 7-12. Considering these previous studies, the length of the intervention for the current study (30-40 minutes) and can be considered a relatively appropriate length.

**Pre-test and Post-test.** The pre-test and post-test items were selected from the CCSS practice items related real-life situations (i.e., real-life applications) where students were asked to apply basic and advanced fraction concepts (e.g., fraction equivalence and ordering, extending fraction concepts, and extracting fraction concepts). Six experienced math teachers were involved in selecting appropriate test questions based on the CCSS practice items. The pre-tests and post-tests (see Appendix D and E) were originally comprised of 18 questions. Based on the pilot test results (described in the following section), two questions were removed (i.e., due to item difficulty and discrimination levels). The score range was from 1-16. The allocated time for test administration was approximately 30-40 minutes each. Six math teachers helped to finalize the number of the test questions, the content range, and the allocated time for both tests. The tests were administered in written format with pencil and paper. The pre-test was administrated 7-10 days prior to the actual experiment.

**Pilot Test Results for Pre- and Post-Test Items.** 23 fourth graders participated in a pre-test and post-test for the pilot study. The assessments were completed approximately 24 hours apart. Item, or question analysis was completed based on the classical test theory (CTT). Item difficulty index (p-value) in CTT represents the percentage of students who answer questions correctly. If the p-value is close to 1, the item was answered correctly by most of the students. In terms of item difficulty level (see Appendix F), the analysis showed that item 3 had a p-value of
1.00 and was thus answered correctly by all students. Therefore, the Statistical Package for the Social Sciences (SPSS) while calculating Cronbach alpha reliability automatically removed item 3. Likewise, item 13 was eliminated from both tests using item discrimination. Final pre-and post-tests omitted items 3 and 13. Also, the reliability of the pilot test in the pre- and post-test was each, 0.78 and 0.81. Also, the reliability alpha of the actual both the pre-and post-tests for the achievement was 0.73 and 0.80, respectively.

**Motivational Quality Assessment Instrument.** This current study adopted the Short Instructional Materials Motivational survey (SIMMS) developed by Keller (1987b) to assess the motivational quality of the instructional materials. The SIMMS is consisting of 16 items. The score range for the SIMMS was from 16-80. The total score range for the SIMMS was from 16-80. Five scales were used for each survey question (1: Not True, 2: Slightly True, 3: Moderately True, 4: Mostly True, 5: Very True). It is a short version of the original IMMS of ARCS (Bickford, 1989).

Some words of the SIMMS have been revised to reflect the context appropriately for the current study; the word, ‘lesson’ has been replaced by ‘activity’ and the word, ‘content’ is replaced by ‘given tasks’ for the comprehension level of elementary school students; the original version was developed for college students. Appendix E presented the revised SIMMS with the inclusion of permission email (see Appendix H). Appendix I included the original version of SIMMS items for the reader to compare if desired. In addition, teachers reviewed the wording of each statement on the SIMMS to verify the appropriate fourth grader reading level.

Scoring for the survey questions (see Appendix J) was adopted without modification to the original version (Keller, 2006, p. 7). The score did not use a sub-scale for each of the four components. Instead a composite score for the total of 16 items was used. The reliability of the
SIMMS was 0.85 (Bickford, 1989, p. 46). The reliability of the current study in the pre- and post-tests each, was 0.84 and 0.78.

**Virtual Reality Environment.** A sandwich shop was created in the OpenSim-supported virtual world. In the center of the sandwich shop, a menu board was displayed. It acted as the white board that a teacher uses in a classroom setting. Participants received the content, necessary information, and tasks to work through the menu board. The SubStore was created to simulate an actual restaurant. Each participant and a facilitator had their own avatars. The facilitator (avatar) was present throughout the entire experiment for both the experimental group and the control group in order to provide the participants with technical support when necessary. Examples of the virtual settings are shown on Figure 3 and Figure 4.

![Figure 3. Virtual reality setting screen capture (outside of sandwich shop)](image)
Procedures

All procedures for the study took place at the computer laboratories of local elementary schools in Florida. All participants were randomly assigned into two groups: the experimental group and the control group. To randomly assign individual students, a random sequence generator was used. Every participant in the study was assigned an identification number between 1-132. Each school assigned experimental and control groups randomly within the school’s sample. For example, at school #1, there may be 20 participants. These 20 participants were randomly and evenly assigned to the control and experimental groups by using the random sequence generator. Numbers (N=20) were entered into the random sequence generator and two columns were formed. Column 1 represented the control group and Column 2 represented the experimental group. This process was repeated for each school, and the span of numbers was dictated by sample size.

All participants were given a pre-test between 7-10 days prior to the actual experiment. All participants were given preliminary instruction before beginning the experiment (see Appendix A). Preliminary instruction demonstrated how to use an avatar, how to move around,
what the participants had to do while participating in this study, outlined materials given, and how to ask for help. There were approximately 10-15 minutes allocated for preliminary instruction.

When the session began, each student was given 30-40 minutes to solve the given tasks (a total of four tasks). A facilitator was present the duration of the entire session. After completing the session, students were given a ten-minute break. Following the break, post-tests for achievement and motivation were given. The total estimated time duration would be 1.5-2 hours for a participant to complete this current study. Each school provided either a computer lab or a classroom where a participant could concentrate on the experiment without being interrupted by other students or teachers.

Steps for a participant to follow:

1. Take pre-test (7-10 days prior to participating in the experiment) on achievement and the post-test on the SIMMS.
2. Be seated in front of the computer with the facilitator in the computer laboratory at his/her school.
3. Participate in preliminary instruction (approximately 10-15 minutes).
4. Participate in solving the four given tasks (approximately 20-30 minutes).
5. Take the post-test (approximately 20-30 minutes) on achievement and the post-test on the SIMMS (approximately 10 minutes).

Notes

- All participants were only allowed to ask questions regarding technology issues during the experiment. The facilitator did not answer questions related to any of the assigned tasks.
**Study Design**

This study used a pre-test and post-test control group design. The participants were randomly assigned into two groups; the experimental group received a game-based learning (GBL) activity, and the control group received a non-GBL activity. The independent variable was GBL. The GBL in the study was defined as an instruction incorporating game characteristics. The GBL in the study encompassed the selected four game characteristics were: (1) challenges, (2) a storyline, (3) rewards, and (4) the integration of game-play with learning content. The dependent measures were the learning achievement test performance and the perceived motivational quality of a learning activity (MQLA). The pre- and post-test items for math achievement test performance were developed along with six math experts, with its validity and reliability validated by pilot study. The Short Instructional Materials Motivation Survey (SIMMS) developed by Keller was used to measure motivational quality of the learning activity. A post-test was developed to measure the learning achievement.

**Power Analysis and Data Analysis**

The number of the participants (N=128) was drawn from power analysis using G*Power 3.1 software (Faul, Erdfelder, Buchner, & Lang, 2009). A power analysis conducted for an $F$ test of the differences between the treatment and the control group in analysis of covariance (ANCOVA). The suggested sample size (N=128) presented was based on the effect size (0.25), an alpha level ($\alpha$) of 0.05, and an 80% (0.80) power rating, which resulted in a power of 0.8 (see Appendix K).

The improvement in scores from the pre-test to the post-test was checked whether it was greater for the treatment group than the control group by calculating the differences between the pre-test and post-test scores for the individuals. A t-test of mean differences between the two
independent group means was conducted to determine whether the two groups were statistically equal on learning achievement and the perceived MQLA before the intervention.

After implementing the intervention, analysis of covariance (ANCOVA) was used to determine whether there were any significant differences by comparing mean scores of dependent variables, math learning achievement, and the perceived MQLA separately between the two groups. The pre-test scores were used as covariates on each dependent variable (learning achievement and the perceived MQLA). The reason to use ANCOVA was to increase the detectability of treatment effects by statistically controlling a covariate because additional variable, which is not a part of the main experimental manipulation, but could influence the dependent variables.
CHAPTER 4

RESULTS

This chapter provides the results of the current study. This study used a pre-test that all participants were tested on prior to participating in this study. A post-test was used after the completion of the session. The two test forms were not isomorphic, but they were equivalent in content scope. For all statistical analysis, SPSS version 22 was used, and the alpha level was set at 0.05.

The information of general descriptive statistics was presented. Analysis of covariance (ANCOVA) was used to answer research hypotheses 1 and 2. The pre-test scores for research hypotheses 1 and 2 were each used as a covariate in the study.

General Descriptive Statistics on Learning Achievement

Table 3. Descriptive Statistics for Experimental and Control Groups on Learning Achievement

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test Achievement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>66</td>
<td>11.45</td>
<td>2.814</td>
</tr>
<tr>
<td>Control</td>
<td>66</td>
<td>9.14</td>
<td>3.181</td>
</tr>
<tr>
<td>Post-test Achievement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>66</td>
<td>13.88</td>
<td>2.222</td>
</tr>
<tr>
<td>Control</td>
<td>66</td>
<td>10.74</td>
<td>3.115</td>
</tr>
</tbody>
</table>

Although the participants in the current study were randomly assigned into two groups (treatment vs. control), a t-test of mean differences between the two independent group means was conducted to confirm whether the two groups were statistically equal on the pre-test scores before the treatment. The data showed that the two groups were significant ($p = 0.001$) on the
pre-test scores. Thus, conducting ANCOVA with controlling pre-test scores as a covariate in the current study was ensured to reduce additional variables that were not a part of the main experimental manipulation, but could have an influence on the dependent variable in the study. The five assumptions of ANCOVA to provide valid results were as follows:

(1) **Independence of Observations.** This study used a pre-test and post-test control group design. The participants were randomly assigned into two groups. During the recruiting and test taking (i.e., pre- and post-tests) process, all participants had taken the pre-and post-tests during the same session. No particular concerns for violations of independence of observations were anticipated.

(2) **Homogeneity of Variances.** The Levene’s test of equality of error variance ($p = 0.04$) was significant. Thus, the homogeneity of variances was checked by plotting a scatterplot of the standardized residuals against the predicted value (see Appendix K), which is shown circled in red. The residuals plot showed a decrease toward the end of the plot. Based on the data from the Levene’s test of equality of error variance and the residual plot, the assumption for homogeneity of variance did not seem to be met. However, the equal sample size in the two groups brings robustness in ANCOVA.

(3) **Normality.** Normality was examined with the histogram for the residuals from the ANCOVA model. Based on the histogram (see Appendix L), the histogram appeared to be not severely different from a normal distribution shape.

(4) **Linearity.** Linearity was checked by plotting a grouped scatterplot of the covariate, and the post-test scores of the dependent variable, learning achievement (see Appendix M). The correlation between the covariate and the dependent variable was strong, [(Pre-test, Post-test) $r = 0.73, p = 0.001$]. It can be interpreted that the covariate was linearly related to the dependent
(5) **Interaction Effect.** The interaction term was checked between the groups and the covariate. The interaction term (Group * a covariate, \( p = 0.17 \)) was not significant because it was larger than the alpha level of 0.05. This suggests that the use of ANCOVA is deemed appropriate for use in this study.

**Research Hypothesis 1**

After controlling for the covariate (pre-test scores), there is a significant difference between the experimental group and the control group in the post-test scores on learning achievement that focuses on applying knowledge of fractions in real-life situations.

Table 4. **ANCOVA Results for Learning Achievement**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>1</td>
<td>84.96</td>
<td>84.96</td>
<td>21.34**</td>
</tr>
<tr>
<td>Covariate</td>
<td>1</td>
<td>438.26</td>
<td>438.26</td>
<td>110.12</td>
</tr>
<tr>
<td>Within groups</td>
<td>129</td>
<td>513.38</td>
<td>3.98</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>131</td>
<td>1036.61</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** F test value is significant at the 0.05 level.

The result of ANCOVA for the intervention of this current study on learning achievement was significant, shown above in Table 3, [F (1, 129) = 21.34, \( p < 0.001 \)]. The partial eta squared\(^1\) value is 0.14, which is considered to be large. Cohen’s d is for the two independent group comparison case. It should be noted that the usual Cohen’s d is not appropriate for the ANCOVA analysis and hence not reported here (Brown, 2008). The significance in the result indicated the

\(^1\) According to Cohen (1997), Partial eta squared may be interpreted as. 01 = small effect size, .06 = medium effect size, .14 = large effect size.
adjusted post-test mean of the experimental group on math learning achievement was higher by 1.72 than the control group (11.45), and this small difference was significant ($p = 0.001$). The result of ANCOVA on learning achievement supported research hypothesis 1.

**Descriptive Statistics on the Perceived MQLA**

Table 5. *Descriptive Statistics for Experimental and Control Groups on MQLA*

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-Test MQLA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>66</td>
<td>55.03</td>
<td>12.17</td>
</tr>
<tr>
<td>Control</td>
<td>66</td>
<td>54.24</td>
<td>11.00</td>
</tr>
<tr>
<td><strong>Post-Test MQLA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>66</td>
<td>66.79</td>
<td>8.99</td>
</tr>
<tr>
<td>Control</td>
<td>66</td>
<td>65.42</td>
<td>8.80</td>
</tr>
</tbody>
</table>

Although the participants in the current study were randomly assigned into the two groups (treatment vs. control), a t-test of mean differences between these two independent group means was conducted to confirm whether the two groups were statistically equal on the pre-test scores in the population before the treatment. The data showed that the differences between the two groups were non-significant ($p = 0.92$). Five assumptions of ANCOVA to provide valid results were as follows:

(1) **Independence of Observations.** This study used a pre-test and post-test control group design. The participants were randomly assigned into two groups. During the recruiting and test taking (i.e., pre- and post-tests) process, all participants had taken the pre-and post-tests during the same session. No particular concerns for violations of independence of observations were anticipated.
(2) **Homogeneity of Variances.** The Levene’s test of equality of error variance \((p = 0.77)\) was not significant. A scatter plot for the standardized residuals against the predicted value (see Appendix N) circled in red does not appear to be particularly problematic, although clustering occurred toward the middle of the plot.

(3) **Normality.** The normality was examined with the histogram (see Appendix O) for the dependent variable, the perceived MQLA. The histogram appears to be in a positively skewed shape.

(4) **Linearity.** Linearity was checked with the Pearson Correlation. The correlation between the covariate and the dependent variable, the perceived MQLA, \([r \text{ (pre-test, post-test)} = 0.21, p = 0.02]\), appeared to be weak, but still significant. The scatterplot indicated that students who had low scores between 28-45 points on the pre-test (covariate) showed unexpectedly higher scores on the post-test (see Appendix P). This might explain the weak correlation. However, the p-value of the post-test scores \((p = 0.02)\) was significant. The covariate was still linearly related to the dependent variable.

(5) **Interact Effect.** The interaction term was checked between the groups and the covariate. The interaction term \((\text{Group} \times \text{a covariate}, p = 0.23)\) was not significant because it was larger than the alpha level of 0.05. Thus, this study could use an ANCOVA.

**Research Hypothesis 2**

After controlling for a covariate (pre-test scores), there is a significant difference on the post-test scores on perceived motivational quality of the learning activity (MQLA) between the experimental group and the control group.
The result of ANCOVA for the intervention of this study on the perceived MQLA was not significant, as shown above in Table 5, \[ F (1, 129) = 0.84, p = 0.37 \]. Overall, the result indicated that there was no significant difference on the post-test scores on the perceived MQLA between the experimental group and the control group. The result of ANCOVA on the perceived MQLA did not support research hypothesis 2.

**Additional Analyses**

Results for research question 2 did not show a significant difference in the perceived Motivational Quality of the Learning Activity (MQLA) between the experimental group and the control group while using the pre-SIMMS scores. However, students’ prior knowledge of fractions may affect the results of research question 2.

Another ANCOVA analysis was conducted adding students’ pre-test scores in the knowledge test as another covariate along with the first covariate (pre-test scores from SIMMS). The results showed that the interaction terms (between the two covariates and the groups) was significant \( p < 0.001 \). This result violated one of the assumptions in the ANCOVA. Therefore, the ATI model (Aptitude-Treatment Interaction Model) was conducted. However, the result of the ATI model for the intervention on the perceived MQLA still showed non-significance \( p = 0.47 \).
MANOVA. Multivariate analysis of variance (MANOVA) was conducted to test whether there was a statistically significant difference between the groups on the perceived MQLA based on the items categorized by the ARCS components (Attention, Relevance, Confidence, and Satisfaction). The result of MANOVA for the intervention on perceived MQLA was not significant. Also, one more MANOVA was run limited to the four items due to the large range of the mean scores between the groups. The four limited surveys’ responses (e.g., question #4, question #10, question #11, and question #13) were: (1) task difficulty, (2) writing style of the lesson, (3) understanding of fractions lesson, and (4) impact of the reward. However, the result of the MANOVA on these four items revealed a significant MANOVA effect exclusively for only survey question #10 (“The exercises in this lesson were too hard”), \[F (1, 129) = 0.342\], on the pre-test, and \[F (1, 129) = 1.991, p = 0.037\]. No other significant differences were found on the rest of the four items.
CHAPTER 5

DISCUSSION

This chapter provides an overview of the discussion for this current study. Findings were discussed as they related to research question 1 and 2. Then the limitations of this study were addressed, followed by implications for education practitioners. Future research was suggested at the end of this study.

Overview

The purpose of this study was to examine whether Game-Based Learning (GBL) that encompasses particular game characteristics in an OpenSim-supported virtual reality (VR) learning environment can improve mathematical achievement and motivation for elementary school students toward math learning, specifically for fourth graders. An imperative result of the study was that GBL embedded the four game characteristics (challenges, a storyline, immediate rewards, and the integration of game-play with the learning content) had a positive effect on learning achievement. On the other hand, the intervention did not show a positive effect on the perceived motivational quality of the learning activity (MQLA) in the OpenSim-supported learning environment.

Research Question 1

*Is the learning achievement in a knowledge test that focuses on applying knowledge of fractions in real-life situations higher for fourth graders participating in a game-based learning activity, compared to those participating in a non-game-based learning activity, in an OpenSim-supported virtual reality learning environment?*

The findings of this study showed a positive effect toward using GBL in accordance with math learning. Specifically, the results showed that GBL used the four particular game...
characteristics (challenges, a storyline, rewards, and the integration of game-play with learning content) could improve math achievement in an OpenSim-supported VR learning environment. This result is consistent with previous studies stating that GBL produces a positive learning outcome (Chen et al., 2012; Su & Cheng, 2013). Meanwhile, the results from the current study support a prior study reporting that a learner’s ability to transfer teaching materials into real life use can be enhanced through the use of GBL (Chang et al., 2009) as well.

There are several possible reasons why GBL promoted math learning achievement in the current study. The practical exercises combined with rewards, one of the four characteristics, could have influenced to improve learning achievement. This idea is supported by previous research stating that the reward is one of the most important elements in game structure to stimulate more active learning and to help players sustain in game-play (Moon, Jahng, & Kim, 2011). Tangible rewards are also one of the pedagogic benefits to influence game play (Whitton, 2012) for students. In addition, when students faced challenges that were difficult, but accomplishable while participating in the GBL activity, the challenges could have assisted the students to keep immersed in their play, and eventually supported learning. The significance of presenting appropriate levels of challenges was addressed by the previous studies (Garris, 2002; Malone & Lepper, 1987; Riber & Matzko, 2001) which argued that the challenge of one of the game features used in order to promote positive learning outcomes toward learning games.

Another factor that might have contributed to the positive effect for learning achievement is the storyline embedded in the study. The storyline was based on a real-life-like situation that students frequently encounter so students can naturally relate to their personal experiences, while connecting to the learning content. The storyline also helped students to follow the flow of GBL. This game feature was aligned with the previous studies (Dickey, 2007; Morengo-Ger et al.,
2008; Rieber & Matzko, 2001; Rioeber & Noah, 2008) highlighting that the narrative or storytelling could provide contextual references, as well as complexity of interactions to the game activities.

Four studies, shown in Table 6 below used GBL in a computer learning environment in math education. Not all of studies clearly presented game characteristics (i.e., elements, features) used in their studies. These game characteristics displayed in Table 7 were inferred based on their game contexts. As stated earlier in the literature review section (p.11-p.13), three studies (Chen et al., 2012; Ke & Abras, 2013; Ke, 2013) showed a positive impact of using GBL in math learning, but used different game characteristics. As shown in Table 7, though there are common game characteristics used (e.g., rules/goals, rewards, role-play) among these studies, these ‘Game Characteristics Dimensions’ are still insufficient to draw any conclusion that certain game characteristics were more beneficial than the other. These studies did not specifically discuss or provide justifications of selecting game characteristics for their studies. This absence of reasoning may imply the necessity of identifying the appropriate game characteristics and game types that are aligned with the expected learning outcomes for particular subjects and learning objectives (Amory, Naicker, Vincent, & Adams, 1999) that teachers can easily customize and tailor to their classroom (Ke, 2008).

Table 7. Game Characteristics Dimensions

<table>
<thead>
<tr>
<th>Study</th>
<th>Challenges</th>
<th>Rules/Goals</th>
<th>Rewards/Scores (=Game Money)</th>
<th>Interaction</th>
<th>Role-Play</th>
<th>Feedback/Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chen et al (2012)</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ke &amp; Abras (2013)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Ke (2013)</td>
<td>x</td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vogel et al (2006)</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Research Question 2

*Is the perceived motivational quality of the learning activity higher for fourth graders participating in a game-based learning activity, compared to those participating in a non-game-based learning activity, in an OpenSim-supported virtual reality-learning environment?*

Results of this study did not show a significant difference in the perceived MQLA between the experimental group and the control group. Based on the overall result of students’ perceived MQLA, GBL did not seem to influence the students’ motivation. The results appeared to be inconsistent with the previous research finding that GBL method increased motivation in math learning (Chen et al., 2012).

There was a similarity that emerged between the groups: preference toward an OpenSim environment. At the same time, four distinguishable differences between the groups in the pre-test scores in the SIMMS were found from the survey’ responses: (1) task difficulty, (2) writing style of the lesson, (3) understanding of fraction lesson, and (4) impact of the rewards.

**Preference toward an OpenSim Environment.** Survey question #16—“I like this lesson”, (Five scales of survey measurement--1: Not True, 2: Slightly True, 3: Moderately True, 4: Mostly True, 5: Very True). Although the result of research question 2 did not show a significant difference toward MQLA, the increased scores in the post-test from both groups showed positive attitudes toward learning the tasks utilized with an OpenSim environment, compared to print-based resources (e.g., worksheet, in class lectures). The mean score in the pre-test on survey question #16 (i.e., cognitive gains in printed-based resources) for both groups were nearly the same (experimental group score: 3.4 vs. control group score: 3.3). The mean score in the post-test scores on survey question #16 for both groups increased to 4.6 and 4.5, respectively. This result implied that learners might have become bored with mundane tasks (i.e.,
printed-based resources, worksheets) given by teachers. Two survey questions (survey question #2, “The pages of this lesson looked interesting”, and survey question # 4, “The style of writing in this lesson is boring”) on the SIMMS responses showed the increased scores on the post-test for both groups. These two survey questions did not directly question whether students felt bored with the printed-based resources. But participants’ responses for these two survey questions might provide a clue of the conjecture. In addition, Carr (2012) stated that GBL provides students a more interesting and immersive environment. Participants’ preferences toward an OpenSim environment supported the positive aspects of GBL environments in motivating students to learn and engage them in the activities (Chang et al., 2009; Jong, Lai, Hsia, Lin, & Lu, 2013). Meanwhile, participants’ responses to the open-ended questions in the SIMMS (see Appendix G), support participants’ preference of an OpenSim environment as well.

As stated earlier, there are findings in this study that showed some differences between these two groups: (1) task difficulty, (2) writing style of the lesson, (3) understanding of fraction lesson, and (4) impact of the rewards.

**Task Difficulty.** For survey question #10 (“The exercises in this lesson were too hard”), the experimental group indicated that printed-based resources were more difficult than the learning activity in an OpenSim-supported learning environment (the difference of the total scores on survey responses on question #10 between the two groups was 10 points), while the scores for the control group indicated that the learning activity in an OpenSim-supported environment was only slightly (1 point higher) more difficult than that of the printed-based instruction. The analysis in survey question #10 revealed a significant effect on the perceived task difficulty between the groups.
The potential reason of this finding might arise from student’s attitude toward the learning materials. This idea is supported by the literature on the positive association between affective factors (e.g., attitude, motivation etc.) and academic achievement (Allison, 2012; Gottfried, Marcoulides, Gottfried, Oliver, & Guerin, 2007; Lewis, Ream, Bocian, Cardullo, Hammond, & Fast, 2012). During the experiment, students in both groups followed instruction relatively well. However, some students from the control group who answered given tasks incorrectly appeared to be unfocused on the tasks. The instances of their behavior were: (1) creating new objects, (2) flying around in the sandwich shop while working on the given tasks, (3) attempting to get out of the sandwich shop to explore others areas, and (4) playing with objects without attempts to find a correct answer. On the other hand, when students from the experimental group answered incorrectly, they selected feedback (i.e., hints) options or asked the facilitator to elaborate the hints for additional help.

Writing Style of the Lesson. Survey question # 4 (“The style of writing in this lesson is boring”) is related to the ‘attention’ component of the ARCS model (Keller, 2008). The responses for survey question #4 indicated that both groups reported higher scores on the learning activity in an OpenSim-supported environment than the printed-based resources. The summed scores in the survey responses for question #4 were; experimental group score: 55, vs. control group score: 73. The possible reason of this finding is that the writing style of the lesson used in the printed-based resources is less likely to capture students’ attention on their learning tasks (Feng & Tuan, 2005). The result supports the importance of grabbing the students’ attention (Feng & Tuan, 2005; Malik, 2014) to improve performance goals in learning.

Understanding of Fractions Lesson. A participant’s understanding of the fraction lesson was assessed by survey question #11 (“I could understand most of this lesson”) on the
SIMMS that is related to the ‘confidence’ component of the ARCS model. The responses on item 11 indicated different responses from both groups. The experimental group’s responses indicated that the learning activity in an OpenSim-environment was easier to understand than the printed-based-resources for the summed scores (the experimental group showed 25 points higher mean scores). In comparison with the experimental group’s responses, the control group’s responses did not show increased scores on survey question #11. This finding is consistent with the perspective from previous studies stating that the integration with games and mathematics may reduce fear of learning mathematics (Chang & Su, 2012; Mayer, Mautone, & Prothero, 2002) and help to build confidence. Meanwhile, a better understanding of the fraction lesson from the experiment group might result from the students’ learning experience. Such experience enables students to learn by doing and applying what they had learned in real-life situations, and thus students were engaged in completing the tasks successfully in the learning activity (Chen, Chuang, & Liu, 2012). These “learning by doing” and “active learning” behaviors are essential constructivist principles that underlie GBL (Yang, 2012, p.365; Richey, Klein & Tracey, 2011, p.133).

**Impact of the Rewards.** The responses from both groups on survey question #13 ("I felt rewarded for my work because of the way that the answers to the exercises") showed increased scores on the post-test. This implied that both student groups felt more rewarded for their work in an OpenSim-supported VR learning environment compared to the printed-based resources (i.e., worksheets). One notable result from the students’ responses was that the experimental group still showed 20 points higher than the control group scores (the summed scores from survey responses on survey question #13). The result indicated that the experimental group students were motivated by rewards (e.g., virtual money). This result is consistent with the
previous studies showing that rewards motivate further learning (Larsen, 2012), as well as an appropriate reward (e.g., moving up a level, and gaining a new artifact) that supports ongoing motivation for learners (Whitton, 2012, p. 253). Meanwhile, the result on impact of rewards showed that rewards used as one of the four game characteristics (i.e., challenges, a storyline, rewards, and the integration of game-play with the learning content) in the current study also influenced to positively motivate students.

Overall, the intervention in this study was not able to show a significant difference on the perceived MQLA between the two groups; both groups still showed increased scores on the post-test. This may imply that students from both groups enjoyed the OpenSim-supported VR learning environment. This result might assure that an OpenSim-supported VR learning environment could also act as a good stimulant for elementary students as an exciting new environment in math learning. An OpenSim-supported VR environment might bring students meaningful educational experiences (Roussou, 2004).

**Implications**

According to scholars (Ball & Bass, 2000; Hill, Rowan, & Ball, 2005), a crucial factor in students’ learning outcomes is closely related to students’ learning experiences that teachers can bring into the classroom. From the current study results, GBL with the four game characteristics (i.e., challenges, a storyline, rewards, the integration of game-play and the learning content) could support the applications of math knowledge of fractions in real-life situations. This finding is aligned with the perspective by the Vatuli and Rohs (2007) study that learners need to have student-centered experiences through GBL applications (e.g., iPad) which can pique their interest (Carr, 2012). It supported the positive aspects of GBL environments for active and meaningful learning (Chang et al., 2009; Jong, Lai, Hsia, Lin, & Lu, 2013).
The four specific game characteristics used in the present study which might be used as a reference or a conceptual design framework in designing GBL math education. These design conjectures may aid teachers to appropriately customize their lessons tailored to GBL in a classroom. In addition, VR using an OpenSim environment could be positioned as a game environment that can reduce the concern for the budget. This might be another benefit for teachers to consider.

The results of the study showed that adding GBL to an OpenSim-supported VR learning environment can improve math learning achievement, by providing students with opportunities to practice math knowledge in real-life tasks. The embedded game characteristics in the study can be suggested as salient design elements of a VR-supported, GBL learning environment. The study results should inform teachers on how to appropriately design and implement GBL in the school setting.

On the other hand, the experimental group and the control group did not show a significant difference on the perceived MQLA. Both groups presented increased scores on the learning activity in an OpenSim-supported VR learning environment. This result may imply that both groups enjoyed learning in an OpenSim-supported VR environment regardless of academic achievement. This result supports a claim from the studies that showed a limited causal relationship between achievement and related affected factors, such as attitude and motivation (Rennie & Punch, 1991; Schibeci & Riley, 1986; Singh et al., 2002; Willson et al., 2000).

According to the previous literature reviews (Papastergiou, 2009; Thomas, Thomas, Mark & Elizabeth, 2011; Miller, Chang, Wang, Beier & Klisch, 2011), students feel that the printed-based resources (i.e., textbooks, worksheets) may require activities to memorize many rules, and follow numerous steps, but lack practical applications. This perspective may explain
the reason for the results shown for the students’ preferences toward an OpenSim-supported VR learning environment.

Lastly, the previous studies (Gregory & Masters, 2012, p.424; Mamo et al., 2011, p.121) stated that preliminary training is needed to make students feel comfortable using a VR learning environment. The study results partially supported the necessity of the preliminary training for students. This study provided informal verbal instruction (less than 5 minutes) on the activity prior to participating in the experiment. All participants were given approximately 10 minutes to become familiar with the use of the OpenSim-supported VR learning environment before participating in the learning activity. None of the participants mentioned having any difficulty in the use of the OpenSim-supported VR environment during the activity. Instead, many students insisted in having more time to play after they completed their participation.

Overall, the integration of OpenSim-supported VR and GBL could show a positive effect on learning achievement in mathematics. Meanwhile, the result implied that OpenSim-supported VR learning environments could be a potential solution for the GBL environment, as well as playing the role of a motivator to promote math learning for students.

It should also be noted that there were approximately 20 students that were not able to participate in the experiment due to their lower levels of mathematical skills in fractions. They exceeded the allocated intervention time (20-30 minutes) without being able to understand even the first given task. They were mostly from technical, arts or alternative schools. This information suggested that students who want to play this GBL activity may need to have a certain level of prior knowledge and skills on fractions, which reflected the original design assumption of the present study. The current GBL activity was designed to provide students an
opportunity to practice their learned math knowledge and skills in fractions in order to promote the applications of math knowledge of fractions in real-life situations.

**Limitations of the Study**

The length of the intervention was chosen based on the literature of game research, but it was not sufficient for the participants to fully enjoy their game play. Not many schools were willing to participate in the current study due to the preparation of standardized testing, thus the majority of the participants were under the pressure of missing class time in their school while participating in this study. That might have affected their attitude or motivation toward this study. Although the results from this study showed that the treatment showed a difference in academic measure (i.e., math learning achievement), multiple sessions of the intervention or longer time lengths might better promote the effectiveness of the intervention.

A single individual (researcher) was primarily responsible for the entire research process. The facilitating ability in conducting the experiment, and the design skills of the game environment might have affected to the extent of a more powerful impact. The participant schools were mostly charter schools and research developmental schools, which were 57% students African American. Thus, the study result suggested that integrating game characteristics to a virtual-reality-based learning environment should promote learning for a learner group that includes minority students.

**Suggestions for Future Research**

The focus of this study is limited to the four game characteristics. Diverse game characteristics using dynamic visuals, interaction, rules, goals and others that have been popular in game research should also be examined. Also, the present study employed the four game characteristics and examined whether these four game characteristics promoted students’ math
performance. Students’ perceived gaming characteristics in the GBL should be investigated. A series of experimental studies that will systematically examine individual game elements is necessary for the better in-depth understanding of the impact on math performance.

A longitudinal study can help to test whether there is a novel effect toward an OpenSim learning environment. More empirical research is needed on how to identify the appropriate game elements and types which are aligned with the expected learning outcome for the specific subject, in order to use GBL as an effective and practical tool in terms of utilization by teachers in their classes. Under the same learning context, examining the effects of GBL activity with the gender differences considered may lead to different solutions to enhance math performance.

Additionally, a collaborative learning activity in an OpenSim-supported VR learning environment along with a longer intervention, and using students from various elementary grades should be adopted for the future research on the effects of a game-based, VR-supported learning environment.

Lastly, future research should recruit private and public schools to examine the intervention with a more diverse population since the participated schools were mostly charter schools with a large population of minority students.
APPENDIX A

PRELIMINARY INSTRUCTION

Instruction

**Description:** In the computer lab, a facilitator will stand in the front facing the participants. Computers will be loaded with appropriate software and logged in prior to the experiment. Participants will be assigned a computer. An avatar should be ready to move around once a participant touches his/her mouth.

A Facilitator will provide three important instructions.

**First instruction: Demonstrate how to use an avatar**

A facilitator will demonstrate how to use and move around an avatar and give the participants time to practice with their computers.

**Second instruction: Provide information about the number of tasks and assigned time duration.**

A facilitator will provide information that each participant will be asked four questions and that they will be given 20 minutes to solve the tasks. However, participants will be allowed additional time if necessary to correctly complete the tasks.

**Third instruction: Notify participants that they can ask questions and seek for assistance, at any time while participating.**
APPENDIX B

FOUR CHALLENGES FOR THE EXPERIMENTAL GROUP

Challenge 1

Note: A player enters the sandwich shop and will be given the first challenge displayed on the center of the menu board. The facilitator will be present with the player. The facilitator will ask the player to stand in front of challenge table #1. The player will begin to work on Challenge# 1. The player will move the sandwich pieces above the tray in table 1 in order to solve challenge #1. If the player gets a correct answer, the player walks to the cashier to get his/her virtual money from the facilitator. The player will place virtual money wherever he/she wants to put it (e.g., Virtual money on the tray on the table #1). If the player gets an incorrect answer, she/he can either make continuous attempts if desired or have the option to quit the game.

Challenge 2

Note: Once the player gets a correct answer from challenge #1, then the player will have an opportunity to move up to the next challenge. Then, the same event will happen as described in note for Challenge #1 (in the case for a correct answer & for the case of an incorrect answer). This same pattern will continue for all players until Challenge #4.
# APPENDIX C

## FOUR QUESTIONS FOR THE CONTROL GROUP

### Task 1

![Task 1 image](image1)

**Note:** A participant will enter the sandwich shop and will be given the first task displayed on the center of the menu board. The facilitator will be present with the participant. The facilitator will lead the participant to where he/she can play with the sandwich pieces on the far left side. The participant will begin to work on Task #1. The participant will manipulate the sandwich pieces on the far left side in order to solve Task 1. If the participant gets a correct answer, the menu will display the words, “You got a correct answer. Good job.” If the participant gets an incorrect answer, she/he can either make continuous attempts if desired or have an option to quit the game. *The three dividers used on the long table to separate the sandwich pieces.*

### Task 2

![Task 2 image](image2)

**Note:** Once the participant gets a correct answer from Task #1, then the participant will have an opportunity to try Task 2. Then, the same event (in the case for a correct answer & for the case of an incorrect answer) will happen as described in the notes for Task #1. This pattern will be given to all participants until Task #4.
APPENDIX D

PRE-TEST FOR ACHIEVEMENT

Student ID:
Date and Time:

Mark the Best Answer.

1. Sharon measured two apples. The green apple weighed \( \frac{3}{8} \) pound. The red apple weighed \( \frac{1}{3} \) pound. Which apple was heavier?

2. Javier and Mark drew straws to see who went down the waterslide first. Javier’s straw was \( \frac{5}{12} \) inch long and Mark’s was \( \frac{7}{12} \) inch long. Which symbol makes the comparison true?

\[ \frac{5}{12} \quad \circ \quad \frac{7}{12} \]

A. \( \times \) B. = C. \( < \) D. \( > \)

3. Does this fraction represent Point P? Mark Yes or No.

\( \frac{3}{4} \) A. Yes B. No

\( \frac{5}{6} \) A. Yes B. No

4. Which of the following numbers is a multiple of 4?

9, 15, 21, 40

Answer:

5. Tracy is at school for \( \frac{7}{4} \) hours each day. One day the school lets out early. She is at school for \( \frac{3}{4} \) hours that day. How much longer is a regular school day? Simplify, if possible.

Answer:

6. What is the sum of \( \frac{7}{8} + \frac{3}{8} \)?

Answer:

Continue to See the Next Page
Mark the Best Answer.

7. What mixed number does this model show?

Answer:

8. Which equation is represented on the number line shown? Please circle your answer.

A. \( \frac{3}{5} + \frac{4}{5} = \frac{7}{10} \)
B. \( \frac{5}{5} + \frac{3}{5} = \frac{1}{10} + \frac{2}{10} + \frac{3}{10} + \frac{4}{10} \)
C. \( \frac{3}{5} + \frac{1}{5} = \frac{4}{5} \)
D. \( \frac{3}{5} + \frac{1}{5} = \frac{4}{5} \)

9. On Tuesday, \( \frac{2}{9} \) of the students in a class wore jeans. What fraction of the class did NOT wear jeans? Please circle your answer.

Answer:

10. Three of the 5 students in Wayne’s reading club are girls. What decimal represents \( \frac{3}{5} \)?
A. 0.15  B. 0.20  C. 0.60  D. 0.75

11. Tracy measured the mass of four samples in a science lab. Which shows the masses in order from the least to the greatest?
A. 3.07, 3.28, 3.38, 3.1
B. 3.38, 3.28, 3.10, 3.07
C. 3.10, 3.07, 3.28, 3.38
D. 3.07, 3.10, 3.28, 3.38

12. Write a multiplication equation with a whole number and a fraction that describes the model shown.

Answer:

13. Which fraction is best represented by point C on the number line?

Answer:
APPENDIX E

POST-TEST FOR ACHIEVEMENT

Student ID: ____________________________  Date and Time: ____________________________

Mark the Best Answer.

1. David measured a black chocolate and a white chocolate. The black chocolate weighed 3/4 pound. The white chocolate weighed 4/6 pound. Which was heavier?

   | 1/4 | 1/8 | 1/8 |
   | 1/6 | 1/6 | 1/6 |

   Answer: ____________________________

2. Luis and Bill raced from their house to the big tree in the backyard, but stopped when their mother called them in. They decided that whoever had gotten farther would win the race.

Luis made it 5/8 of the way and Bill made it 3/8 of the way to the tree. Which symbol makes the comparison true?

   5/8 ___ 3/8

   A. <  B. X  C. =  D. >

3. Does this fraction represent Point M? Mark Yes or No.

   | 1/6 | 1/6 | 1/6 | 1/6 | 1/6 |

   Answer: ____________________________

4. Which of the following numbers is a multiple of 7?

   12, 15, 32, 35

   Answer: ____________________________

5. Avi watches a movie that is 2 1/4 hours long. Jenae watches a movie that is 1 3/4 hours long. How much longer is Avi’s movie? Simplify, if possible.

   Answer: ____________________________

6. What is the sum of 5/6 + 1/6?

   | 1/6 | 1/6 | 1/6 | 1/6 |

   Answer: ____________________________

Continue to See the Next Page
Mark the Best Answer.

7. Yao drank $\frac{11}{4}$ bottles of water during a soccer game. What is this number written as a mixed number?
Answer:__________

8. Which equation is represented on the number line shown? Please circle your answer.

A. $\frac{6}{10} - \frac{2}{10} = \frac{4}{10}$
B. $\frac{6}{10} + \frac{2}{10} = \frac{8}{10}$
C. $\frac{6}{6} + \frac{2}{6} = \frac{8}{6}$
D. $\frac{10}{10} - \frac{10}{10} = \frac{0}{10}$

9. On Friday, $\frac{3}{12}$ of the students in class were absent. What fraction of the students attended class?

A. $\frac{12}{12}$ B. $\frac{9}{12}$ C. $\frac{8}{12}$ D. $\frac{3}{12}$

10. Robert has 5 sports movies. Two out of 5, or $\frac{2}{5}$, of his movies are about baseball. What decimal represents $\frac{2}{5}$?  
A. 0.15  
B. 0.4  
C. 0.6  
D. 6.0

11. Which shows the gymnastic scores in order from least to greatest?
A. 9.72, 9.8, 9.78, 9.87  
B. 9.78, 9.72, 9.87, 9.8  
C. 9.78, 9.8, 9.72, 9.87  
D. 9.72, 9.78, 9.8, 9.87

12. Write a multiplication equation with a whole number and a fraction that describes the model shown.

Answer:__________

13. Which fraction is best represented by point D on the number line?

A. $\frac{12}{12}$ B. $\frac{9}{12}$ C. $\frac{8}{12}$ D. $\frac{3}{12}$

Answer:__________
APPENDIX F

ITEM STATISTICS FOR THE PRE-TEST AND POST-TEST

<table>
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<th>Pre-test Items</th>
<th>Pre-test Item Difficulty</th>
<th>Pre-test Item Discrimination</th>
<th>Post-Test Items</th>
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APPENDIX G

SHORT INSTRUCTIONAL MATERIALS MOTIVATION SURVEY

(SIMMS)

1 (or A) = Not true
2 (or B) = Slightly true
3 (or C) = Moderately true
4 (or D) = Mostly true
5 (or E) = Very true

1. The way that the information is arranged on the pages got my attention.
2. The pages of this lesson looked interesting.
3. This fraction lesson made me curious.
4. The style of writing in this lesson is boring.
5. Finishing this fraction lesson successfully was important to me.
6. I can see how the content of this fraction lesson is related to things I already know about
7. The knowledge in this fraction lesson is NOT useful to me.
8. There were stories, pictures, or examples that showed me how this fraction lesson could be important to some people.
9. The way the information was organized made me feel that I could learn this fraction lesson.
10. The exercises in this fraction lesson were too hard.
11. I could understand most of this fraction lesson.
12. After I worked this fraction lesson for a while, I felt that I could pass a test on it.
13. I felt rewarded for my work because of the way that the answers to the exercises were given.
14. I was happy about finishing this fraction successfully.
15. I did NOT think this fraction lesson was well designed.
16. I liked studying this fraction lesson.
Dear Heesung,

Thank you for your interest in the ARCS model and sharing the description of your research project. You are welcome to use the IMMS in your study.

Best wished for success
John K.

John M. Keller, Ph.D.
Professor Emeritus
Educational Psychology and Learning Systems
Florida State University
APPENDIX I

INSTRUCTIONAL MATERIALS MOTIVATION SURVEY (IMMS)

1 (or A) = Not true
2 (or B) = Slightly true
3 (or C) = Moderately true
4 (or D) = Mostly true
5 (or E) = Very true

1. When I first looked at this lesson, I had the impression that it would be easy for me.
2. There was something interesting at the beginning of this lesson that got my attention.
3. This material was more difficult to understand than I would like for it to be.
4. After reading the introductory information, I felt confident that I knew what I was supposed to learn from this lesson.
5. Completing the exercises in this lesson gave me a satisfying feeling of accomplishment.
6. It is clear to me how the content of this material is related to things I already know.
7. Many of the pages had so much information that it was hard to pick out and remember the important points.
8. These materials are eye-catching.
9. There were stories, pictures, or examples that showed me how this material could be important to some people.
10. Completing this lesson successfully was important to me.
11. The quality of the writing helped to hold my attention.
12. This lesson is so abstract that it was hard to keep my attention on it.
13. As I worked on this lesson, I was confident that I could learn the content.
14. I enjoyed this lesson so much that I would like to know more about this topic.
15. The pages of this lesson look dry and unappealing.
16. The content of this material is relevant to my interests.
17. The way the information is arranged on the pages helped keep my attention.
18. There are explanations or examples of how people use the knowledge in this lesson.
19. The exercises in this lesson were too difficult.
20. This lesson has things that stimulated my curiosity.
21. I really enjoyed studying this lesson.
22. The amount of repetition in this lesson caused me to get bored sometimes.
23. The content and style of writing in this lesson convey the impression that its content is worth knowing.
24. I learned some things that were surprising or unexpected.
25. After working on this lesson for a while, I was confident that I would be able to pass a test on it.
26. This lesson was not relevant to my needs because I already knew most of it.
27. The wording of feedback after the exercises, or of other comments in this lesson helped me feel rewarded for my effort.
28. The variety of reading passages, exercises, illustrations, etc., helped keep my attention on the lesson.
29. The style of writing is boring.
30. I could relate the content of this lesson to things I have seen, done, or thought about in my own life.
31. There are so many words on each page that it is irritating.
32. It felt good to successfully complete this lesson.
33. The content of this lesson will be useful to me.
34. I could not really understand quite a bit of the material in this lesson.
35. The good organization of the content helped me be confident that I would learn this material.
36. It was a pleasure to work on such a well-designed lesson.
APPENDIX J

SCORING FOR THE SIMMS ITEMS

Scoring

The survey can be scored for each of the four subscales or the total scale score below the table. The response scale ranges from 1 to 5. This means that the minimum score on the 16-item survey is 16, and the maximum is 80.

An alternate scoring method is to find the average score for each subscale and the total scale instead of using sums. For each respondent, divide the total score on a given scale by the number of items in that scale. This converts the totals into a score ranging from 1 to 5 and makes it easier to compare performance on each of the subscales.

Scores are determined by summing the responses for each subscale and the total scale. Table 8 is revised based on the IMMS scoring guide. Please note that the items marked reverse (Table 8) are stated in a negative manner. The responses have to be reversed before they can be added into the response total. That is, for these items, $5 = 1$, $4 = 2$, $3 = 3$, $2 = 4$, and $1 = 5$.

Table 8

**Scoring Guide**

<table>
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<th>Attention</th>
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<th>Confidence</th>
<th>Satisfaction</th>
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<td>4 (reverse)</td>
</tr>
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<tr>
<td>15 (reverse)</td>
<td>8</td>
<td>12</td>
<td>16</td>
</tr>
</tbody>
</table>
APPENDIX M

HISTOGRAM OF ACHIEVEMENT SCORES

Mean = -2.78E-16
Std. Dev. = .992
N = 132
APPENDIX N

SCATTERPLOTS OF COVARIATE (PRE-TEST) AND ACHIEVEMENT SCORES
APPENDIX O

SCATTERPLOT OF MQLA SCORES
APPENDIX P

HISTOGRAM OF MQLA SCORES

---

Normal
Mean = -2.95E-17
Std. Dev. = .992
N = 132

---
APPENDIX Q

SCATTERPLOTS OF COVARIATE AND MQLA SCORES
APPENDIX R

COMMENTS FROM PARTICIPANTS

Experiment Group

- I would like to play this game at home.
- Boys mostly wrote, ‘Wow’, this is cool.
- This is so neat.
- You did good on making the places and designing the lesson.
- I would like to be able to play this at my house, I want to change my own avatar, and learn math in a fun way.
- This was very well setup, it took time to learn, but the game is interesting.
- This was the best. I would also love to play this at home.

Control Group

- I am learning but I am still having fun, it really brings kids into to a world where learning can be fun.
- I want to do this game again. It was fun.
- I would like to suggest the name for your game, “imagination”
- I really enjoyed it and I want to play more.
- Please send me information if this game will be published.
- I think you should make virtual pets that follow you around.
- I would want to play this game at home or at school! It is fun and a math game at the same time. Please! Please! Please, publish the game
- This was fun.
APPENDIX S

IRB APPROVAL LETTER (FSU)

Florida State University
Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
(850) 644-8673 - FAX (850) 644-4392

APPROVAL MEMORANDUM

Date: 02/18/2015

To: Heeoung Kim [Redacted]

Address: [Redacted]

Dept.: EDUCATIONAL PSYCHOLOGY AND LEARNING SYSTEMS

From: Thomas L. Jacobson, Chair

Re: Use of Human Subjects in Research

Examining the Effects of Game-Based Learning in an OpenSim-Supported Virtual Reality Learning Environment on Mathematical Performance

The application that you submitted to this office in regard to the use of human subjects in the research proposal referenced above has been reviewed by the Human Subjects Committee at its meeting on 02/11/2015.

Your project was approved by the Committee.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals which may be required.

If you submitted a proposed consent form with your application, the approved stamped consent form is attached to this approval notice. Only the stamped version of the consent form may be used in recruiting research subjects.

If the project has not been completed by 02/10/2016 you must request a renewal of approval for continuation of the project. As a courtesy, a renewal notice will be sent to you prior to your expiration date; however, it is your responsibility as the Principal Investigator to timely request renewal of your approval from the Committee.

You are advised that any change in protocol for this project must be reviewed and approved by the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report, in writing, any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the chairman of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Human Research Protection. The Assurance Number is IRB00000446.

Cc: Fengfeng Ke <fke@fsu.edu>, Advisor
HSC No. 2015.14549
APPENDIX T

INFORMED CONSENT FORM

Parental Permission Form
Florida State University

My name is Heesung Kim and I am a doctoral student in the College of Education at Florida State University as a part of the Instructional Systems and Learning Technologies. I am currently working under the direction of Dr. Fengfeng Ke, an associate professor in the College of Education at Florida State University. I am interested in conducting the study about the effects of game-based learning to practice fractions in a virtual learning environment with 4th-6th graders (approximately ages 10-11). I would like your permission to allow your child to participate in this research study. The study intends to examine whether a game-based learning can improve mathematical performance. I am asking that your child take part because your child is in the age group I am interested in studying. I ask that you read this form and ask any questions you may have before agreeing to allow your child to take part in this study.

The study
The purpose of this study is to examine whether game-based learning (GBL) in a virtual reality-learning environment can improve mathematical achievement and motivation for elementary school students toward math learning, specifically 4th-6th graders. Your child will also be asked to complete approximately four to eight tasks in the virtual reality, a post-test and survey. It will take approximately 1-1.5 hours including a break time. All procedures for the current study will take place in a computer laboratory at school where your child attends. While your child completes the given tasks with his/her computer, he/she will be asked to wear a headset (Approximately 20 minutes). Your child will be able to take breaks as he/she needs. Additionally, the child will complete a demographic survey with questions pertaining to age, ethnicity, gender, and previous schooling information.

Risks and Benefits: The risks in this study are that the child could feel discouraged because some questions may be difficult. It is important to keep in mind I am NOT testing your child’s ability and the assessments are not meant to be evaluative. Although there are no personal benefits to you or your child, the study could better inform instructional practices in mathematics education to ultimately improve mathematical performance for elementary school students in the future.

Confidentiality: The records of this study will be kept confidential, to the extent permitted by law. The demographic survey will not include your child’s name. It will not be possible to figure out your child’s answers because names will be removed and all answer sheets will be assigned random numbers. Testing scores will be kept securely for one year after this study ends in a secure server in College of Education at Florida State University. Any report that might be published from this data will not include any identifying information.

Voluntary Participation: Your child’s participation in this study is completely voluntary. Your child may skip any questions he/she does not feel comfortable answering. Your decision whether or not to allow your child to take part will not affect your current or future relationship with Florida State University. If you decide to allow your child to take part, your child is free to not do the demographic survey, skip any questions, or stop at any time. You are free to withdraw your child at any time without affecting your relationship with the University.
Please enter your child’s name and sign below if you give consent for your child to participate in this study.

Print your child’s name (First and Last): ______________________

Parent’s signature: ______________________ Date: ______________

Print Parent(s) or guardian’s name (First and Last):

The primary researcher for this study is Heesung Kim. You can reach me at [email protected], or [redacted]. The major professor that guides this study is Dr. Fengteng Ke. You can reach her at (850) 644-8794 or [email protected]. Please feel free to ask any questions you have now, or at any point in the future. If you have any questions or concerns about your child’s rights as a research subject, you may contact the FSU Institutional Review Board (IRB) at (850) 644-8633 or by email at humansubjects@fsu.edu. You will be given a copy of this consent form for your records.

FSU Human Subjects Committee approved on 3/06/15. Void 2/10/16. HSC # 2015.14973
REFERENCES


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BIOGRAPHICAL SKETCH

Kim, Heesung is originally from Seoul, South Korea and joined in the Instructional Systems and Learning Technologies program at Florida State University in Fall 2011. She received her Master’s degree from Pennsylvania State University in the Learning, Design, and Technology program. Prior to joining the Instructional Systems and Learning Technologies program at Florida State University, she was a Senior Instructional Designer/Project Manager/Researcher at Hyundai Research Institute for four years in order to gain hands-on experiences.