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AUTHOR:
Sandra Skal-Gerlak

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RONG-JI CHEN		5/10/12
THESIS COMMITTEE CHAIR	SIGNATURE	DATE
Holly OSTROSKE		5/4/12
THESIS COMMITTEE MEMBER	SIGNATURE	DATE
THESIS COMMITTEE MEMBER	SIGNATURE	DATE

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A Case Study on the Effects of A Computer Game on A Homeschooled Student's Motivation and Performance in Algebra

Sandy J. Skal-Gerlock

California State University San Marcos

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Abstract

Mathematics is crucial in our technologically oriented world, and it is important that all children become proficient in the subject, including in algebra. Homeschooled students are perhaps at a particular disadvantage in this regard. Without the rigor of daily mathematics instruction in a classroom with a trained educator, they may need additional reinforcement and tools to further develop algebraic understanding and competency. Computer games are popular and engaging, and have been used for educational purposes, though research has been inconclusive as to their effectiveness in learning mathematics. The purpose of this case study was to investigate and understand the ways the computer game *Dimension M* could improve the motivation and performance of a homeschooled high school student in beginning Algebra. This study was conducted using interviews, a pre-test, a log of the student's comments regarding game play, and a post-test.

Although no measurable improvement in mathematics performance was demonstrated by the post-test, the student went on to pass the mathematics portion of the CAHSEE, a significant accomplishment. The student's motivation to learn algebra appeared to increase as a result of his experience with the game. Previous research as well as the results of this study suggest that incorporating computer games such as *Dimension M* into daily learning activities may be advantageous and warrants additional research.

Chapter One

Introduction

Background

Jason sits comfortably at the dining room table, staring at a page in the algebra textbook before him. He fiddles with the page and his pencil, but makes no marks on the paper. He is focused intently on a problem very near the beginning of the book. His facial expressions range from relaxed to determined to totally perplexed. Eventually, he asks his mom if she can take a look and help him make sense of what he is reading. She is tending to a litter of newborn puppies, but quickly comes to his assistance. Unfortunately, she is equally puzzled by the problem, and says, as she has many times before, "Maybe we need a tutor."

Jason is a homeschooled high school student. After a challenging series of negative experiences in elementary and middle school, his parents decided homeschooling would provide him a healthier environment, as well as additional time to pursue his interests in animals and a multitude of sports, plus allow more flexibility for frequent family outings and the numerous chores on their ranch.

Algebra can be challenging for many students. It is, as one might imagine, likely even more difficult for a student who is homeschooled without benefit of a trained teacher and the mandatory formal daily instruction and practice found in most traditional schools.

Algebra teaches students how to think logically and introduces the concept of abstract thinking. According to EdSource, a non-profit organization which distributes information regarding education issues in California, these skills will help students in their lives and work, even if they do not go on to college (2009). In addition, it is the foundation for the career fields concerning mathematics, science, and technology which are critical to the economic success of the United States.

Unfortunately, we are in serious trouble regarding the education of our youth in this regard. According to the 2008 Final Report of the National Mathematics Advisory Panel, "international and domestic comparisons show that American students have not been succeeding in the mathematical part of their education at anything like a level expected of an international leader" (National Mathematics Advisory Panel, 2008, p. xii). Further, they express concern as to "the consistency of findings that American students achieve in mathematics at a mediocre level by comparison to peers worldwide" (National Mathematics Advisory Panel, 2008, p. xiii).

Since algebra is the foundation and language system on which higher order mathematics, science, technology, and engineering courses are built, it is imperative that we provide the tools students need to become proficient in the subject. In California, efforts are being made to improve preparation programs for teachers of mathematics and to begin working with students earlier on concepts which are necessary in order to go on to learn algebra. Although algebra proficiency is considered a gateway to success in the 21st century, many students never master it,

closing the door to higher level math classes and college, and many careers. This is arguably more pronounced in the case of students who learn at home.

While students in school generally have many opportunities to learn algebra and develop their skills through structured lessons, repetition, tests, and assistance when needed, homeschooled students may not have adequate exposure to the subject. A key reason is that there are many different ways to home school, and ultimately the parents and the interests of the child tend to determine the focus of educational pursuits which may or may not include mathematics. This may be due to many factors, such as inconsistent scheduling, limited access to materials or an instructor, or a lack of emphasis on the subject by parents. These limitations may prevent consistent growth and progress in early mathematics and later in algebra. For instance, one popular homeschooling website provides the following description about mathematics: "Many homeschooling parents are mathphobic. They're cool with teaching their little ones their numbers, and even simple addition and subtraction. But go much past that and the possibilities scare them silly…And don't even bring up the A word (algebra)" (Frank, 2010).

In addition, if the parent is not proficient in algebra, is not particularly interested in the subject, or simply does not personally see the benefits of teaching or learning algebra, it is more likely the homeschooled student will not be taught or assisted in a way that casts mathematics in a positive light. For example, the author of another popular homeschool website, *Homeschool Oasis*, professes: "I do not believe that most kids need most of the math they are being required to endure… I am

still not seeing one good reason to take Math… Basically, the real reason is just to perpetuate the system!" (Shelton, 2004). Clearly , a de-emphasis on algebra might influence both motivation and performance of students, as would parents' unfamiliarity with the research-based strategies in teaching algebra to which a credentialed teacher would be exposed.

The National Mathematics Advisory Panel recommends a number of strategies to best prepare for success in algebra, many of which can be applied to home schooling. The most notable are as follows: a focused, coherent progression of mathematics, building deep understanding; emphasis on fractions and related concepts; comprehensive instruction to develop conceptual understanding, computational fluency, and problem-solving skills; adequate practice; encouragement of effort and persistence; and explicit instruction for struggling students. Many of these strategies rely on a well-trained teacher (National Mathematics Advisory Panel, 2008, p. 5).

Similarly, a recent meta-analysis of methods of instructional improvement in algebra found that "Put into consistent practice, the use of coherent curricula, teaching strategies, manipulatives, and technology to develop conceptual understanding may hold the key…" (Rakes, Valentine, McGatha, & Ronau, 2010). Utilizing technology in particular, with the availability of computers in most homes, is an intriguing possibility for assisting students who learn at home.

Focusing on the use of technology, and given the popularity of computer and video games with young people today, this study will examine whether an algebra

computer game can be an innovative strategy which improves the motivation and performance of a homeschooled student in mathematics.

Statement of the Problem

Algebra can be difficult to learn, especially without a well-trained teacher, thus homeschooled students are at a distinct disadvantage. After having worked with homeschooled students for over ten years, my experience indicates that learning algebra at home using a textbook, online tutorials, or other resources is generally not as effective as a traditional class.

Research as to whether homeschooled students struggle in the area of Algebra is divided, largely because many homeschooling parents are strongly opposed to any sort of governmental oversight of their efforts, and therefore refuse to participate in any data-gathering attempts, skewing the research to inaccurately suggest that homeschooled students excel in most academic areas, compared to their traditionally educated counterparts. This is often because the self-selected group who opt to be tested are those who know they will perform well (Kunzman, 2009). Those who struggle may not get help, partly because they do not participate in the standardized tests which would bring their difficulties to the attention of administrators who might intervene.

Motivation is another important part of the puzzle. Homeschooled students tend to have more freedom of choice in their activities, so their motivation to do mathematics is relevant. Research has shown that tailoring activities to provide

stimulation and student control and matching activities with students' interests increase intrinsic motivation (Middleton, 1993). Further, students who begin to value and enjoy mathematics increase their achievement as well as their confidence (Meece, Wigfield, and Eccles, 1990; Pokay and Blumenfeld, 1990). We know that failure to construct meaning can result in decreased motivation; a lack of success in an algebra course often causes consternation and a disdain for the subject, rather than increased motivation to ultimately succeed. Thus, both performance and motivation should be addressed in seeking a remedy for this problem.

Video and computer games are extremely popular among young people today and have been used in many areas of education for two decades; however, research on the effects of video games on student learning is inconclusive. According to Garris, Ahlers, and Driskell (2002), computer games can invoke an intensity of engagement in learners. But the meta-study of computer games as learning tools by Ke (2009) was unable to quantify and synthesize the impact of games across the 89 studies for several reasons, one of which being that the previous studies failed to fully describe all relevant aspects of the games and their applications. An earlier meta study (Vogel, 2006) was also inconclusive. Such results are likely due to the complexity of human learning with computer games.

The purpose of this study was to investigate and understand the ways the computer game *Dimension M*: *Evolver*(see Chapter 3 for a detailed description of the game) could improve the motivation and performance of a homeschooled high school student in beginning Algebra. In what ways can a student gain mastery in a difficult

subject with the additional support a computer game can provide? Which elements of the game are appealing to the student and why? In what ways does student exposure to a game correlate to increased interest in Algebra?

Significance of Study

By studying the effects of utilizing a computer game for mathematics, the researcher has developed a deeper understanding of its potential use in the homeschooled community, thereby enhancing this community's mathematics learning and the potential for more well-trained citizens. Additional research is needed; individual circumstances will need to be considered to determine whether this game can be effective for homeschooled students, but there is likely benefit for those who could use the same instrument for reinforcement or remediation, rather than initial instruction.

The *Dimension M: Evolver* game was provided to one student to supplement his regular algebra studies over a six week period. Case study research methodology was used due to significant differences between the learning experiences of the homeschooled student versus the student educated in a traditional school and the difficulty of implementing a quantitative study involving a control group. The significance of this case study lies in an in-depth understanding of this particular student and the complexity of his interaction with the game. This methodology optimized understanding by allowing many elements to be examined, such as how and when the game was played by the student; which elements of the game were or

were not appealing; whether the student related to the game as "fun" or "math" or "homework"; and ultimately whether motivation and/or performance in algebra improved through the use of the game for this particular student.

Summary

Mathematics is crucial in our technologically oriented world, and it is important that all children become proficient in the subject, including algebra. Homeschooled students are likely at a particular disadvantage in this regard. Without the rigor of daily mathematics instruction in a classroom with a trained educator, it is likely they are in need of additional means of reinforcement and tools to further develop algebraic understanding and competency. Computer games are popular and engaging, and have been used for educational purposes, though research has been inconclusive as to their effectiveness in learning mathematics. By studying whether we can improve the motivation and performance of homeschooled students who are learning algebra through the use of a computer game, we can potentially help not only these students but society as a whole.

Definition of Terms

Homeschooling. Homeschooling, also called home education or home learning, is the education of children at home, typically by parents or professional tutors, rather than in a public or private school. Although before the introduction of compulsory school attendance laws, most childhood education occurred within the family or community, homeschooling in modern times is an alternative to formal education.

In the United States, homeschooling is a legal option for parents who wish to provide their children with a different learning environment than the one which exists in local schools. Requirements vary from state to state and district to district. The motivation for homeschooling can range from dissatisfaction with the schools in their area to the desire for better academic test results. It is also an alternative for families living in isolated rural locations. Sometimes homeschooling refers to instruction in the home under the supervision of correspondence schools or umbrella schools.

Educational Computer Games. Educational computer games have been specifically designed to teach people about a certain subject. Their intention may be to expand concepts for the learner/player, to reinforce development of a skill for the player, to help the individual understand an historical event or culture, or assist them in learning a new skill as they play.

Motivation. Motivation is the set of reasons that determines one to engage in a particular behavior. It is an internal state or condition, sometimes described as a need, desire, or want, that serves to activate or energize behavior and give it direction .

Chapter Two

Review of Literature

Introduction

For several decades, educational professionals have contemplated the potential for applying computer games to learning (Gee, 2003; Prensky, 2001). In today's society, children and adults interact with computers in all kinds of environments, including school, and there is some evidence that computer games may be more effective than traditional teaching in engaging children (Jenkins, 2002). Today, the preferred form of play often involves technology. Children love to play, and playing is considered essential for the development of cognitive structures (Rosas, 2003), thus increasing the potential for learning. Can utilizing educational computer games improve the mathematics performance and motivation of home schooled students? A review of the literature on homeschooling, motivation, and computer games in education is warranted.

Homeschooling

The homeschooling movement began in the 1960's as a result of criticism of the educational system (Collom, 2005). Parents were frustrated by the bureaucratization of public schools and sought personalization in education. In the 1980's, it expanded to include conservative families who wanted to educate their children with a religious focus. Today, there is no one "type" of homeschool family.

According to the U.S. Department of Education, 1.1 million students were homeschooled as of 2003 (National Center for Education Statistics, 2003).

Families who homeschool are a diverse group, from their reasons to homeschool to the ways in which the children are educated. The reasons most frequently reported by parents as to why they chose to homeschool their children were concerns about the school environment, such as safety, drugs, or negative peer pressure; wanting to provide religious or moral instruction; and/or dissatisfaction with academic instruction (National Center for Education Statistics, 2005). Homeschooling can be implemented in any number of ways; laws vary from state to state. For instance, parents who teach their children at home are not required to have a teaching credential in any state, although in some states they must have yearly evaluations performed by state certified teachers (Farenga, 2004). As such, the academic performance of homeschooled children is difficult to ascertain. Parents utilize a variety of methods and materials: students may be taught by parents or other adults, learn independently or subscribe to distance learning programs, or may not even be "taught" at all in a style referred to as "unschooling". Many students are homeschooled "under the radar" without any connection to public charter schools or registration through the state, preferring to take their chances at being caught violating state rules than comply. Students' success in mathematics and other academic subjects is likely as variable as it is for students in public schools.

Homeschooled Students' Learning and Performance in Mathematics

It is challenging to find data which accurately represents the academic achievement of homeschooled students in Algebra, other mathematics, or any subjects. There are several reasons for this. Some who self-identify as homeschoolers belong to charter schools which actually fall under public school jurisdiction, making it difficult to determine just who is "homeschooling" as they take the same standardized tests as other students within the school district. Others are not registered in any way through school districts or the state, and prefer to remain independent and virtually undetected; no tests are taken or scored. A 1999 study by Lawrence Rudner, showing high standardized test scores for homeschooled students, is frequently cited as evidence that homeschoolers academically outperform public and private school students in mathematics and other subjects. However, Rudner acknowledged that it was not a controlled experiment and that the participants were an unrepresentative sample. For example, participants were homeschoolers who elected to take the tests through a Bob Jones University standardized testing program in which parents administered the exams to their own children. The numerous families who prefer to opt out of all testing, some because of concerns about proficiency, and others who resist involvement with government programs or supervision, were not included.

Some organizations which purport to provide statistical data and research regarding homeschooling are arguably biased, as they are strong advocates of homeschooling. For example, one organization, The National Home Education

Research Institute, has articles which address such issues as socialization and various educational strategies, but as is clear from perusing the articles posted on their website, the organization does not offer any scientific evidence of academic achievement among homeschooled students (NHERI.org, 2012).

One study whose focus can be applied loosely to the topic of homeschooling and mathematics achievement was not regarding homeschooling per se, but rather *home factors* related to mathematics learning and performance. A study of 986 fourth grade students found a weak correlation between technology use at home and at school and mathematics performance (O'Dwyer, 2008).

In short, there is a lack of research on homeschooled students' learning of mathematics. Only one relevant recent study was found regarding mathematics competency of homeschooled students. In her study of students who entered a virtual charter school, Wilson (2010) found no significant difference in mathematics and reading assessment scores of homeschooled students compared to public school students.

Having worked with homeschool families for many years, it is my experience that it is the rare homeschool student who is successful at learning algebra at home, and it is very common for students to return to public school when they reach high school age for exactly this reason. Some parents are fearful of attempting to teach algebra at home, and others have tried and failed and recognize their limitations. Among teachers who work with homeschooled students, the challenge of learning algebra at home is perhaps the topic of most concern. As a matter of fact, at the

charter school at which I am currently employed, we were recently advised that the annual standardized mathematics tests reveal that the longer students homeschool under the auspices of our charter, as they reach the middle and high school grades, the worse their math scores become.

Motivation

To a certain degree, academic performance is generally considered to be dependent on the learner's motivation, which can be extrinsic or intrinsic. Extrinsic motivation is when learners engage in activities for the purpose of attaining rewards, such as praise or high grades (Alderman, 1999). When people choose to invest time in activities without apparent reward it is due to intrinsic motivation. Intrinsic motivation is engagement in actions for pleasure, learning, satisfaction, interest, or challenge. Some researchers believe that intrinsic motivation can be enhanced through the use of particular strategies and materials, resulting in an increase in learning performance.

Lepper and Hodell (1989) suggest four useful strategies for enhancing intrinsic motivation: challenge, curiosity, control, and fantasy, all of which are elements in successful video and computer games. First, they posit that educators should design challenging activities which convey the message to the learners that they have competitive skills; the competition with others, or to "beat a level" in a game, or to outscore your previous score, is one of the key components in most computer games. It is essential to find a balance between learner competence and the difficulty of the goals. Next, in order to pique curiosity, it is important to introduce

ideas which conflict with students' prior knowledge or beliefs, prompting students to seek information that will resolve the discrepancy. Moderate discrepancies are the most effective in providing appropriate challenge because they are easily incorporated into an individual's mental framework. Large discrepancies, on the other hand, may be quickly discounted (Pintrich & Schunk, 1996). Again, games are designed this way to manipulate the user to continue to play, but in an educational game this feature will ideally increase the user's knowledge or skill in an academic area. By control, Iyengar and Lepper (2002) suggest that a sense of responsibility will be better fostered in learners if they are allowed to make meaningful choices in the learning process. In an educational computer game, these choices will reflect skill mastery and will move the player along through the levels of the game. Finally, the design of simulations and games that involve fantasy can increase intrinsic motivation (Kenny & Gunter, 2007). The "virtual reality" of a computer game allows the player to experience another level of enjoyment as he or she pretends to be a character in that world.

These four strategies may be very effective in increasing motivation for learning mathematics through the use of educational computer games. For instance, curiosity for most students will come from the mere option of playing a computer game to learn mathematics. Their curiosity will be further aroused by design, by wanting to know what the next level holds. The challenge is provided with incremental learning of new material. The structured levels with increasing difficulty entice the players' appetite for more of the game. Control and challenge work hand in

hand, according to Gee (2003), as the exposure to new skills within each level of the game lets players practice each new skill until it becomes automatic. Once they have achieved mastery, they go on to the next level and find that these skills are challenged, and they must think differently and learn something new. The different tiered challenges in a computer game shift the equilibrium causing the player to rethink their old mastery, learn something new, and integrate the new mastery with the old one, thus giving the player a sense of control and power. In addition, the student will control his results, often working at his own pace, with no grades nor the pressures of regular pencil and paper exercises. In mathematics, the tedium of working problems by hand is in itself a deterrent for many. The fantasy of being put into the game, with a different identity, fosters engagement which takes the focus off of the mathematics, helping motivation but with the added benefit of possibly relieving the anxiety that is present for some when learning mathematics. Ideally, all of these factors combine to increase students' motivation to learn, which leads to increased practice and mastery (Vogel, 2006).

Educational Games for Mathematics Teaching and Learning

The role of computers in education continues to grow, advances largely due to accessibility, increased power, and improved graphical capabilities of computers (Kirriemuir, 2002). In addition to filling the gap where there is a shortage of qualified teachers in specific subject areas or geographical regions, computer-based learning can allow schools to offer more courses to students, offer options to students with different learning styles, or supplement traditional instruction. Yet there is very

little evidence-based research to substantiate decisions to use particular computer applications as interventions for learning. Additionally, there is disagreement as to which educational technology results in the highest gains for learners. Options include computer-assisted instruction, computer games, or interactive simulations, all of which may or may not include online elements.

Computer-assisted instruction, without a gaming modality, has become a generally supported method of teaching (Wang, Wang, & Ye, 2002). Computer-assisted instruction, or CAI, usually refers to drill-and-practice or tutorial programs offered either by themselves or as supplements to textbooks and traditional, teacher-directed instruction. Numerous studies and reviews during the past ten years have shown small but positive effects supporting computer assisted instruction (Bayraktar, 2001; Chambers, 2002; Christmann & Badgett, 2003; Lowe, 2001).

Video games and the engaging fantasy worlds they create provide a preview of how we might develop new ways to learn in schools and communities by building on the educational properties of games, integrating thinking and technology. Although similar in many ways, depending on the source, games are considered different from simulations by including a goal or challenge (Van Horn, 2007). Most research, however, combines simulations into the category of computer games, and these games and simulations have been proposed as a learning tool in a plethora of disciplines by educational researchers and game developers (Aldrich, 2004; Barab, 2005; Squire, 2003), and have been shown to encourage active learning (Garris, Ahlers, & Driskell, 2002; Vogel, Vogel, Cannon-Bowers, Bowers, Muse, & Wright,

2006). In addition, there is empirical evidence that games can enhance learning and understanding of complex subject matter (Ricci, Salas, & Cannon-Bowers, 1996).

Can the addition of games to computer-assisted instruction further influence the way students learn mathematics? Various studies show both positive and negative results; a meta-analysis shows no definite causal relationship between academic performance in mathematics and the use of computer games (Vogel, Vogel, Cannon-Bowers, Bowers, Muse, & Wright, 2006). That may be for a variety of reasons. For instance, some students simply may not like the games, or they may be distracted by game-playing, counter to the intent of enhancing learning (Ke, 2008). Some games may feel more like "school" than a game, limiting the students' interest. There are also many variables which influence the success or failure of game play; the structure of much computer game play is based on the digital world, but the player is also influenced by his interactions with his real-life physical surroundings, including peer interaction, the active guidance of a facilitator, access to additional technology as needed, and the arrangement of the classroom (Ke, 2008). In addition, although educational software is a fast-growing genre, some products have not been developed using validated scientific principles or adherence to academic standards (Vogel et al., 2006). Many games lack a direct connection to curricula in school and are too general to fulfill requirements (Egenfeldt-Nielsen, 2005). Research is also limited due to justifiable skepticism among some teachers regarding the use of computer games for learning mathematics because of a lack of an empirically-grounded framework for integrating computer games into classrooms (Ke, 2008).

Using a mixed-method approach, Ke (2008) studied the use of educational computer games in a summer mathematics program to facilitate 4th and 5th graders' cognitive mathematics achievement and positive attitudes toward mathematics learning. ASTRA EAGLE, a series of web-based games developed by the Center for Advanced Technologies, was used in the study and was designed to reinforce academic standards for mathematics required by the state of Pennsylvania. Participants played the games during 10 two-hour sessions. At the end of the five week period, there was no significant difference between pretest and posttest scores, so no evidence that computer gaming facilitated students' achievement in cognitive mathematics skills. However, the students developed significantly more positive attitudes toward mathematics learning through the mathematics gaming. Several reasons became apparent to the researcher. According to Garris (2002), self-reflection by participants is essential in turning gaming events into a learning experience. With the ASTRA EAGLE games, very few students reflected on their performance. This was due to two factors. First, the games reward players based on the number of correctly solved problems, rather than the ratio of items solved to items tried, so to earn a higher score, players played as quickly as possible, cutting off valuable time for analysis and reflection. Second, the feedback in the games was limited, with answers rated "correct" or "wrong" rather than more informative feedback, so participants did not receive helpful input. In addition, sometimes the questions were presented in a "cut scene" outside of the main game play; the learning was situated "outside" the game play. This caused participants to be less engaged and persistent.

The study findings suggest that learning activities be incorporated within the game story, that games be made pleasantly challenging, and that there be related off-computer activities (Ke, 2008).

In another research by Kebritchi (2010), 193 algebra and pre-algebra students and 10 mathematics teachers from an urban high school in the southeast United States participated in a study in which students were taught by integrating the computer mathematics game, *Dimension M*, into mathematics class. The study examined the effects of *Dimension M* on students' mathematics achievement and motivation over an 18-week semester. The game is a learner-centered game in which the players learn or review the mathematical concepts by accomplishing virtual missions; a player cannot move on to the next level until he completes the objectives of the preceding one. The researchers used a combination of quantitative instruments and interviews to collect data. The quantitative instruments allowed the researchers to examine the effect of the game on a large number of students in order to increase the possibility of generalizing the findings. The interviews helped the researchers cross validate the quantitative results and explore the cause of the game effects. Teachers were randomly assigned to treatment and control groups and were provided with online teaching modules, lesson plans, and resources to use the games consistently across the treatment classes. Lesson plans helped the teachers integrate the games into the school curriculum. The results of the study show that *Dimension M* had a significant positive effect on students' mathematics achievement in the public high school setting. Students who played the mathematics computer games scored significantly

higher on the district-wide math benchmark exam than students who did not play the games. It is important to note that both control and treatment groups improved from the pretest to posttest after attending the school for 18 weeks; however, the treatment group who played the games had greater gain.

Findings from teacher and student interviews support the quantitative findings. The majority of the interviewed teachers and students reported that the participants' mathematics understandings and skills improved as a result of playing the mathematics games. According to the teachers, the games were effective because they had an experiential nature, offered an alternative way of teaching and learning, gave the students reasons to learn mathematics to solve the game problems and to progress in the games, diminished students' mathematics phobia, and increased time on task. Students considered the games effective because they combined learning and fun, offered mathematics in adventurous and exploratory context, and challenged students to learn mathematics. The results agreed with findings from two meta-analyses of 94 empirical studies, including Vogel (2006) and Dempsey (1994), which concluded students who played mathematics video games and attended the traditional classroom instruction achieved higher mathematics scores than students who only attended traditional classrooms.

No significant improvement was found in the motivation of the participants, based on the motivation surveys; however, the teachers and students reported in their interviews that the games improved the participants' motivation toward mathematics (Kebritchi, 2010).

Summary

There is little research regarding the academic performance of homeschooled students, and what exists has not been done as a controlled experiment (Rudner, 1999). But assuming homeschooled students perform similarly in mathematics achievement as traditional students in the United States, especially in Algebra, these homeschooled students would benefit from additional methods of instruction. Ideally, these methods would improve both academic performance and motivation. There are four useful strategies which are thought to enhance intrinsic motivation: challenge, curiosity, control, and fantasy, all of which are elements in successful video and computer games (Lepper & Hodell, 1989).

Like the rest of the population, homeschool families interact with computers and other electronic devices on a daily basis, for both work and play. Play is considered essential for the development of cognitive structures (Rosas, 2003), which increases the potential for learning, so it is reasonable to suspect today's preferred form of play, computer and video games, can be an effective tool in academics. There is evidence that computer games may be more effective than traditional teaching in engaging children (Jenkins, 2002). Yet there is very little evidence-based research to substantiate decisions to use particular computer applications as interventions for learning. Additionally, there is disagreement as to which educational technology results in the highest gains for learners.

Video and computer games can gain and hold a player's attention for an extended period of time, and may create a new learning culture that better meshes with the way of life and interests of today's children (Prensky, 2001). Computerized games could help address our compelling need to strengthen education and to better prepare workers for our technology-oriented society. More research on the effectiveness of educational computer games in mathematics is needed. A study of homeschooled students using computer games to supplement their algebra program will guide educators, parents, and students towards understanding the potential benefits as well as limitations.

Chapter Three

Methodology

Introduction

The purpose of this study was to gain an in-depth understanding of a homeschooled student's learning experience with a mathematics game. The researcher wanted to determine which elements of the game would appeal to the student and why, how exposure to the game might correlate to increased interest in mathematics, and in what ways the student might gain mastery with the additional support of a computer game. A tenth grade student in a charter school in Southern California participated in the study and played the computer mathematics game as a supplement to his textbook and regularly assigned work. There was a pre-test and post-test in mathematics performance, as well as before and after interviews about motivation regarding the subject. The research took place during a 6-week period.

Design

A case study using a mixed-methods approach was undertaken in this study. The case study approach allowed the researcher to delve deeply into the topic, becoming familiar with the background and experience of the student to ascertain how he interacted with the game and learned from it, and to develop a thorough understanding of the individual case. A combination of quantitative (pre and post tests) and qualitative (informal interviews) methods was used to enable a grounded understanding of the impact of computer games in mathematics education. The

interviews helped the researcher cross validate the quantitative results and explore in-depth the many factors involved and the effect of the game.

The student was directed to play the computer game for two hours or more each week of the study. At the beginning of the study, the researcher administered a self-designed pretest of 15 questions covering beginning algebra; the same test was administered again at the end of the 6-week period. A semi-structured interview based on a motivation assessment consisting of 23 questions was also used to guide a discussion with the student before he began playing the game. These questions were related to the student's previous experience with mathematics, attitudes toward mathematics, and so on. The researcher and student are well-acquainted, and academic issues as well as related matters were discussed comfortably, allowing for open, honest dialog. The student's mother, who is the homeschooling parent, observed the student's game play and reported her impressions to the researcher as well.

Setting

The student was homeschooled under the supervision of a K-12 public charter school in Southern California. The school offers a choice of curriculum and program options and serves approximately 4000 students in 5 counties through a network of California credentialed homeschool education specialists. Approximately 2000 of these students are homeschooled, and the remaining students are enrolled in one of 8 academies. The school employs over 300 teachers and support staff to serve students' educational needs.

The student in this study did not attend a school, but learned at home as part of the homeschool program. In this program, coursework is provided through textbooks, workbooks, websites, and other materials as needed or requested. An educational specialist/ teacher is assigned to each student and meetings are held at least once a month to discuss assignments and other issues, with the teacher providing ongoing support by phone, email, or in person as needed. Meetings are usually at the students' homes, but may be arranged at times and places which suit both participants. For these students, their home is their classroom and therefore their learning environment varies widely from student to student. Parents provide educational support as able, and students speak regularly to a credentialed teacher as necessary.

Participant: Jason

Jason was 16 years old, in the tenth grade, and is Caucasian. He is somewhat of an introvert, is clearly intelligent, very polite, and has a good sense of humor. He has two brothers, one about 4 years older, and one 4 years younger. His family reports that he is a great son and brother, is reliable, hard-working, sensible, and a true friend. Further, they say that everyone who knows him likes him. He has a very supportive, close-knit family and they have a large network of family and friends. He was born and raised in what his mom refers to as a "horse town". She describes it as somewhat isolated. However, a city was nearby so the family had relatively easy access to essentials such as groceries and the other things a family needs or wants, despite living in a rural area.

Every family in their community had a farm or ranch, with many animals, usually including at a minimum horses, goats, pigs, and chickens. Jason's family was very fond of animals, horses in particular; this extended to business, with breeding, training, and selling animals an important component of life. However, they enjoyed many other activities, largely those involving the outdoors and physical activity. At the same time, the children had access to technology, and were well-rounded, enjoying a variety of activities like many other children, with the added bonus of horseback riding and other rural pursuits.

Beginning at an early age, Jason enjoyed using the computer, starting with simple games designed for children. His mother recalls one game that included math, spelling, and reading, with a rabbit. She described it as very basic, but he enjoyed it immensely and learned a great deal from it, from preschool skills into the early elementary grade level essentials. He was never particularly comfortable at school, and it is interesting to note that his mother very specifically recalls that without this game, she is not sure he would have ever begun reading! Using technology for learning as well as gaming has become a way of life for Jason.

Jason's love of gaming later extended to video games played on consoles, such as Nintendo, Playstation, and Xbox. He continued to enjoy many games of this type, and also went on to play more advanced games on the computer. He played games typical for his age, such as the various Mario and Zelda games for Nintendo, hand held games played on devices such as the Gameboy, the popular Halo game for the Xbox, and numerous others, which he has continued to enjoy.

Several years ago, the family moved to another similar community, and at that time, decided to homeschool rather than attend the local traditional school. Jason is an avid reader, is physically fit, active in athletic pursuits, an exemplary individual in character, but not particularly academically driven. He is considering work as a firefighter after high school, or in some capacity where he might be able to help others.

Materials

Tests. The researcher administered a self-designed 15-question pre-test in algebra performance. The test measures skills which should be learned in the first semester of a high school algebra course. A post-test using the same questions as the pre- test was administered in week 7.

Motivation Interviews. The interview was loosely based on a list of 23 questions regarding mathematics motivation and was completed during the same meeting. It was recorded and notes were taken for later review. A brief follow-up interview was also conducted, with notes compared to the initial interview.

Software. The computer game used for this study was Tabula Digita's *Dimension M* educational computer game called *Evolver Single Player*, which consists of twenty Pre-Algebra related missions within a 3-D immersive environment. *Dimension M* is described as a 3D immersive video game world that engages students in learning and applying mathematics. In the Evolver game, you and your colleagues are scientists. The premise is that you have been investigating the closure and quarantine of a

government research facility on a mysterious island called Xeno. The leader of the team, Darienne Clay, received a letter from her father, Dr. Robert Clay, who had been the chief researcher on the island. He implied that he had been attempting to fuse biotechnology and nanotechnology. She then received a message of condolence from the federal government, informing her that her father had been lost at sea and his research had been discontinued. She is skeptical and wants to find out what really happened. As the game begins, you soon learn that you must contain a “bio-digital virus” that is causing life forms to mutate on the island. The virus has transformed life on the island into “bio-mutes,” including a deadly species called Sentinels. The data you collect and analyze is used to figure out where Darienne's father’s research went wrong, by comparing it to his early research linking algebraic structures to natural organisms. The game has 20 missions and covers the following learning objectives: prime numbers, even and odd numbers, and perfect squares; prime factors, greatest common factor, and least common multiple; the identities and properties of numbers; order of operations; equivalent fractions, fractions, decimals, and percents; ratios, rates, and proportions; integers and number lines; adding and subtracting integers; multiplying and dividing integers; variables and expressions; combining like terms; distributive property with variables; writing equations; solving equations; pattern recognition; function tables; linear equations; finding coordinates; plotting coordinates. Each mission has specific directions and objectives; the students needs to find the directions for that particular mission from a terminal, console, animal, or crystal. Students watch videos which lead them to their next objective and take them

in the direction they need to go. They listen to various communications to get directions and hints within each mission. Number or letter keys, and the arrow keys, will activate various features such as an "analyzer" or a "blaster." Successfully completing one mission is required in order to move on to the next. Mathematics topics are covered in the general order listed above during game play.

For instance, in Mission 1, you land on a secluded beach and need to break into an abandoned research and development facility. You are instructed to collect the prime numbered nautilus shells, charge the even numbered guardians, then take the numbers that are perfect squares back to the console to turn off the power to the energy gate, allowing access. Items are picked up and dropped, or blasted, in order to complete the objectives.

Procedure and Timeline

Week one. The student was given the 15-question pre-assessment and a brief, casual oral interview regarding his mathematics experience and attitudes to determine his general motivation and thoughts and views about the topic of mathematics. The interview was recorded, and notes were taken by the researcher. In addition, the student received the software so that he could play the game at home. All of the instructions were included. He was advised to call, email, or text message the researcher/teacher with any questions, and also had access to the website from the software developer for additional support. He was instructed to try to play at least two hours each week, at any time of his choosing, and to note the amount of time

played, missions completed, and comments on any positive and negative features of the game play. A follow-up call was made by the researcher the next day to confirm installation proceeded without problems and that the student was able to play the game. The researcher stopped by two days later and briefly observed the game being played to confirm the student had no problems.

Week two through six. The student continued playing the game. During weekly meetings by phone or in person, the researcher/teacher confirmed that he was playing the game and asked if there were any questions or problems. He was advised to stop playing at the end of week 6 until after taking a post-test and having a final interview.

Week seven. The researcher administered the 15-question post-test and had a follow-up discussion regarding his game play experience.

Data Analysis

Each of the questions and answers on the pre- and post-test were analyzed by determining whether the content matched the concepts covered in the game, and whether the student's skill improved. Another test considered was the CAHSEE, on a pass/fail basis. The interview notes were analyzed to determine the student's overall attitudes about mathematics, the study and value of the subject, and his motivation to learn it.

Chapter 4

Findings

Introduction

Algebra is used in many areas of life and is essential for numerous careers, yet some students never gain proficiency, seriously limiting their options. Homeschooled students are likely further hindered by not having the benefits of a traditional classroom. How might the addition of the educational computer game *Dimension M:Evolver* help motivate such a student and enable him to learn algebra fundamentals? How does playing the game correlate to an increased interest in mathematics?

A case study approach using a mixed-methods approach was used. The case study method was selected to develop a thorough understanding of the particularity of the case and context. A pre-test of 15 beginning algebra questions was given at the start of the study. In addition, a semi-structured pre-game motivation interview regarding mathematics attitudes guided a discussion with the student. Next, game play was to consist of playing the computer game for two hours or more each week for 6 weeks, with the amount of time and relevant impressions logged, which was followed by a post-test and a post-game motivation interview.

Pre-Game Motivation Interview

Jason has not had positive experiences with school, though he is adamant that he loves to learn about many things, which is evident from his broad interests. He spoke positively of many hours playing computer games beginning around the age of

4, which helped him learn reading and math skills; technology has strongly influenced his education. He also particularly liked a computer game which involved building things using specific components, which he said involved math and science. He attended traditional school until grade 7, when he moved and began homeschooling. When asked how he would rank his school experience on a scale of 1 to 10, 10 being the highest, he said 4-5 when he attended traditional school, and 7-8 with homeschool. During the initial meeting and discussion, he revealed that while he was never crazy about school, he did pretty well in math until around the 4th grade. He did not particularly care for his teacher that year. In addition, there were timed multiplication tests which he found extremely stressful; he went so far as to say he never did well on them, precisely because of his fear of doing poorly making him freeze and forget what he knew. This problem has continued. From that point on, he needed help with math, but felt he could never get the help he needed at school.

When asked to rank how much he likes math, he said, "A 2 or a 3. The only math I like is when you need to use it for a project, like measuring for something you have to build. Or sometimes you need to multiply." His motivation, therefore, seemed related to whether he thought the mathematics was practical to know. His overall attitude about the value of learning math seemed relatively high, as evidenced by his mentioning that he envies a close friend who happens to be very good at math.

When asked how hard he works in math class, he said he worked harder now, at home; in traditional school, he would just give up. However, his parents cannot help him much with his math studies, and so he has to rely on attempting to learn on

his own from the textbook, with occasional help from friends. His negative experience in fourth grade and subsequent years has left him with a feeling of inadequacy about his math skills and ability to learn. He has developed a sort of "love/hate" relationship with mathematics. Jason had previously taken pre-algebra and said he did not do well in that course. It is interesting that Jason felt he worked harder at home, presumably because he is able to get more support than he did in school, even if it is more moral support than actual mathematics help. Significantly, he recognizes, perhaps from his mother's elucidation, that his problems with math were not his fault, but rather due to the circumstances at school. From his comments, it is evident that Jason would likely want to learn algebra if he found it useful and personally meaningful, though he is unsure of the purpose of knowing algebra.

His grades in subjects other than math have been good. He likes to read because "I like to know a lot." He said his mom is very encouraging about his education. After high school, he doesn't plan to go to college but thinks he may take courses at a technical school if necessary for a trade or to become a firefighter.

Considering math problems in general, when asked what he thinks of the problems in textbooks, he described them as "boring, confusing, and frustrating." As we discussed what, if anything, he enjoys about math, he said, "Venn Diagrams and real life problems." One of the specifics he mentioned was the math he used when having to plan and build a fence around their property. He has enjoyed elements of construction, such as measuring, and the satisfaction of building things. He also mentioned using math in calculating time.

In answer to the question, "Do you sense your parents use mathematics much?" he said that he thinks probably everyone uses math. He thinks his mother does, because she has her own business and he knows she must determine expenses and how much to charge her clients in order to be profitable. He was not sure about his father, although he said he might use math in his work as a driver for a chemical company. When asked how much he likes math on a scale of 1 to 10, he said 2. He wants to complete the minimum amount of math necessary to graduate.

Regarding his overall attitude about math, Jason feels his mother is very encouraging about mathematics and tells him it is important. He said he knows this is true. When asked how good he is at math and what he thinks about that, he responded, "Not extraordinarily good, but I could be if I needed it and when it is interesting." This comment is quite revealing, as far as his potential to succeed in the subject. He said that he prefers geometry to algebra, referring again to his fence building experience and needing to determine the perimeter measurement in order to buy the supplies for the project. He also said that he is better at adding than multiplying; he understands the concept of multiplication but has never managed to memorize the multiplication table. When asked if he thinks it takes special talent to do well in mathematics, he said that some people are naturally talented but everyone can learn it if they are willing to work. "My mom says everyone has their strong suit." Asked if someone is dumb if they make mistakes in mathematics, his answer was a resounding "No! If you don't make mistakes, you can't learn." As a strong proponent of computers in mathematics education, Seymour Papert (1993), has stated, "Errors

benefit us because they lead us to study what happened, to understand what went wrong, and through understanding, to fix it." It is revealing that Jason feels this way, a clear indication that his previous failures in mathematics have not necessarily made him question his innate ability. In the same way that his love of reading has fostered his knowledge of history, incorporating his love of technology and video games with learning algebra made sense, and was generally a positive experience for him. When offered the opportunity to play a computer game to help him with math, he jumped at the chance.

As previously indicated, due to some negative experiences at school, Jason is generally not academically inclined. As a matter of fact, he has developed a tendency to avoid school work, which of course is not terribly unusual for teenagers, but for such a very "good" kid it seems a bit troubling. In his case, he can perhaps successfully avoid academics more than most students because he does his schoolwork at home rather than in a classroom. His mother is quite flexible regarding the time spent doing school assignments. Often, the family gets sidetracked due to other demands of life, such as chores and errands, and so the students (Jason's brother as well) get behind in their work, and have difficulty catching up.

Fortunately, Jason is an avid reader. He particularly enjoys reading of the experiences of others and learning about eras of which he has no personal experience. It is interesting to note that while he personally admits to not being interested in academics, at the same time, he greatly enjoys reading historical fiction, which is a perfectly valid way to learn about social studies. In addition, Jason has a wide range

of personal interests which expand nearly daily. For example, he loves animals of all kinds, and they have quite the menagerie at his home, some of which are his personal pets. He doesn't simply enjoy having animals, but rather he needs to know everything he can about them, from observable traits of the species to their emotional and sustenance needs and peculiarities. This has provided a great deal of his science education. Jason has, therefore, in the researcher's opinion, exhibited an extreme interest and willingness to learn, given the right circumstances and topic.

Regarding the study of mathematics, Jason has come to feel that he is not very good at it. This attitude likely is a factor in his ongoing difficulty in learning the subject, as his intelligence and overall capability would not hinder him in learning mathematics. He seeks knowledge, in general, and has had no problem filling this need through reading widely. His reading encompasses areas such as history, science, self-defense, religion, and much more. However, this passion has been interrupted in the case of mathematics. He said that his best experiences with math were with computer games when he was much younger, and in first, second, and third grade at school. He has no deeply compelling urge to learn more mathematics, though he knows there are requirements to do so in order to finish high school. He also knows that math is important in some areas of life, though he admits he is not sure exactly when a person will use algebra. He doesn't think he will likely need it, but says that since he doesn't know for sure yet what he will do for a career, there is a chance he might need to know it. Further, he says he thinks he will need to study more math at

college if he should choose to attend. In other words, he knows there are practical reasons to understand algebra.

Jason expressed a strong interest in playing a computer game to help him with math when presented with the opportunity. He actually seemed quite excited about it. Part of this reaction was no doubt due to his enjoyment of gaming in general. He regularly uses a variety of video game systems and also continues to plays games on the computer, as he learns of them from friends and elsewhere. Over the years, he has played a significant number of video and computer games and has enjoyed them immensely. In addition, he said that he would love to be able to learn math by playing a game, compared to the more traditional way.

Game Time

Rather than the two hours per week he was asked to play, Jason played the game at least once a week for the first 6 weeks, during the time he would normally study math. He was asked to log the time spent on the game, but he did not, so I asked him for his progress and thoughts regarding the missions he played during our weekly phone conversations and noted what he said. Table 1 provides a brief synopsis of his impressions.

In order to progress through the game, tasks must be accomplished which involve picking up, blasting, or charging objects which meet the mathematics requirements for that particular objective. The math can be learned through the game, or it can be played as practice or review. The player can move through the game at a relatively rapid pace if they already know the math concepts. If they do not, the

narration sometimes presents clues. Otherwise, the player can read about the concept in the journal provided, where he can also see several samples, somewhat similar to a textbook but without practice problems. At that point, for someone just learning the concepts, it would be a matter of trial and error, slowing game play considerably. Each time a task is successfully completed, the player gains access to a previously closed area, providing motivation to master the concepts as the story continues.

When Jason downloaded the game, he initially had some trouble getting it to work on his computer. He was mildly frustrated, but after some minor troubleshooting, it was installed properly and he was able to proceed. He was instructed to begin with the tutorial and complete the missions in the order they were assigned.

Table 1

Log of Game Play

WEEK	LEVEL	MATH TOPIC	NEW CONCEPT FOR STUDENT?	TOTAL TIME PLAYED	MISSION	PROS	CONS
1	Mission 0	None	N/A	30 minutes	Tutorial	Learning how to play the game, like how to aim, how to shoot, picking up things	Slow, and it's hard to know where you are supposed to go without a map of the entire Mission. It looks kind of choppy compared to other games.
1	Mission 1	Primes Odds and Evens Perfect Squares	New Review New	45 minutes	Xeno Island	You learn about prime numbers and squares	The questions are hard
2	Mission 2	Prime Factors Greatest Common Factors Least Common Multiples	New New New	1 hour	R and D	Learning about common factors	The map is really big and confusing.
3	Mission 3	Associative Property Commutative Property Distributive Property Identity Properties	Review Review New Review	1 hour	The Valley	Equalities and properties	It is slow to play
4 5 6	Mission 4	Order of Operations	New	1.5 hours	Growth	The story is interesting and I learned what I needed to beat the level	It is slow to play and the math is a little hard to understand and it takes a lot of time to learn

The tutorial is set up in a seemingly user-friendly manner, with the player given numerous tools to help with the missions. For instance, there is a visor the player "wears" which displays various options, such as a blaster and a charger device. There is "radar" which provides a general overview of your location. You are introduced to a journal which can be accessed to read the words characters have spoken, as well as to read about the mathematics which are being used within the mission. Samples of the types of math problems which will be needed to succeed in each mission are also provided. The keyboard keys A, W, S, and D are used to navigate to the left, forward, right, or back, and the mouse is used to change the view (to look up, for instance) and also to aim and shoot as necessary. In addition to learning the basics of game play, two specific tasks are assigned in order to get the feel of the game and utilize the tools, while accomplishing your mission. An overview of the controls as depicted in the game is shown in *Figure 1*.

Figure 1. The controls used in Evolver Single Player.

Around this time, the researcher, an individual personally inexperienced with computer or video games, also installed a copy of the game without much difficulty. However, the tutorial was significantly challenging to this researcher, mostly in regard to simply getting around the area on the screen and knowing how and where to go next. It appeared that it would be difficult for other reasonably intelligent people as well, a significant cognitive load which would interfere with the learning and practice of new mathematics concepts. However, in discussing this with Jason, he said it is much like all or most other video games; these things have become, in general, almost intuitive to him. His extensive experience with video and computer

games has provided an excellent foundation so that the interface did not pose a problem. In fact, he could maneuver through the game in some ways almost effortlessly, except for the math problems along the way. He explained that he played through the entire tutorial because it was set up as game play, and in fact taught you the game by having you go through the same type of challenges you would in actual game play. For instance, the narration advised you that you had to look for certain fuses and to blast them. For additional information about which fuses you needed, you were instructed to refer to a journal which gave details about your mission. Another challenge had you "charge" something, using another one of the items in your possession. He mentioned that in general one could navigate by knowing that if there were mountains, you were likely not to go past them, as they would serve as a border of sorts, keeping you on a path to the right place. This is apparently a common device used in video games, so Jason's experience with technology again made getting around relatively easy and pleasant.

The first actual part of the game, Mission 1, involves even numbers, odd numbers, prime numbers, and perfect squares, which Jason would have certainly been exposed to in earlier math classes. Yet he found the math problems "hard." In this level of the game, the player has to collect the right shells and bring them back to open a gate, use the analyzer to "charge" the security guardians, then blast them to neutralize them. The first objective has you locate 5 prime numbers and the next requires you to locate 3 perfect squares. If you find a shell which is not one of the required ones, you can pick it up, take it to the designated location, and drop it there,

but you will see you have not earned the "credit" you need. Since Jason did not know what a prime number was he was confused about why he was failing the mission. Jason at this point was not that invested in the game, and did not seem to find it terribly engaging; he implied the story thus far was a bit convoluted. It was difficult to determine whether he felt this way because he had trouble with the math, or if he was not inspired to learn the math because the game did not engage him. Yet he did, in fact, stick with it, using the journal to read about the math he needed to meet the objectives and proceed.

As he moved through Missions 2 through 4 of the game, Jason seemed to be more immersed in the game play. He enjoyed it more and was more animated in his discussion of the game play, even though it sounded more difficult. For example, Mission 2 involves prime factors, greatest common factors, and least common multiples. The player is to disable the guardians, then find certain parts which are marked with the correct prime factors of a given number, pick them up, drop them at the correct location, and perform other such tasks, such as battling enemies as they attack. Jason said he liked this level once he understood what he was supposed to do, and said the math was not too difficult, but he was a little annoyed about the map, which covered a very large area and made it hard to locate the needed items. He specifically mentioned one suggestion to improve the game based on his experience on this level: a "way point marker" which would make it more clear on the map where you were in relation to where you want to be. *Figure 2* shows the tiny map

("radar") in the upper left hand corner of the screen which is all you have to guide you to the various items you must locate.

Figure 2. Mission 2 as seen through the visor of the player.

The next level, Mission 3, covers mathematical properties (commutative, associative, etc.), and though this was a topic that Jason said was new for him, he used the "math concepts" section of the mission journal to learn about the math needed. The player must "hunt" for equalities that represent the given properties. During this mission, he felt it would be good if you were able to save your progress,

because if you quit and have not completed the mission, you have to start at the beginning the next time, which would be understandably frustrating. A sample of the math concepts section of this mission is shown in Figure 3.

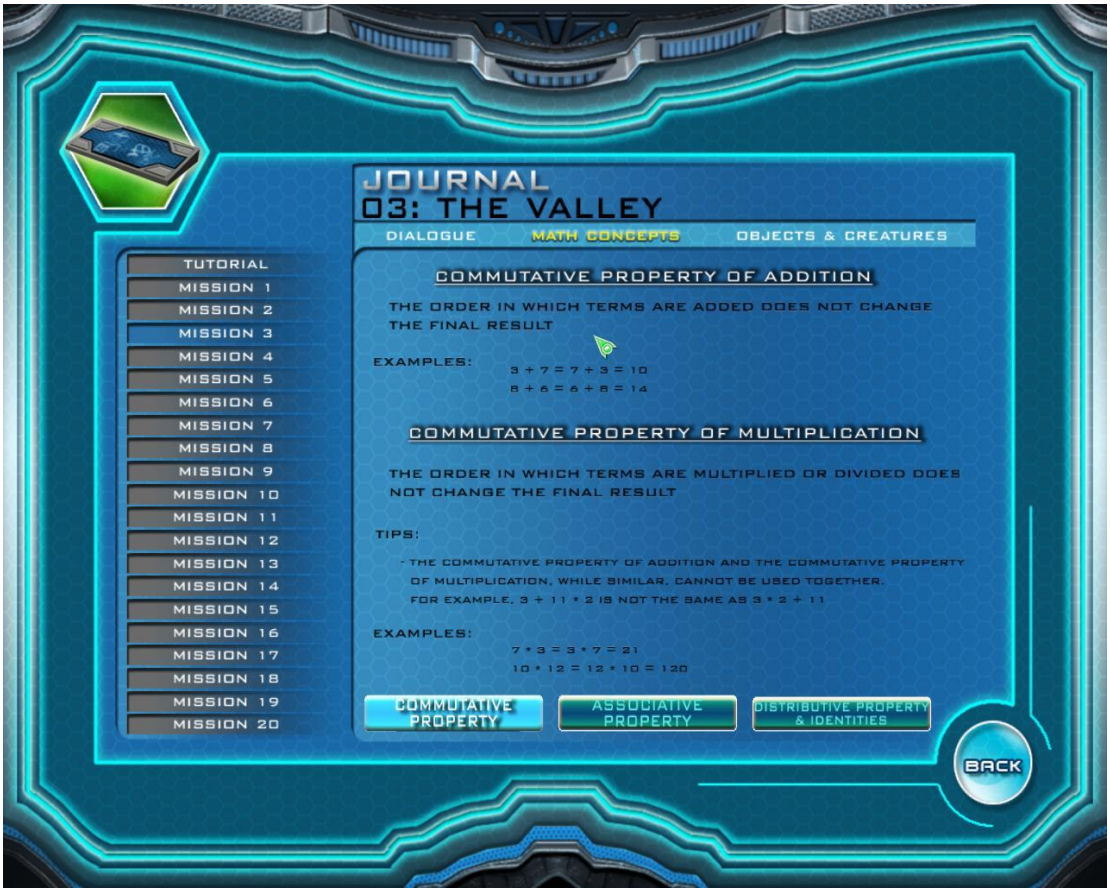

Figure 3. Mission 3 Mathematics Concepts.

Mission 4 deals with the order of operations; Jason said he was totally unfamiliar with this, but learned in order to complete the mission. By reading the journal, seeing the examples, and applying this knowledge in the game, he was able to correctly perform the required tasks. The tasks involved blasting or picking up objects marked with the right mathematical expression. For instance, in one part of

the mission, Jason had to blast the parts of the expression in the correct order, first blasting the part in parenthesis, which then gave him a new number, which he needed to use to find the next correct expression. Unfortunately, by the time he finished Mission 4, Jason had clearly lost interest in the game to a certain degree. This was primarily due to a combination of three factors: the game play was relatively slow; the entire "map" of a level was not visible, leading the player to have to spend much time searching for things in the wrong places; and his lack of familiarity with the math concepts made the game a bit frustrating at times. First, regarding the play of the game being slow, Jason said that this was in stark contrast to many of the games which are popular today, which are very, very fast-paced with a great deal of action and noise and constant feedback. His comment might have also been in reference to his simply not being able to proceed as quickly as he wanted due to not knowing the required math. The second perceived flaw, the map not being adequate, made for wasted time while "looking" for the correct path to whichever object or challenge you were to find. The third factor is perhaps the most relevant; Jason had a hard time being successful at the game because he didn't know the math. It would have been much more enjoyable for him had he already known the concepts covered in the game, with the game simply providing reinforcement. Perhaps worst of all for Jason, when he ended a session, his progress on that level was not saved; he therefore had to start over the next time, and he did this several times. He considered this a negative, but from an educator's viewpoint, the extra practice would likely be needed if the player had not managed to complete the objectives the first time.

Jason's mom, who would also be considered his teacher, noted that he really liked the fact that a game could be used to learn math skills, though he ultimately did not think he learned much from it. She observed his game play and encouraged him to play, partly because she is not proficient in mathematics and hoped it would help him. Jason seemed to genuinely enjoy this game, although he did not find it as much fun or as well done as the games he plays for pleasure.

Pre- and Post-Test Results

Dimension M is structured so that the player cannot complete a mission without successfully demonstrating competency in the mathematics concept taught in that mission. In other words, the student is tested as they play, with progress in the story limited unless all of the math-related tasks are solved correctly. This is, in effect, like having tests within the game. In addition, a 15 question test covering beginning algebra concepts was given by the researcher both before and after the game was played to determine whether Jason's score would improve. Although he had previously taken prealgebra and algebra, he had not done well in those courses, and on the pre-test, answered only 2 of the 15 questions correctly. After playing the game for a total of 4 hours and 45 minutes and taking a post-test with the same questions, he answered the same 2 questions correctly.

The missions he played, 1 through 4, covered prime numbers, odd and even numbers, perfect squares, prime factors, greatest common factor, least common multiple, additive identity, additive inverse identity, associative property, commutative property, distributive property, multiplicative identity, and order of operations. He said that he knew some of these things before the game, but not knowing all of them slowed his progress. By Mission 4, he had to stop and learn the concepts before he could play in a meaningful way. Two of the concepts he felt he learned from the game were the distributive property in Mission 2 and the order of operations and the acronym PEDMAS for remembering them in Mission 4. However, Jason got two relatively simple problems involving those concepts wrong on the post-test. Since they were new concepts for him, he may have not yet internalized the processes and also may not have put forth his best effort on the post-test. Also, his interest in the game had waned by the time he played Mission 4, and his required efforts to learn the math in order to win took a bit of a toll on him.

Post-Game Motivation Interview

The positive results of Jason's game play were more evident in discussion than through formal testing. When asked if he thought this game would be good for other students to play, he said, "Definitely." He said it was a good game and much better than a math class. When asked why he did not play more of the game, for longer periods of time, and more missions, he said that it was because he did not know the

mathematics involved and that it took a lot of time to learn it so that he could do well enough to proceed through the game. This detracted from his enjoyment of the game.

Although he did not play enough of the game to gain the kind of competency he would have needed to have been able to solve many of the other problems on the post-test, there were some notable differences in his attitude, or motivation, regarding mathematics. Motivation is an interesting and complicated part of the equation (algebra pun intended), with no simple answers. When I asked him specifically to tell me honestly what he thought of the game after having played it for 6 weeks, Jason said, "It was fun." I asked if he had any interest in playing it again, and he said, "If there was something in it for me, like I would get school credit for it."

As a follow up to his game play, Jason was asked to write a brief summary of his experiences with computer games for education, and here is what he wrote:

> I started gaming at a very young age, which may be the reason I still game today. At around age 4, I played a very basic game on the computer with a rabbit, that taught things like adding, subtracting, and maybe later multiplication.
>
> The first game consoles I ever owned are the Sega Genesis and Super Nintendo. I probably played them starting around the age of 6 or 7. I can't say I had learned anything academic from those older systems. From those systems I moved on to the Nintendo 64, playing games like Mario Cart, Zelda, Star Fox, and Mario 64.

After those we upgraded in technology and bought a Playstation 1. Now that was an awesome gaming system. One day my brother Brian brought home Final Fantasy 7 or FF7 for short. I can honestly say that game really helped me learn to read. There wasn’t really any voice acting, it was mostly subtitles, so if I wanted to play I had to read.

Then I got an Xbox, which had much more action-packed games. Although I did not learn how to read from these games, I did develop hand-eye coordination.

I shouldn't say I didn't learn anything academic from Xbox. In fact, I think it was on this console I first encountered a math-related game. It was based off the old school Donkey Kong except you had to solve an equation to complete a level and every now and then Donkey Kong would swing by. Being that I had never seen the math displayed in the game, naturally, I wasn't very good at it. Yet it did make me very determined to beat the game, and in turn I learned math I had never used before.

It was when I graduated to computers that I really started learning. There is a game called Garry's Mod that taught me to remember all kinds of things that are needed to construct things. You construct small things within the game. I learned measurements and

> also how to use the wide range of tools that required a "thinking before using" strategy.
>
> Also one of my teachers gave me a computer game that was surprisingly fun, even though it was about a math subject I never really cared for. As it turns out, it had action and some story line in it, while educating me at the same time. I think that one was called Jump Start Math.
>
> If I were to give my honest thoughts on the question, "Has gaming helped my education?" I would give a resounding Yes!

This enthusiasm for learning through computer games is sufficient to suggest more research is essential. It is very interesting to note that approximately 6 months after playing the computer game, Jason passed the CAHSEE (California High School Exit Exam) Mathematics assessment. This is a significant achievement for Jason. If in fact Jason might have suddenly felt better about math just from a "fun" experience with it, and if that might have helped ease his near phobia about the subject, then *Dimension M* must be considered a rousing success.

Chapter 5

Discussion, Limitations, and Implications

Introduction

Algebra provides the foundation for higher-level mathematics and is essential for many 21st century careers, yet students in the U. S. have fallen behind. We must better prepare our students for the increasingly complex mathematics which are part of our technologically advancing society through whatever means available, including through the use of educational computer games, if shown to be successful. Anecdotal evidence suggests students who are homeschooled may be particularly challenged in the area of algebra as they may not have sufficient exposure to the subject without the daily reinforcement provided in a traditional classroom with a well-trained teacher. They might, therefore, be especially in need of more innovative solutions. This study was conducted to investigate and understand the ways the computer game *Dimension M* could improve the motivation and performance of a homeschooled high school student in beginning Algebra. An interpretation and discussion of the findings, limitations, and implications for teaching, learning, and future research follow.

Discussion

Today's children interact with computers and technology on a daily basis. The *Dimension M* game has many of the features of other video games which have the ability to enthrall young people endlessly; by incorporating algebra concepts, can it be an important tool to enhance the learning of algebra, an essential skill in our

modern world? In particular, how can *Dimension M* benefit homeschooled students' motivation and performance?

In some ways, the experience of Jason with *Dimension M* was similar to older style computer-assisted instruction, which was usually a drill-and-practice or tutorial offered as a stand-alone program or as a supplement to a textbook and traditional, teacher-directed instruction. Although the game has the added feature of a story and a 3-D immersive environment, learning the math was done incrementally by reading from an in-game journal, then practicing the skill by selecting the correct expressions, equations, and the like. Just as numerous studies have shown small but positive effects supporting computer assisted instruction (Bayraktar, 2001; Chambers, 2002; Christmann & Badgett, 2003; Lowe, 2001), Jason seems to have at least somewhat advanced his mathematics proficiency. There is three-fold evidence of his learning: he was able to progress through 4 levels of the game by mastering each concept, he himself acknowledged having learned new math concepts, and he passed the CAHSEE. This bodes well for homeschooled and other students as educators search for viable ways to improve algebra instruction and proficiency.

The addition of game play to computer assisted instruction was a welcome addition for a student like Jason, providing, at least to a degree, the intensity of engagement to which Garris, Ahlers, and Driskell (2002) referred. Jason's experience with video and computer games for learning and entertainment since childhood have given him an affinity for the medium. He is likely not alone in this regard.

He said he enjoyed playing the game, and as Jenkins noted (2002), to engage students, computer games may be better than traditional teaching, though this is not conclusive. This has been quite true for Jason in general, though, who has an aversion to learning math the old-fashioned way, and has successfully learned many things in the past through computer games.

Computer games have been shown to encourage active learning (Garris et al, 2002; Vogel et al, 2006), which Jason attests to have been the case throughout his life and more recently with *Dimension M*. Having played part of the game briefly, the researcher recognizes its potential for reinforcing the mathematical concepts which must be utilized successfully to progress through the game. Regarding the effectiveness of the game in improving Jason's mathematical performance, it is interesting to note that while Jason's score on the post-test did not improve, he was able to pass the California High School Exit Exam. To this researcher, it seems highly possible that this was due to a lessening of his fear of math and improved motivation through the game experience, rather than actually learning or reviewing math concepts through game play, yet either may be true.

Motivation is an area the researcher imagined would be greatly enhanced by using a computer game to learn algebra concepts. Intrinsic motivation refers to motivation that is driven by an interest or enjoyment in the task itself. The design of simulations and games can increase intrinsic motivation, as a computer game allows the player to pretend to be a character in a "virtual" world (Kenny & Gunter, 2007). Although Jason seemed to enjoy, to a certain extent, playing the game as though he

were a character in the game, he did not seem to develop intrinsic motivation in the process. Ideally, increasing intrinsic motivation would result in an eventual increase in learning performance. In analyzing why this did not work in Jason's case, we can look to Lepper and Hodell (1989) and the four strategies they found necessary for enhancing intrinsic motivation: challenge, curiosity, control, and fantasy. These elements are found in most video and computer games. The main flaw, it appears, for Jason, was that the challenge was too extreme. A more moderate discrepancy between what he could do mathematically and what he needed to do in the game would have been ideal. Without a better balance and appropriate challenge, the game is not pleasant enough that intrinsic motivation is developed.

On the other hand, extrinsic motivation was evident when Jason said he would continue playing the game if there were something in it for him. Alderman (1999) explains that extrinsic motivation is when learners engage in activities for the purpose of attaining rewards such as high grades; this does not tend to produce the optimum learning, although any focus on mathematics is better than none, particularly if there is concern that mathematics is not being studied regularly, as may be the case with homeschooled students.

Limitations

This research was limited by the single individual case. Jason, unfortunately, did not know much of the math in the game. Rather than using the game to reinforce mathematics concepts as they were learned through direct instruction, this student was learning from the game itself, accompanied by some mathematics knowledge he

had learned previously. Jason struggled with the math, which infringed on his enjoyment of game play, and ultimately seemed to sour him on continuing. The recommended method, according to the developer, is as a supplement, to reinforce skills learned in class; future research with homeschooled students who have a more formal approach to learning algebra would be helpful. Also, studying one student rather than multiple students of course eliminates the variety of responses possible with a group, allowing for personality differences, learning styles, and experience levels which might have demonstrated different motivation and mathematics performance results.

Another limitation was the length of a study. It was relatively short, and the student did not play as long as intended. It would have been helpful to have several months or an entire semester with the game, to see whether that improved the interest and motivation as well as the mathematics performance. More time devoted to game play on a regular basis over a longer period of time might provide clearer insight to the game's effectiveness. An additional limitation was that the pre- and post-test questions not being more closely aligned with the missions of the game, with questions based on each level, made it difficult to determine whether the game's concepts were being learned well enough to transfer to outside of game play.

One further limitation was not having observed more than a few minutes of the student's game play, in either this individual case or with additional students. It is uncertain what might have been gleaned, but watching the actual experience of how the student learned and used the math, and seeing how his interest grew or waned,

and what elements of the game caused frustration would have helped develop deeper understanding.

Implications

Education must change to accommodate new developments in the way students learn. *Dimension M* is designed to provide the same kind of rewards through incremental progress as the games young people play for fun, but competency in each mathematics concept must be demonstrated before the player can proceed, which theoretically seems ideal to this educator. There are numerous implications for teaching and learning, as well as future research.

The amount of time the student spends on the game on a regular basis could contribute to its effectiveness, as would playing the entire game through, for the full 20 missions. For homeschooled students who have flexible hours, abundant time would generally be available for game play time, which could be quite advantageous. Observing the student while he plays to determine likes and dislikes about the game, what aspects cause frustration, how the math is incorporated into the game, and other factors would enable the teacher to determine whether additional instruction is needed, and to see clearly if the game was effective in each area of mathematics learning for a given mission.

Research should be extended to cover a much longer time period. Ideally, this might be a semester or at least the length of time it takes to cover the mathematics concepts which are addressed in the 20 missions of the game. This research could focus on additional homeschooled students who are learning algebra in a variety of

ways, so that it might be determined which approach works best with the game. In addition, clinical observation as a component of the research would reveal more elements of the learning process, by witnessing the student's strategies in playing the game and solving the problems, as well as determining which elements of the game are successful for the student with each mathematics concept to be learned.

Using technology to learn algebra can be further studied by delving into other variables. For example, while playing the game and learning a concept, does the student use the internet to look for additional information to enhance understanding if needed to "beat" the level? Is the game played only when offered as an alternative to math study time, textbook work, or direct instruction, or is it played for fun and/or learning? Are there other computer games that might be better alternatives for learning algebra? Are more simple tutorials perhaps more effective, though less fun? A multiplayer game, with more advanced algebra, is available and allows students to play against other students who are learning the same concepts. Might this addition of online competition further aid motivation or performance as one research suggests (Kebritchi, 2010).

These kinds of games and the "learning culture" they create may be more relevant to our twenty-first century way of life than the traditional model of learning (Prensky, 2001). More research on the effectiveness of educational computer games in mathematics, with both homeschooled and traditional students, is warranted.

Appendix A

Mathematics Motivation Interview Questions
(Adapted from Assessing student motivation in high school mathematics. Paper presented at the annual meeting of the American Education Research Association, Chicago.)

1. What other high school math courses have you taken? What grades did you get in those math courses?

2. What other math courses do you think you'll take in high school?

3. What grades do you tend to get in other courses (English, history, PE, etc.)?

4. What plans do you have when you leave high school (4-year college, 2-year college, job, join the army, etc.)? Be as specific as you can.

5. On a scale of 1 to 10, with 10 being the highest, how much do you like school? What specific things do you like and dislike about school?

6. On a scale of 1 to 10, with 10 being the highest, how useful do you think school is for the things you want to do? Are there some things you do in school that are more useful than others?

7. On a scale of 1 to 10, with 10 being the highest, how much do you like math? Are there some parts of math you like and some you don't? Please explain. (Look for topics the student likes, such as likes fractions but dislikes algebra. Also look for level of challenge student prefers -- are textbook exercises boring? -- are story problems too hard?)

8. How hard do you work in math class? Do you always do everything the teacher assigns?

9. In general, what influences you to work hard in math? Is there anything that causes you to work very hard? (Although this issue comes up again later, if there is any evidence of <u>task orientation</u>, <u>ability orientation</u>, or any type of <u>social orientation</u>, make sure it is noted.)

10. How do you like math in comparison to other subjects? Are the factors that make you work hard in other subjects different from the ones that make you work hard in math?

11. Do you sense that your parents use mathematics very much? How do they use it? (Look for examples of job related or any other parental uses of mathematics.)

12. Do your parents want you to do well in school? How much support do they give you? Do they ever help with home work? Do they ask you about school?

13. Do you have, or have you had, paying jobs -- anything from baby-sitting and lawn mowing to working at McDonalds. Did you like those jobs? Did you use any math in those jobs?

14. Do your parents do anything special to encourage (or discourage) you in math as compared to other subjects?

Appendix B

1. What is z^2 if $z = -3$?

2. Simplify $\frac{x^3}{x}$.

3. Simplify $(3b^3)(4b^4)$.

- □ A. $7b^7$
- □ B. $12b^{12}$
- □ C. $7b^{12}$
- □ D. $12b^7$

4. Simplify $(a^3b)(ab^2)$.

- □ A. ab^5
- □ B. a^4b^4
- □ C. a^3b^2
- □ D. a^4b^3

5. Evaluate y^3 when $y = -2$.

6. Evaluate $b^2 - 2b + 1$ when $b = 3$.

7. What is the reciprocal of $\frac{3}{5}$?

- □ A. 3
- □ B. $3 \div 5$
- □ C. 5
- □ D. $1\frac{2}{3}$

8. Simplify $\frac{12}{7} \cdot \frac{21}{4}$.

9. Add $(2y^2 + 6y + 1) + (y^2 + y + 4)$.

- □ A. $2y^2 + 6y + 5$
- □ B. $3y^2 + 7y + 5$
- □ C. $3y^2 + 7y + 4$
- □ D. $3y^2 + 6y + 3$

10. Subtract $(7a^2 + 8) - (2a^2 + 3)$.

11. Expand $3x(x+1)$.

- □ A. $3x^2 - 3x$
- □ B. $3x^2 + 3x$
- □ C. $4x^2 - 1$
- □ D. $3x^2 - 1$

12. Solve $4(x+3) = 24$.

13. Solve $14 - 3x = -4$.

14. Solve $\frac{6x}{5} = 12$.

15. Solve $4(z+1) \geq 32$.

- □ A. $z \geq 7$
- □ B. $z \leq 7$
- □ C. $z \leq 16$
- □ D. $z \geq 8$

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