EFFECTS OF A 3-D VIDEO GAME ON MIDDLE SCHOOL STUDENT ACHIEVEMENT AND ATTITUDE IN MATHEMATICS

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A Thesis Submitted to the
University of North Carolina Wilmington in Partial Fulfillment
of the Requirements for the Degree of
Master of Science

Watson School of Education

University of North Carolina Wilmington

2008

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ABSTRACT

Today's student has unprecedented access to media, information, and even global interaction that was unheard of only a few years ago. With all of the various media our students are exposed to daily, engaging student learning in a traditional classroom might prove challenging. The purpose of this study was to determine whether or not a highly interactive, 3-D video game, *Dimension-M,* can achieve the goal of not only positively influencing middle school student achievement in mathematics, but also positively influencing their attitude. In addition, this study examined whether or not gender interacts to influence this hypothesized impact on achievement and attitude.

Cape Fear Middle School created a mathematics remediation course called Virtual Math for students who achieved below proficient levels on their state end-of-grade mathematics exams. The Virtual Math class provided a setting for the study. Achievement and attitude data was collected for 21 girls and 8 boys in grades six through eight prior to their exposure to the video game environment. Following a pre-test and pre-attitude survey, students played the game's Tutorial mission and the Xeno Island mission, which addressed the concepts of prime numbers, even and odd patterns, and perfect squares. Students received no direct mathematics instruction during the treatment period in order to test the impact of the game alone. Following the treatment, a post-test and post-attitude survey were administered.

Students displayed a significant gain in achievement ($t(27) = -3.96$, $p < .05$), but no significant differences were detected between their pre- and post-attitude surveys. An interview with the tutor assigned to the students, the school's math coach, and the principal of the school, indicated a positive impact on students' mathematics performance in their regular math classes as well as a positive impact on students' self-efficacy in mathematics.

The results of the study imply that *Dimension-M* can potentially have a positive impact on student achievement and that students respond enthusiastically to the *Dimension-M* environment.

ACKNOWLEDGMENTS

I'm indebted to Dr. Florence Martin for her guidance and assistance throughout this study. I also salute the administration of Cape Fear Middle School and the Pender County School District for their willingness to try innovative strategies to engage student learning, setting a standard for true 21st – Century education and allowing me to be a part of it. Lastly, I want to thank the Master's of Instructional Technology program in the Watson School of Education for allowing me the flexibility to custom-tailor my graduate experience to incorporate video game studies.

DEDICATION

All of my work and credit is dedicated to my Lord and Savior, Jesus Christ. Without His sustenance and guidance, none of this would have been possible. This work is also dedicated to my wife, Elizabeth, and my two beautiful daughters, Elorah and Teaghan, who have been incredibly supportive of my time spent at the local coffee shop writing. Lastly, I dedicate this to my parents who have made my graduate studies possible and whose prayers and support have been a source of encouragement.

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INTRODUCTION

Background

Today's teachers are faced with a dilemma. Students are exposed to a variety of media on a daily basis. The media exposure presents challenges for teachers striving to engage their students in a traditional classroom setting. Of course finding motivated students, keeping students motivated, and further still, creating motivated learners is not a new problem to education (Skinner and Belmont, 1993). Yazzie-Mintz (2006) the author of *Voices of Students on Engagement*, reports on a survey, conducted by the University of Indiana Bloomington, of over 80,000 students from across the nation, which indicated that at least two out of three students reported being bored in school at least every day, with 17% of those reporting boredom in every class. Traditional classroom teachers are faced with the challenge of delivering instruction that competes with the media-rich and interactive experiences the typical student is exposed to daily.

Today's student has unprecedented access to media, information, and even global interaction that was unheard of only a few years ago. Whether watching television, watching a video on their iPod, interacting with their peers via text-messaging using their cell phone, or playing the latest game on their XBox 360, today's average student is bombarded by interactive media experiences, averaging over six hours daily (Grunwald, 2004). In fact, there is growing evidence in the field of neuroscience that today's student may in fact be "programmed" to learn in ways fundamentally different from the ways that *Baby Boomers* learn (Prensky, 2001) because of their increased exposure to interactive media. When students are faced with lecture-based instruction and repetitive drill-and-practice, many of them quickly lose interest because they crave

interactivity (Oblinger & Oblinger, 2005, p. 46). As one student put it in an interview with games researcher, Mark Prensky, "Whenever I go to school, I have to 'power down'" (Prensky, 2006, p. 10). Clearly, educators in the 21st-Century are faced with the challenge of finding new, interactive ways of teaching age-old concepts in new, media-driven and interactive ways. Mathematics instruction is no exception.

The hypothesis of this study is that the game Dimension-M can positively influence middle school students' achievement in mathematics as well as their attitude.

Student Performance in Mathematics and Remediation

The 2007 National Assessment of Educational Progress in Mathematics indicates that nationwide students are making gains in 4^{th} and 8^{th} grade mathematics (NAEP, 2007); however, not all students score proficiently and often, classroom remediation is utilized to help them achieve proficiency. Innovative remediation strategies across all grade levels have proven valuable in increasing student success in mathematics (Selvin, 1992). School-based remediation programs, such as after-school tutoring, often have a positive influence on student performance as well as their attitude toward the subjects in which they receive tutoring (Cohen, 1982).

Why Student Attitude Is Important

Research conducted by Haladyna and Thomas (1979) indicated that positive student attitude toward school and toward specific subjects such as science or mathematics, tends to decrease with age. Their research demonstrated that students' attitudes toward a specific subject area

become more negative between grades six and seven. In their review of previous studies, Anderman and Maehr (1994) suggest a link between the factors often stressed in the middle school setting as contributing to the motivational problems that occur during adolescence. They go on to suggest that ultimately, a student's attitude toward school and specifically mathematics might lead to their not considering future career options in that field or more drastically could be a factor in their decision to drop out of school. Highly motivated and engaged students are more likely to experience success in the classroom (Dev, 1997).

Self-efficacy, or a student's "judgments of their capabilities to organize and execute courses of action required to attain designated types of performances" (Bandura, 1986, p. 391), can also have an impact on their performance in courses such as mathematics. Pajares and Graham (1999) demonstrated that a middle school student's self-efficacy can be a strong predictor of their potential for success in the mathematics classroom.

Students and Video Games – Why Game Play Is Important for Learning

Researchers in the field of cognitive science have long speculated that play is often coupled with deep learning (Piaget, 1951, Bruner, 1962). Game play can be a valuable tool in student learning.

> Seymour Papert (1998) suggested that: What is best about the best games is that they draw kids into some very hard learning. Did you ever hear a game advertised as being easy? What is worst about school curriculum is the fragmentation of knowledge into little pieces. This is supposed to make learning easy, but often ends up depriving knowledge of

> personal meaning and making it boring. Ask a few kids: the reason most don't like school is not that the work is too hard, but that it is utterly boring. (para 4)

Papert (1993) goes on to say that the computer is the "children's machine" because children can so easily adapt to its digital environment. Factoring in this idea about play in multimedia-rich environments, Lloyd Rieber (1996) suggests that instructional media designers might utilize the constructivist concept of microworlds, or simulated environments, to digitally provide a space for play and thus learning.

It is argued that nearly all good video games have an instructional component (Gee, 2007). Today's popular titles, such as *World of Warcraft, Halo 3*, *The SIMS*, and *Assassin's Creed*, are increasingly complex, requiring the player to invest hours of time learning the mechanics of game play, background story, and even time outside of the game learning strategies and "cheats" in order to master the game (Becker, 2006). Jim Gee (2007) suggests that the principles of learning in "good" video games are better theories of learning than many of our students encounter in a typical classroom. Additionally, research has found that simply playing electronic games can increase critical thinking skills in students who play them (Keller, 1992). It has even been suggested that learning is what games are all about (Koster, 2004).

Research conducted by games researcher, David Shaffer (2006) demonstrated that the use of video games and associated pedagogies can be effectively used in classroom instruction, even teaching us new ways of learning. A study by Kurt Squire (2005) demonstrated that games not marketed as "educational" could be effectively used for instruction, especially with "academic underachievers."

The Pedagogy of Video Games

Becker (2006) argues that some of the most effective lessons have been developed by writers, directors, and producers of film, radio and television, who, not being instructional designers, have produced "outstanding examples of 'educational' objects." She goes on to suggest that video games, as an emerging form of media, can not only be effective educational objects, but also warrant attention for their ability to engage the player's attention for thousands of hours of play.

Gee (2007) states that "good" video games utilize sound learning principles. In their work on the principles of instructional design, Gagné and Briggs (1974) classify five kinds of learning capabilities. These capabilities are: motor skills, attitude, verbal information, cognitive strategy, and intellectual skills. Becker (2006) suggests that "good" video games support each of these and that game designers must use these multiple approaches to aid and challenge the widest range of players. Gagné (1985) outlines nine events of instruction, that when employed by an instructional designer, will support development in each of these learned capabilities. These events are: gaining attention, informing the learner of the objectives, stimulating recall of prior learning, presentation of the content, providing "learning guidance," eliciting performance or practice, providing feedback, assessing performance, and enhancing retention and transfer. Again, Becker (2006, p. 29) states that "When looking at "good" games through lens of Gagné's Nine Events, we find that they do indeed possess the necessary conditions for learning and facilitate the required events."

Becker (2006) further suggests that "good" games meet the seven qualifications of Reigeluth's (1983) elaboration theory, supporting: an elaborative sequence, learning prerequisite

sequences, summary, synthesis, analogies, cognitive strategies, and learner control. Becker (2006) goes on to suggest that these games meet Jerome Bruner's (1996) nine tenets outlined in his psycho-cultural approach to education, and David Merril's (2002) *First Principles of Instruction*, which include activation, demonstration, application, and integration. She also cites ways in which video games address Gardner's (1983) Multiple Intelligences Theory, and a variety of other theories and models utilized in instructional design today.

Characteristics of Video Game Design and Impact on Gender

Just as individuals prefer different genres of movies or books, video game players prefer different genres of video games. Some players prefer strategy titles, such as *Age of Empires*, *Civilization*, or the *Starcraft* series. Others might prefer fast-action, first-person oriented shooters like *Halo 3* or *Unreal Tournament*. Rather than using typical video game industry terminology such as real-time strategy or simulation, Joseph and Kinzie (2005) outlined six activity modes of game play based on middle school students' preferences: *Active*, *Explorative*, *Problem-solving*, *Strategic*, *Social*, and *Creative*. These modes describe the various activities middle school students engage in while playing games. According to their research, gender plays a significant role on game play and game choice.

Both boys and girls prefer games that contain customization options, open-ended game worlds, a non-linear flow, built-in tutorials and learning curves that increase gradually (Chu, 2004). However, the same study indicated that girls value games that emphasize a storyline, have multiple levels of difficulty, and contain ample instruction built into the game. Conversely, the study indicates that boys prefer action, weapons, complex interfaces, and controlling ships. This

parallels later findings by Kinzie and Joseph (2008) that boys tend to prefer *Active* and *Strategic* modes of game play, whereas girls preferred *Exploratory* and *Creative* modes. A case study of girls playing the mathematics-based game, *Phoenix Quest*, indicated that girls have a preference for games in which the protagonist is female, the story is non-linear, there is opportunity for problem-solving, and the mathematics is embedded in the game play (De Jean, Upitis, Koch, & Young, 1999). Despite these differences, research indicates that games and simulations benefit students of both genders (Vogel et al., 2006).

Virtual Worlds as Educational Environments

Research by Ketelhut, Dede, Clark & Nelson (2006) demonstrates that virtual environments, in this case multi-user virtual environments (MUVEs) can teach standards-based science with complex inquiry better than traditional approaches. These virtual environments can effectively engage students in immersive, situated learning and critical thinking (Clarke & Dede, 2005). It has also been demonstrated that virtual environments can have positive effects on the self-efficacy and motivation for learning in all students, especially girls and minorities (Dede, Ketelhut, & Nelson, 2004).

Not all studies in the use of virtual environments have had a positive influence on student engagement. A 2002 study of a 3-D mathematics-oriented virtual environment called *AquaMOOSE* met with results disappointing to the researchers. Results of the study suggested that interface and usability are critical components of any virtual environment's design. The authors also speculate that students compare the design of educational software to that of

commercially available games that take many software designers and years to produce, setting the AquaMOOSE software up for failure (Elliot, Adams, & Bruckman, 2002).

Previous Studies of Video Games in Mathematics

A number of studies, similar to this one, have focused on video games as a means of enhancing student attitude and achievement in the mathematics classroom. Research by Lopez-Moreto and Lopez (2007) utilized recreation-oriented objects in a collaborative learning environment finding a positive effect on student attitude toward mathematics. Similar, yet earlier work by Sedighian and Sedighian (1996) suggested that certain elements of video games can impact student attitude providing a strong motivation for learning, stating, "Our findings point to some elements of computer games that satisfy children's learning needs and motivate them to learn mathematics" (p. 1). A study by Rosas et al. (2003) examined the effects of the use of video games into 1st and 2nd grade classrooms, focusing on learning, motivation, and classroom dynamics in an economically disadvantaged region in Chile. Their research concluded that these games had a positive influence on students' attitude and learning.

A study conducted in Central Florida examined the effect of a 3-D game called *Dimension-M*. Researchers studied the game's effect in a high school setting and revealed a positive effect on student achievement in mathematics and a possible relationship to game play and students' motivation in their mathematics course (Kebritchi, Hirumi, & Bai, 2008). The study of 193 students was conducted over a full semester at the high school level used three different games that are part of the Dimension-M software, including pre-Algebra and Algebra games as well as a multi-player version of the software. Students were given a pre and post-study survey to

determine their perceived math course motivation. The district's benchmark pre and post-test exams were used to determine the game's impact on achievement. Conclusions of this study suggest that integration of the game into a typical mathematics class can be logistically challenging due to computer lab scheduling and the length of the game's "missions," and that a better implementation might be in a standalone course, especially for remediation, as will be used in this study.

Purpose of This Study

This study attempts to demonstrate that *Dimension-M*, an immersive, interactive, 3-D video game, produced by Tabula Digita, can be an effective instructional tool for teaching middle school students pre-Algebra and Algebra concepts. The research conducted in this study also examined the game's influence on student attitude and examined whether gender influenced student achievement and attitude. The primary research questions for this study are listed below.

- Do educational 3-D video games positively affect middle school student achievement in mathematics?
- Do educational 3-D video games positively affect middle school students' attitudes toward mathematics?
- Does gender interact to influence student achievement and attitude on playing educational, 3-D video games?

This study differs from previous studies in several ways. Aside from the study conducted in Central Florida, no studies were found that dealt with a 3-D, first-person format game that resembled the quality of commercially popular games of the same format. This study differs

from the Central Florida study in that it focuses on middle school students in a remediation setting. This study was conducted in a short time frame with a smaller sample size that the Central Florida study; however, it only examines the impact of the game and its built-in assistance and assessment for students without the influence of supplemental instruction from a classroom teacher.

METHODS

About the *Dimension-M* Game

Dimension-M is a highly interactive, first-person oriented, three-dimensional video game that is very similar in presentation to commercially popular games such as the *Halo* or *Unreal Tournament* series of games (Figure 1). The game is designed in a problem-based format in which players assume the role of a college student who lands ashore on a deserted island, once home to a military bio-technology facility. Experiments on this island have gone awry and the player must use their skills in pre-Algebra and Algebra to solve various situational dilemmas and to ultimately escape. Mathematics instruction and practice are integrated into the storyline of the game (Figure 2). In order for the player to progress through the game's storyline, they must master certain pre-Algebra and Algebra skills.

To support student learning, the game features a built-in journal that allows the player to review any of the game dialogue as well as the math concepts presented in the game. These tools provide a way for students to review mission objectives and to learn about the math concepts addressed, often with worked examples. A simple calculator is also integrated for use in quizzes.

At the close of each mission, the student is presented with a quiz, integrated into the game's storyline, which includes both multiple-choice and short answer questions about the mathematics concepts they learned in the mission. At the close of the mission the results of this quiz and their game play are used to calculate an overall mission score. The players are then rewarded with a gold, silver, or bronze medal.

The game's "Tutorial" and "Xeno Island" missions were used by students in this study. In the

"Tutorial" mission, students are acquainted with basic navigation in the game world. Controls in this game match the controls used in typical, computer-based first-person shooter format games. Additionally, the "Tutorial" orients students to the game's built-in reference tools: the journal, mission objectives, and math concepts. At the close of the "Tutorial," student players are given their first sample quiz which reviews the basic concepts of game play and prepares them for future mission quizzes, which will focus on math concepts.

The "Xeno Island" mission is the first mission that incorporates mathematics. This mission addresses the concepts of prime numbers, even and odd rules, and perfect squares. Students begin the mission ashore Xeno Island behind a locked gate. To unlock the gate, the students must use their "visor" to locate shells on the beach that have a prime number associated with them. Once they pick one up, they drop it off in the gate's console. After collecting four correct shells, the gate unlocks and the student can advance to the next phase of the mission.

In the second phase of mission one, the student must use their "visor" to locate spider-like robots that can broadcast a radio signal to a nearby console controlling a second locked gate. In this phase, students see a variety of even and odd expressions over the robots. They must evaluate the ones that have an even result and use their "analyzer" tool to charge the robots so they will transmit the unlock signal.

In the third, and final phase of mission one, students must find a way to cross a chasm to a control station on the other side. The only way to accomplish this is by activating a bridge. As the player is instructed by a console close to the bridge, this is achieved by collecting power cells nearby that have numbers associated with them that are perfect squares. Once the student has deposited five of these perfect square power cells in the bridge's console, the bridge appears and the student can cross to the control station.

At the close of the mission, the student is told that there are still a few obstacles to moving on to the next mission and that by answering a series of questions, their assistant, a game character who provides them voice assistance throughout the mission, will be able to "hack" into the island's computer system. These questions are the game's embedded quiz, and assess the student's learning of the missions concepts.

Figure 1 - A typical screenshot from Tabula Digita's *Dimension-M.*

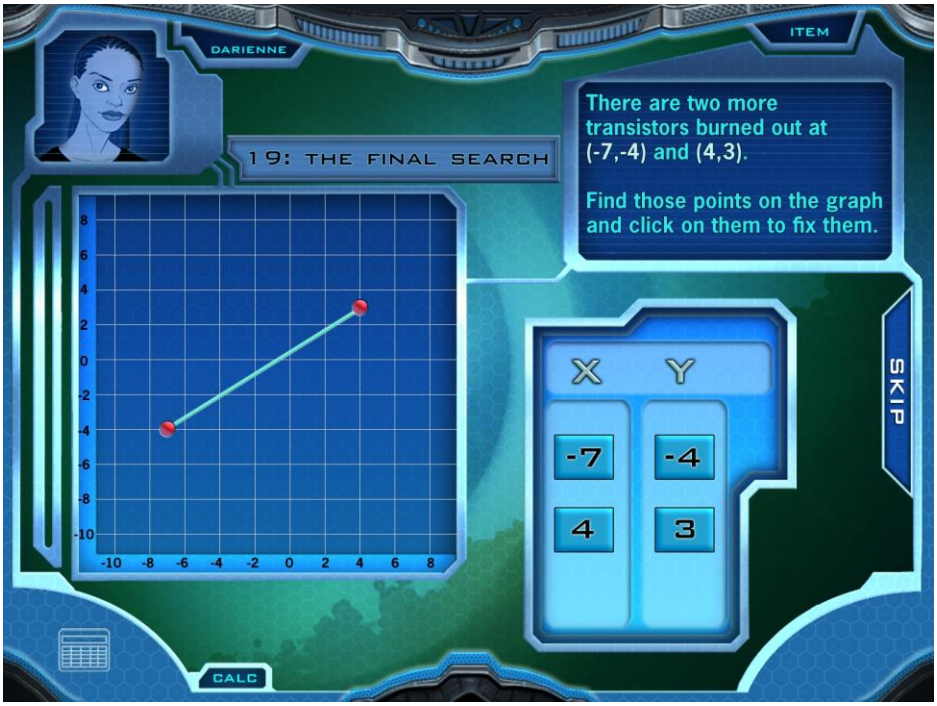

Figure 2 - Screenshot demonstrating *Dimension-M's* embedded quizzes.

Setting of the Study

This study took place at a rural middle school of roughly 500 students located in North Carolina. According to the North Carolina School Report Card (2007), only 63.1 percent of the students in the school were at or above grade level for mathematics on state-mandated End-of-Course testing. This performance is below the district and state averages. To address this area of struggle, the school has created an innovative remediation course, called Virtual Math, to bolster students in the 6^{th} – 8^{th} grades who achieved below proficiency on state exams. This course, offered as an elective, meets for 75 minutes on Tuesdays and Thursdays, and every other Friday for approximately 35 minutes. Sixth grade students meet during the daily schedule's 2^{nd} period, seventh grade students meet during 3^{rd} period, and eighth grade students meet during 5^{th} period. The course is instructed by a tutor hired by the school.

Participants

There were approximately 34 students enrolled in Virtual Math, 28 of whom participated in this study. The students that enrolled and participated in the study represented a wide range of backgrounds including: 13 Caucasians, 9 African Americans, 4 Hispanics, 1 Native American, and 1 Multi-racial student. Of these, 21 out of 28 are female. Ten of the students are sixth graders, nine are seventh graders, and nine are eight graders. These students ranged from 11 – 14 years of age.

Procedure

The goal behind this study is to examine the effects of the game, alone on student achievement and attitude with as little influence from an instructor as possible; therefore, all research was conducted during the first five days of Virtual Math and no direct mathematics instruction was used to supplement game play.

Students were recruited to participate in the study as a regular part of their Virtual Math curriculum. This procedure was approved by the Office of Sponsored Research Programs at University of North Carolina Wilmington, where the student researcher was studying.

Day One of Virtual Math

Since day one of the course is also the first day of school, the entire class period was devoted to an explanation of course expectations and procedures by the course tutor. This also allowed an

additional time for students who did not submit their course paperwork on the first day of school to bring it the following day.

Day Two of Virtual Math

Before playing the game for the first time, students completed a twelve-question student survey that addressed their attitudes toward video games, math, and the use of a video game for learning math. The first ten questions of this survey were based on a four-point Likert scale. The last two questions were open-ended and gathered information about their favorite video games and favorite subject in school.

Immediately following the survey, students completed an eight-question pre-test that included questions covering the learning objectives for the first "mission" of the game. These questions, written in multiple-choice format, are similar to those integrated into the game play and address the concepts of identifying prime numbers, evaluating even and odd expressions, and identifying perfect squares. These items were reviewed by two licensed middle school math teachers to verify their content and appropriateness for this research supporting the validity of the questions.

Both the pre-survey and pre-test were administered on day two of the class, by paper, and with guidance provided by the student researcher, and the course tutor. It was decided that a paper-based format would be most familiar to middle school students.

Day Three of Virtual Math

The third class session involved the students completing the game's orientation mission. This mission was designed to orient players to the game's mechanics and controls. Skills such as player movement, environmental interaction, and the use of the game's integrated help features

were addressed. The course facilitator and the student researcher were available to assist students with any technical issues that arose. The orientation mission did not address any specific math skills. Students who completed the mission early were allowed to repeat the mission in an attempt to improve their overall score.

Day Four of Virtual Math

During the fourth class session, students began their first true mission in the game that integrated the concepts of prime numbers, even and odd patterns, and perfect squares. Students were given approximately 60 minutes to work through the first mission. Students who finished early were allowed to repeat the first mission or the orientation mission to improve their overall score. During this time, the student researcher and the course tutor only provided technical assistance to the students, encouraging them to utilize the game's built-in journal and mathematics resources.

Day Five of Virtual Math

On the fifth and final day of the research study, students were given approximately 40 minutes to complete the first mission, either for the first time or again to improve their overall score. Each student completed the first mission in this time frame. Immediately following this 40-minute period, a post-survey and post-test were administered by paper.

Following Day Five of Virtual Math

Both post-achievement and post-attitude data were aggregated and analyzed to address the research questions. The Virtual Math class continued for students throughout the semester,

meeting two and a half class periods per week. Students continued to progress through the game's missions with each class involving approximately 50 minutes of game play and 25 minutes of debriefing and instruction provided by the course tutor.

Criterion Measures

There were two criterion measures used in this study: a post-test and an attitude survey. In addition, a pre-test and a pre-attitude survey were used to assess subjects' knowledge of the content prior to the game-based instruction. A follow-up interview was conducted with the school's math tutor, math coach, and principal.

Pre-test

The pretest consisted of 10 multiple-choice questions covering the content of the Xeno Island lesson. The pre-test consisted of three questions addressing prime numbers, four questions concerning even and odd patterns, and three questions concerning perfect squares. The overall mean score on the pretest was 46%, indicating that participants were not very knowledgeable about the content prior to instruction.

Post-test

The post-test was identical to the pre-test. The pre- and post-test can be found in Appendix A.

Attitude Survey

The survey assessed student attitudes towards video games and using games for learning math. The survey consisted of 10 Likert-type questions that were rated from strongly agree

(scored as 4) to strongly disagree (scored as 1) and two open-ended questions asking students to state their favorite game and favorite subject in school. The survey was administered after the game based instruction and the post-tests were completed. The attitude survey can be found in Appendix B.

Interviews

Brief interviews with the Virtual Math course tutor, the school's math coach, and the school's principal were conducted seven weeks following the treatment period. The purpose of the interviews was to collect additional data regarding their observations of changes in student achievement and how they perceived the game was impacting students' attitudes. The interviews were conducted, one-on-one, at the school. The following questions were asked in the interview:

- "Have you seen an improvement in students' math performance since implementing the game?"
- "How do you feel this game has impacted students' attitudes toward mathematics?"
- "Do you feel this game in an effective teaching tool?"

Data Analysis

A *t*- test was conducted on data obtained from the achievement pre-test and post-test to analyze the impact of the game's first mission on student understanding of prime numbers, even and odd patterns, and perfect squares. A one-way ANOVA was conducted on student achievement data to determine what role, if any, gender played on achievement results. The

open-ended questions (items 11-12) on what participants' favorite subjects and favorite video games were analyzed using frequency data.

A series of *t*-tests were conducted on attitude survey data for groups of similar questions on mathematics (1, 3, and 5) and gaming (2, 4, and 6). Additionally, one-way ANOVA tests were conducted on the same groupings to determine the impact of gender on student responses. Alpha was set at .05 for all statistical tests.

RESULTS

Achievement

Students who played *Dimension-M*'s Tutorial and Xeno Island missions made significant gains, $t(27) = -3.96$, $p < .05$, in their overall achievement between pre- and post-test assessments. Mean scores increased from 46% (*SD* = 15.92) on the pre-test to 63% (*SD* = 19.74) on the post-test.

	Pre-test	Post-test
Male	4.7 (47%) (*SD* = 2.36)	6.3 (63%) (*SD* = 2.06)
Female	4.6 (46%) (*SD* = 1.32)	6.2 (62%) (*SD* = 2.00)
Overall Average	4.6 (46%) (*SD* = 1.60)	6.3 (63%) (*SD* = 1.97)
Note: Maximum possible pre-test and post-test score was 10.		

Table 1. Mean and standard deviations for posttest scores.

The results of a one-way ANOVA test on this achievement data revealed no significant differences in the achievement results between male and female students. Consistent with the mean data reported in Table 1, both male and female students demonstrated equitable gains between pre- and post-test assessments.

	Pre-test Mean Percent Correct	Post-test Mean Percent Correct
Prime Numbers (Questions 1, 2, and 3)	2.5 (25%) (*SD* = 3.22)	6.0 (60%) (*SD* = 3.78)
Even and Odd Patterns (Questions 4, 5, 6, and 7)	8.4 (84%) (*SD* = 2.74)	8.3 (83%) (*SD* = 2.51)
Perfect Squares (Questions 8, 9, and 10)	1.8 (18%) (*SD* = 1.92)	3.8 (38%) (*SD* = 2.93)

Table 2. Mean student performance by math concept.

Table 2 shows an analysis of student performance pre- to post-test based on the concepts addressed in the Xeno Island mission. Students showed the greatest improvements in

achievement gains for the concepts of prime numbers and perfect squares, though even after the treatment, students still seem to struggle with the concept of perfect squares.

Attitude

Survey Item	Mean Pre-survey Response	Mean Post-survey Response
1. I like math.	2.64 (*SD* = 0.87)	2.54 (*SD* = 1.00)
2. I like playing video games.	3.54 (*SD* = 0.69)	3.71 (*SD* = 0.46)
3. I am good at math.	2.79 (*SD* = 0.63)	2.61 (*SD* = 0.92)
4. I am good at video games.	3.64 (*SD* = 0.56)	3.57 (*SD* = 0.63)
5. Math is easy to learn.	2.18 (*SD* = 0.86)	2.54 (*SD* = 0.96)
6. Video games are easy to learn.	3.18 (*SD* = 0.82)	3.29 (*SD* = 0.81)
7. A video game about math would be fun.	2.89 (*SD* = 0.83)	2.82 (*SD* = 0.98)
8. A video game can help me learn math.	2.89 (*SD* = 0.83)	3.18 (*SD* = 0.72)
9. I would play a video game about math at home.	2.71 (*SD* = 0.94)	2.64 (*SD* = 1.06)
10. I would play a video game about math at school.	3.25 (*SD* = 0.75)	3.25 (*SD* = 0.75
Note: 4=Strongly Agree 4=Agree 2 =Disagree 1=Strongly Disagree.		

Table 3. Mean and standard deviations for attitude scores.

The results of the student survey given at the end of the treatment illustrate some differences between students' views of mathematics and their views of video games. The data collected suggests that students have a higher self-efficacy when it comes to video games ($M = 3.57$) as opposed to mathematics ($M = 2.61$), along with the belief that video games ($M = 3.29$) are easier to learn than mathematics ($M = 2.54$). Student survey data indicated that students do believe that

video games can help them with their learning (M = 3.18), but student responses point to a preference for playing such games at school (M = 3.25) as opposed to in the home (M = 2.64).

A number of statistical analyses of pre- and post-survey data were conducted to test for statistical significance. Paired *t*-tests of the math-oriented questions (1, 3, and 5) and the video game-oriented questions (2, 4, and 6), comparing pre- and post-survey responses were conducted however, no significant differences were found. Similar comparisons, using a one-way ANOVA test were conducted that analyzed the effect of gender on the same sets of questions, again with no statistical evidence discovered.

Game Title	Number of Responses
Guitar Hero Series	3
Madden Football Series	3
Mario-based Games	3
Need for Speed Series	2

Table 4. Students' most frequently identified favorite video games.

When asked about their favorite video games, responses varied widely with the most frequent responses being the Guitar Hero series (n = 3), sports-based games such as Madden Football (n = 3), Need for Speed (n = 2), and Nintendo's Mario-based games (n = 3).

Subject	Number of Responses
Social Studies	6
Mathematics	5
Science	4
Reading	4

Table 5. Students' most frequently identified favorite subject.

In response to the question asking their favorite school subjects, the most frequent responses were mathematics (n = 5) and social studies (n = 6), followed closely by science (n = 4) and reading (n = 4).

Observations

During the treatment, observations of students using the game environment were made. Many students seemed willing to take a trial-and-error approach early on to advancing through the Xeno Island mission. For example, in the first part of the Xeno Island mission, players are asked to pick up nautilus shells on a beach whose number of rings is equivalent to a prime number. Many students began this task by simply picking up any shell and dropping it in the console that controls the locked gate that prevents their advancement to the next stage of the mission. Soon, students began referring to the game's built-in journal which includes "Math Concepts" help. Once they understood the concept of prime numbers, their actions were more purposeful and they advanced through the stage more quickly in successive attempts. Thus, an understanding of the math concepts became observable in their game play.

Students were allowed to repeat the mission if they completed it prior to the end of class. Students seemed very willing to replay the same mission multiple times in an attempt to improve their overall score for the mission. Students were encouraged to attempt to beat the scores of their classmates and were willing to make multiple attempts to do so.

Interviews

Approximately seven weeks after Virtual Math began, the course tutor, the school's math coach, and the principal were interviewed regarding their observations of the students since they had begun using the game. Each gave very positive responses regarding the implementation of the game as a remediation tool, noting the high level of enthusiasm students had toward playing

the game. As the math coach stated, "Because they need to know the math to advance in the game, they're willing to learn it. It's building their confidence and it's putting them ahead in their regular math class" (G. Goble, personal interview, October 28, 2008). This is consistent with statements made by the course tutor. She said, "I've absolutely seen an improvement in students' performance since we began using the game and their regular math teachers have seen the improvements as well" (J. Joseph, personal interview, October 28, 2008). The school's principal has also noted a positive impact on student attitude and enthusiasm. She said, "The game is an effective teaching tool. [The game] is the way children learn so they are more likely to be motivated" (E. Skipper, personal interview, October 28, 2008).

DISCUSSION

The Game's Effect on Achievement

The results of the achievement data collected in this study are consistent with previous studies of the use of video games in the mathematics classroom, especially the Central Florida study of the *Dimension-M* software (Kebritchi, Hirumi, & Bai, 2008). The positive gains in achievement are likely a result of the game's engaging environment. *Dimension-M* provides a context for learning with its story-line and encourages students to master concepts before advancing to subsequent levels in the game. Students were very willing to repeat missions in an attempt to improve their overall scores, thus drill-and-practice of the concepts occurred, but in a way in which students enjoyed and willingly embraced.

One of the primary goals of this study was to determine if the game, without direct instruction from a teacher could increase student achievement. In other words, "Can the game alone be effective in teaching students mathematics concepts?" The results of the student achievement data collected in this study provide evidence that this may be the case. It should be noted, however, that the methods used in this study were not what the developers of *Dimension-M* prescribe as a method of implementation of their product. When a school licenses this software, they are also granted access to teaching materials online, including web-based instructional tools that an instructor can use to teach the math concepts prior to students playing a mission or as enrichment following. Combining the game play of *Dimension-M* with supplemental instruction from a classroom teacher, could potentially result in greater student achievement gains.

The Game's Effect on Attitude

Though the pre- and post-attitude survey revealed no statistical evidence indicating a significant impact on student attitude toward either math or video games resulting from the treatment, observations of the students indicate that students were very enthusiastic about playing the game. Based on the interviews with the course tutor, math coach, and the school's principal, the game had a noticeable impact on the students' general enthusiasm, especially regarding the Virtual Math course. Both the math coach and the tutor reported positive observations regarding student performance in mathematics, and all three have noted an increase in students' enthusiasm. A couple of factors may have contributed to the discrepancy between the survey results and observations made by the researcher and interviewees. The short duration of the treatment period followed closely by post-attitude data collection, only using one of the game's missions, might not have been sufficient for students to have a good understanding of what the game and what Virtual Math involved. Also, the Likert-based survey was a new experience for these middle school students and they may not have fully understood the design of the survey. Seven weeks following the beginning of the study, students remain very enthusiastic about the Virtual Math course and the *Dimension-M* game. As the math coach stated in an interview several weeks following the beginning of Virtual Math, "The buzz surrounding this class and the game has been remarkable" (G. Goble, personal interview, October 28, 2008).

The Role of Gender in this Study

Based on statistical tests conducted, gender played no significant role in either achievement or

attitude data. Both boys and girls showed equitable gains in their achievement. Analysis of the pre- and post-attitude data collected revealed similar responses between both genders regarding both mathematics and video games. This is perhaps consistent with video games becoming a more mainstream activity for girls as indicated by a recent report (Entertainment Software Association, 2008). This is likely due to some of the design aspects of the game. The ability to select a female protagonist, an engaging storyline, and embedded mathematics and problem solving are aspects of the game that likely make it appealing to female players. This is parallel to the findings of the *Phoenix Quest* study (De Jean, Upitis, Koch, & Young, 1999).

Implications of this Study

The results of this study add evidence to the idea that video games such as *Dimension-M* might be useful tools for delivery of instruction. The highly-immersive nature and exciting game-play of *Dimension-M* are elements that are effective in engaging students and teaching them mathematics concepts. The overall design of this game may serve as a model for the future development of games that address other curricular areas, such as science or social studies.

Limitations of this Study

There are several limitations associated with this study that should be noted. Due to time constraints and the design of the research, the treatment period was limited to only a few days at the beginning of the school year. Due to budgeting issues and technical constraints, the study could only be conducted at a single site, resulting in a small sample size. This sample also included a high proportion of female students, possibly affecting statistical results related to

gender influence.

Several factors may have had an influence on the results of the study. Again, due to time constraints, data could not be collected from standardized testing such as state exams. Because of this, the questions used in the achievement measurement were very similar to those used in the game. An assessment designed independent of this study might provide different results. Lastly, the concept of attitude, as used in this study, might be better defined as student feelings toward math and video games.

Future Studies

Adding the element of class competition, encouraging students to try to achieve the highest score and beat their classmates' scores, as well as the scores of the course tutor, the school's math coach, and even the school's principal, seemed to have a positive impact on students' willingness to repeat missions multiple times. Competition in the form of multiplayer team-based games or free-for-all scenarios might be an even more effective way of increasing student performance. Students enjoyed a more collaborative approach even to the single player game. This was evidenced by the observation several weeks after the treatment study that students began playing with headphones around their necks rather than over their ears. This allowed them to continue to hear the game's audio, but also allowed them to consult each other for assistance on various stages of the single player missions for hints and tips on advancement. A future study on multiplayer-based missions would certainly be warranted.

Additionally, it would be valuable to go beyond simply looking at the game's impact on student achievement and attitude and to focus on what cognitive processes students employ

while playing the game. Research focusing on whether or not students are able to transfer these processes to non-game situations such as real-world mathematics problems or even standardized mathematics tests would be valuable.

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APPENDIX A

Pre- and Post-test Questions

The following questions were used to measure student achievement as a result of the game's second mission. The same questions were used in the post-test.

Directions: Using your pencil, mark the circle beside the answer that best answers the question.

1. Which of the following is a prime number?

   a. 3 b. 8 c. 10 d. 12

2. Which of the following is a prime number?

   a. 8 b. 16 c. 23 d. 40

3. Which of the following IS NOT a prime number?

   a. 2 b. 3 c. 8 d. 11

4. Which of these numbers is an even number?

   a. 1 b. 9 c. 19 d. 28

5. Which of these expressions results in an even number?

   a. 1 + 2 b. 3 + 8 c. 7 + 4 d. 8 + 4

6. Which of these expressions results in an even number?

   a. even + even b. even + odd c. even – odd d. odd + even

7. Which of these expressions results in an odd number?

a. $3 \cdot 7$ b. $4 \cdot 6$ c. $2 \cdot 8$ d. $10 \cdot 4$

8. Which of these numbers is a perfect square?

a. 5 b. 8 c. 9 d. 12

9. Which of these numbers is a perfect square?

a. 45 b. 86 c. 121 d. 125

10. Which one of these expressions will result in a perfect square?

a. $1 \cdot 2$ b. $3 \cdot 5$ c. $6 \cdot 6$ d. $8 \cdot 9$

APPENDIX B

Pre- and Post-survey Attitude Questions

These questions were administered on paper. Questions 1-10 were based on a Likert scale with the following options: Strongly Agree, Agree, Disagree, and Strongly Disagree. Questions 11 and 12 were open-ended. The same questions were used in the post-survey.

Directions: Using your pencil, mark the circle beside the choice that most closely matches your opinion.

1. I like math.
2. I like playing video games.
3. I am good at math.
4. I am good at video games.
5. Math is hard to learn.
6. Video games are hard to learn.
7. A video game about math would be fun.
8. A video game can help me learn math.
9. I would play a video game about math at home.
10. I would play a video game about math at school.
11. What is your favorite video game?
12. What is your favorite subject in school?