Effects of a 3-D Video Game on Middle School Student Achievement and Attitude in Mathematics.

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Abstract

The purpose of this study was to determine whether 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. A Middle School in south eastern United States created a mathematics remediation course called Virtual Math for students who achieved below proficient levels on their state end-of-grade mathematics exams. Achievement and attitude data was collected for 28 sixth to eighth grade students in Virtual Math. 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 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 video game environment.

1. Introduction

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. Yazzie-Mintz [35] 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.

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 [12]. 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 [26] 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 [21]. As one student put it in an interview with games researcher, Mark Prensky, "Whenever I go to school, I have to 'power down'" [27]. 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.

2. Review of relevant literature

In the following sections, literature related to student performance and attitude towards mathematics and gaming are provided. The importance of video games to learning and pedagogy of video games are also discussed briefly.

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 [19]; 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 [33]. 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 [6].

Why Student Attitude Is Important

Research conducted by Haladyna and Thomas [13] indicate 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 [1] 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 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 [7].

Self-efficacy, or a student's "judgments of their capabilities to organize and execute courses of action required to attain designated types of performances"[2], can also have an impact on their performance in courses such as mathematics. Pajares and Graham [22] 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 [25] [4]. Game play can be a valuable tool in student learning. Seymour Papert [24] 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 [23] 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, Rieber [29] 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 [11]. 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 [3]. 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 [15]. It has even been suggested that learning is what games are all about [16].

Research conducted by games researcher, David Shaffer [31] 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 Squire [34] 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 [9] 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 [8] 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) states that "When looking at "good" games through the lens of Gagné's Nine Events, we find that they do indeed possess the necessary conditions for learning and facilitate the required events" (p.29).

Becker (2006) further suggests that "good" games meet the seven qualifications of Reigeluth's [28] 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 [5] nine tenets outlined in his psycho-cultural approach to education, and David Merrill's [18] *First Principles of Instruction*, which include activation, demonstration, application, and integration. She also cites ways in which video games address Gardner's [10] Multiple Intelligences Theory, and a variety of other theories and models utilized in instructional design today.

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. Lopez-Moreto and Lopez [17] 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 [32] 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. [30] 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 by Kebritchi, Hirumi, and Bai [14] 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. 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-survey and post-study survey to determine their perceived math course motivation. The district’s benchmark pre-test 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 attitudes and student achievement. 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?

3. Methods

This section briefly introduces the participants, the setting and procedure of the study. Also, included are the criterion measures and the data analysis techniques.

Participants

There were approximately 34 students enrolled in Virtual Math, 28 of whom participated in this pilot 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.

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 [20], only 63.1 percent of the students in the school were at or above the average grade level for mathematics on state-mandated End-of-Course testing. This performance is below the district and state averages. To address this issue, the school has created an innovative remediation course, called Virtual Math, to bolster students in the 6th – 8th 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 2nd period, seventh grade students meet during 3rd period, and eighth grade students meet during 5th period. The course is instructed by a tutor hired by the school.

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. 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.

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

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.

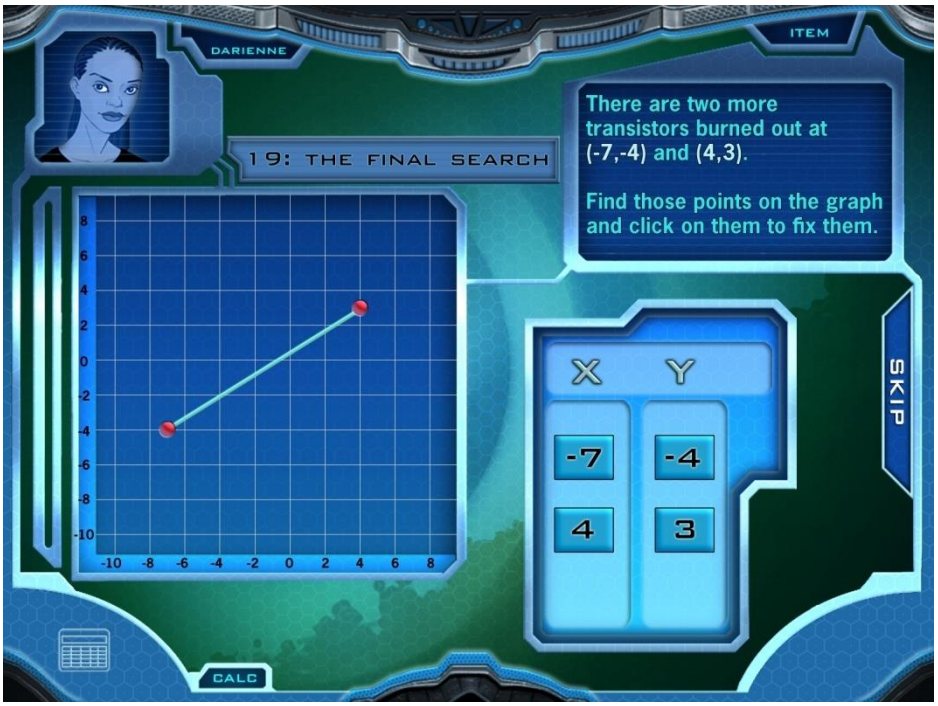

Figure 2: *Screenshot demonstrating Dimension-M's embedded quizzes.*

Subject Area

Though the paper broadly addresses the area of Mathematics the first mission used in this study included three arithmetic topics, Prime numbers, Even and Odd numbers and Perfect Squares. The other missions in the Dimension-M game had other pre-algebra and algebra topics. Integers, Fractions, Solving one-step, two-step equations, variables and expressions are some example topics included in the other missions.

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. The technology coordinator observed the class and took detailed notes.

The entire class period was devoted to an explanation of course expectations and procedures by the course tutor on Day One. On Day Two, 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. On Day Three, the students completing the game's orientation mission. This mission was designed to orient players to the game's mechanics and controls. On Day Four, 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. 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. 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.

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. During game play, students were observed. Interviews with the school's math tutor, math coach, and principal were conducted toward the conclusion of the study.

Pre-test: The pre-test 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 pre-test was 46%, indicating that participants were not very knowledgeable about the content prior to instruction.

Sample Test Questions

1. Which of the following is a prime number?

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

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

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

Post-test: The post-test was identical to the pre-test.

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.

Observations: The technology coordinator observed students while they were playing the video game. Notes were taken on students' comments, body language, expressions, and interactions with other students in the classroom and the game.

Interviews: Brief interviews with the Virtual Math course tutor, the school's math coach, and the school's principal were conducted following the treatment period. The purpose of the interviews was to collect additional data regarding 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 is 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. 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). Alpha was set at .05 for all statistical tests.

4. 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.

Table 1. Mean student performance by math concept.

	Pre-test M (SD)	Post-test M (SD)
Prime Numbers (Questions 1, 2, and 3)	2.5 (3.22)	6.0 (3.78)
Even and Odd Patterns (Questions 4, 5, 6, and 7)	8.4 (2.74)	8.3 (2.51)
Perfect Squares (Questions 8, 9, and 10)	1.8 (1.92)	3.8 (2.93)
Overall	4.6 (1.60)	6.3 (1.97)

Table 1 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

Table 2. Mean and standard deviations for attitude scores.

Survey Item	Pre-survey M (SD)	Post-survey M(SD)
1. I like math.	2.64 (0.87)	2.54 (1.00)
2. I like playing video games.	3.54 (0.69)	3.71 (0.46)
3. I am good at math.	2.79 (0.63)	2.61 (0.92)
4. I am good at video games.	3.64 (0.56)	3.57 (0.63)
5. Math is easy to learn.	2.18 (0.86)	2.54 (0.96)
6. Video games are easy to learn.	3.18 (0.82)	3.29 (0.81)
7. A video game about math would be fun.	2.89 (0.83)	2.82 (0.98)

8. A video game can help me learn math.	2.89 (0.83)	3.18 (0.72)
9. I would play a video game about math at home.	2.71 (0.94)	2.64 (1.06)
10. I would play a video game about math at school.	3.25 (0.75)	3.25 (0.75)

Note: 4=Strongly Agree 3=Agree 2 =Disagree 1=Strongly Disagree.

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 believe that video games can help with their learning (M = 3.18), and students prefer playing such games at school (M = 3.25) as opposed to in the home (M = 2.64).

Math-oriented questions (1, 3 and 5) on the pre- and post-survey were analyzed to test for statistical significance. However no significant differences were found for the paired t-tests, t(27) = -.22, p =.83. The video game-oriented questions (2, 4, and 6) on the pre and post-survey were also analyzed. There were no statistically significant differences, t(27)=-.97, p =.34).

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). 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.

Interview

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" 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.” 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.”

Two of the students were also interviewed. One of the students mentioned "Before we were doing this, last semester I have to admit I was doing kind of bad in math," Another student indicated "This semester you know getting into virtual math, I've been doing pretty good. I brought my math grade up a lot when I was playing."

5. 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 [14]. 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. 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 instruction. 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, followed immediately by post-attitudinal data collection, and use of only one of the game’s missions might have been insufficient for students to have a solid understanding of the game and what Virtual Math involved. In the 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, “The buzz surrounding this class and the game has been remarkable”.

Limitations

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 for this pilot study. A self developed questionnaire was used to measure the student attitudes rather than a standardized instrument due to limited resources. The attitude questions may not have been as well constructed as the standardized measurements. Quotations from the students while playing the game were not recorded by the researcher or the course facilitator.

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.

Future Studies

A future study on multiplayer-based missions is warranted. 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. 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.

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.

Supplementary Electronic Materials

Video of *Dimension-M* play

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