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# Effects Of A Computer Game On Mathematics Achievement And Class Motivation: An Experimental Study

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# EFFECTS OF A COMPUTER GAME ON MATHEMATICS ACHIEVEMENT AND CLASS MOTIVATION: AN EXPERIMENTAL STUDY

by

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# ABSTRACT

In the last few years educational computer games have gained attention as a tool for facilitating learning in different sectors of society including but not limited to military, health, and education. However, advances in computer game technology continue to outpace research on its effectiveness. Few empirical studies have investigated the effects of educational games in the context of formal K-12 settings.

The purpose of this study was to examine the effects of a series of mathematics computer games on mathematics achievement and motivation of high school students. In addition, the role of prior mathematics knowledge, computer skill, and English language skill of the participants on their mathematics achievement and motivation when they played the games were investigated. A total of 193 students and 10 teachers from an urban high school in the southeast of the United States of the America participated in this study. The teachers were randomly assigned to treatment and control groups. Students' mathematics achievement was measured using school district benchmark exams and a game performance test generated by the developers of the mathematics games. A mathematics motivation questionnaire based on Keller's (1987a) ARCS model of motivational design measured students' mathematics motivation. Multivariate Analysis of Co-Variance (MANCOVA) was conducted to analyze the data. In addition, interviews were conducted to cross validate the results of the quantitative data.

The MANCOVA results indicated significant improvement of the mathematics achievement of the experimental versus control group. No significant improvement was found in the motivation of the experimental versus control group. However, a significant improvement was found on the motivation scores of the students who played the games in their school lab and

classrooms compared to the ones who played the games only in the school labs. In addition, the findings indicated that prior mathematics knowledge, computer skill and English language skill did not play significant roles in achievement and motivation of the experimental group. Teachers' interviews revealed that these individual differences had indeed played significant roles in game-playing at the beginning of using the games, but the impacts gradually diminished as the students gained the required game-playing skills.

The overall results indicated that the mathematics games used in this study were effective teaching and learning tools to improve the mathematics skills of the students. Using the games in mathematics education was suggested by the teachers as an appropriate alternative way of teaching, as one of the teachers stated: "This is definitely the way that we have to go to teach mathematics in the future." Mathematics games should be integrated with classroom activities if teachers want to increase mathematics class motivation. Teachers' helps and supports are vital in using the games effectively in a population with different prior mathematics knowledge, computer skills, and English language skills.

This dissertation is dedicated to my husband, Masoud, whose love and support inspired me throughout this endeavor. To my daughters, Yasamin and Sara, whose love strengthened my determination to accomplish this journey.

Their patience, support, and encouragement are greatly appreciated.

And to my parents, Safieh and Ebrahim, who taught me how to work hard to reach my goals.

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# LIST OF ACRONYMS/ABBREVIATIONS

| | |
|---|---|
| ARCS | Attention Relevance Confidence Satisfaction |
| CMS | Course Motivation Survey |
| IRB | Institutional Review Board |
| MCAR | Missing Completely At Random |
| UCF | University of Central Florida |

# CHAPTER ONE: INTRODUCTION

In the last few years instructional games (computer games designed specifically for training or educational purposes) have gained attention as a tool for facilitating learning in different sectors of society including but not limited to military, health, and education. Continuing advances in technology, the increasing popularity of entertainment video games, and recent studies that underscore the potential of game-based learning (e.g., Federation of American Scientists, 2006; Egenfeldt-Nielsen, 2005; Mitchell & Savill-Smith, 2004) have renewed interest in the use of instructional games.

A number of factors have made instructional games attractive learning tools. The advancement of technology has made it possible to play games on simple platforms such as mobile devices. This makes instructional games accessible to many people including those who do not have personal computers (Mitchell & Savill-Smith, 2004). Instructional games may create a new learning culture that better corresponds with students' habits and interests (Prensky, 2001). More importantly, instructional games are thought to be effective tools for teaching difficult and complex procedures because they (a) use action instead of explanation, (b) create personal motivation and satisfaction, (c) accommodate multiple learning styles and skills, (d) reinforce mastery skills, and (e) provide interactive and decision making context (Charles & McAlister, 2004; Holland, Jenkins, & Squire, 2002; Sheffield, 2005).

Given these benefits, many educators are increasingly interested in using the games in the formal school setting. Three UK reports from (a) the British Educational Communications and Technology Agency (Dawes & Dumbleton, 2001), (b) Teachers Evaluating Educational Multimedia (McFarlane, Sparrowhawk & Heald, 2002), and (c) the Department for Education and Skills (Kirriemuir, 2005) discussed how games can be integrated into school settings. Another report from Federation of American Scientists (2006) suggested that integration of the games into schools could help reform the educational system. “People acquire new knowledge and complex skills from game play, suggesting gaming could help address one of the nation’s most pressing needs – strengthening our system of education and preparing workers for 21st century jobs” (Federation of American Scientists, 2006, p. 3).

The problem is that there is a dearth of empirical research to formulate firm conclusions about the effect of the games on learning in the context of formal K-12 school settings (Mitchell & Savill-Smith, 2004) to guide future research and practice. A cursory literature review, using Cooper’s (1985) framework, indicated that out of 40 reviewed studies related to instructional games, only 14 empirical studies and 4 literature reviews focused on the use of instructional games for facilitating learning in a formal school setting.

Methodological flaws in empirical studies are another factor that hinders reaching solid conclusions about the effects of instructional games. One of frequent problems is lack of control groups in the studies. Examining the effect of a treatment without comparison with a control group is problematic (Mitchell & Savill-Smith, 2004; Vogel et al., 2006). Out of the 14 empirical studies, only five studies used experimental research design incorporating control and experimental groups.

Furthermore, the results of the literature review indicated mixed results related to the effectiveness of games as instructional tools. Although the majority of the reviewed empirical studies, 9 out of 11, indicated that using instructional games improves learning and learning environments, the literature reviews indicated mixed results.

The findings of empirical studies revealed that instructional games promoted learners' attention (Yip & Kwan, 2006), state of flow (Kiili, 2005b), motivation (Rosas et al., 2003), delayed retention (Cameron & Dwyer, 2005), mathematics performance (Ke & Grabowski, 2007; Lopez-Moreto & Lopez, 2007; Shaffer, 1997), knowledge transfer (Shaffer, 2006), decision making (Corsi et al., 2006), expert behavior development (VanDeventer & White, 2002), and spatial skills and brain oscillation (Natale, 2002). In addition, using games created dynamic (Rosas et al., 2003) and collaborative (Squire, Giovanetto, Devane, & Durga, 2005) learning environments which positively affected learning.

However, the literature reviews indicated the results were not always positive. Randel's et al. (1992) study that reviewed 67 empirical studies, from 1984 to 1991, compared the instructional effectiveness of the games with conventional classroom instruction and indicated that out of 67 studies, 38 showed no differences between the game and conventional studies, 27 favored games, but again 5 were questionable in terms of their method and 3 favored conventional instruction. The two reviews conducted by Emes (1997) and Harris (2001) found no clear causal relationship between academic performance and the use of computer games. A slight improvement in learning and attitude of learners toward the subject matter was found as a result of using the games instead of traditional teaching methods (VanSickle, 1986). Finally, a recent literature review which analyzed 32 studies concluded that interactive simulation and games were more effective than traditional classroom instruction on learners' cognitive gains (Vogel et al., 2006).

The contradicting views of the literature review, the existence of relatively few empirical studies in the reviews, and the cited methodological flaws in the empirical studies necessitate further rigorous empirical study to help educators and instructional designers reach better conclusions about the effects of instructional games so that they may better understand, implement, and facilitate the games in classroom setting. As suggested by Van Eck (2006), instructional games would likely experience widespread development and use if persuasive examples of empirical studies could show the enhancement of learning by using instructional games. This study was conducted in response to such needs to provide solid results by implementing experimental method.

## Purpose of the Study

The purpose of this study was to investigate the effects of mathematics instructional games on learning in the context of a formal K-12 setting. To fulfill this purpose the effects of 3-D pre-Algebra and Algebra I games (DimensionM™), on high school students' learning achievement and motivation toward mathematics was investigated.

## Research Questions

The following questions guided this study:

1. What effects do the games have on the students' academic mathematics achievement, as measured by (a) the school district-wide benchmark exam, and (b) the treatment game performance test, provided in Appendix A?
2. What effects do the games have on students' motivation as measured by a motivation survey, Course Motivation, developed based on Keller's ARCS Model (1987a) and provided in Appendix A?
3. How do individual differences of prior knowledge, computer experience, and language background affect students when using the game? In this study, prior

knowledge is referred to preexisting mathematics knowledge and language background is referred to English fluency. These two factors were determined based on the participants' school record. Computer skill was determined by the Demographic survey provided in Appendix A.

## Research Hypotheses

Three hypotheses were posed to help answer the research questions.

1. There is no significant difference between learners' achievement of the experimental group, who receive the pre-Algebra and/or Algebra I instructional games, versus the control group, who do not receive the games.
2. There is no significant difference between learners' motivations of the experimental group, who receive the pre-Algebra and/or Algebra I instructional games, versus the control group, who do not receive the games.
3. There is no significant difference between effects of the games on students with differences in (a) prior knowledge, (b) computer experience, and (c) language background.

## Operational Definition

The following terms, variables, and treatments were proposed to conduct this study.

*Modern instructional games,* refers to the latest generation of computer games designed for training or educational purposes. These games are significantly different from edutainment game generation in 1980's and 1990's as they may use advance 3-D graphics and interface, multi-player options, high-speed telecommunication technologies (e.g., Quest Atlantis™), immersive 3-D environments and visual storytelling (e.g., Civilization III™), and learner-centered and constructivist learning principles (e.g., KM Quest™) to engage learners and facilitate learning. In this study, a modern instructional game is used as the research treatment.

*Individual difference,* refers to the ways that individual people differ in their behaviors. In this study, it is used as a term which focuses on the research participants' differences in three aspects of computer skill, prior mathematics knowledge, and language background.

*Academic achievement,* in this study, refers to mathematics performance as a dependent variable and was measured by the school district-wide benchmark exam, the school nine week tests, and the mathematics test developed by the treatment game company and provided in Appendix A.

*Motivation,* refers to an internal state that allows people to work toward certain goals or objectives (Keller, 1987a). In this study, motivation is a dependent variable and was measured by a motivation survey based on Keller's ARCS model (1987a).

*Computer experience,* refers to the level of research participants' skills and abilities in working with computer. In this study computer skill is an independent variable and was measured by the Demographic survey provided in Appendix A.

*Prior knowledge,* in this study refers to the research participants' preexisting mathematics knowledge. It is an independent variable and was measured based on the research participants' school records.

*Language background,* in this study, refers to the research participants' English language skills. It is an independent variable and was measured based on the research participants' school records.

*Student-Centered,* refers to an instructional approach in which learners learn about a given learning objective by actively participating in the instruction activities.

*DimensionM™,* is an instructional game that engages students in the instruction and learning of Pre-Algebra and Algebra I. This game, which was used as the research treatment, includes a series of mathematics instructional games:

1. *SP (Single Player) Evolve™.* This game teaches Pre-Algebra by involving players in completing twenty mathematics related missions within a 3-D immersive environment designed with advanced graphics.
2. *SP (Single Player) Dimenxian™.* This game teaches Algebra I by involving players in completing five mathematics related missions within a 3-D immersive environment designed with advanced graphics.
3. *MP (Multi Player) Evolver™.* This game teaches Pre-Algebra and Algebra I by involving players in completing three individual 3-D games that allow players to play and compete with each other. The games are: (a) *Swarm™*, a team-based game in which players work together to compete against other groups by collecting more point through solving mathematics problems, (b) *Meltdown™*, a strategy game in which individual players compete against each other by gathering more point using their calculation and speed skills, and (c) *Obstacle Course™*, a strategy game in which players compete against each other to faster complete five major stages with mathematics relation obstacles.

*Lesson Plan,* refers to a detailed description of an individual lesson instruction. In this study, lesson plans were used as treatment to help teachers use DimensionM™ in their classrooms. The treatment lesson plans are available in two versions of teacher-directed and inquiry-based and include teacher guidelines, resources, and practice tests.

## Research Design

An experimental design with mixed method was used to conduct the research. Teachers were randomly assigned to two groups of treatment and control. The study was conducted with students at a high school in an urban area in the southeast of the United States of America. A total of 10 Pre-Algebra and Algebra I teachers and 598 students were participated in this study. The study was approved by Institutional Review Board (IRB) at the University of Central Florida and the School district. Copies of the approval letters are provided in Appendix B and C.

## Significance of Study

The results of this study that investigated the effects of a series of modern mathematics instructional games (DimensionM™) on learning and motivation in the context of a formal K-12 setting can be beneficial for (a) educators from implementation perspective, (b) instructional and game designers from design perspective, and (c) researchers from research perspective.

The results of the study inform educators about the benefits, implications and possible negative effects of using DimensionM™ as learning tools in classrooms. A practice guidance of using this series of games in classroom was generated to help educators use them more effectively.

Instructional and game designers benefit from the results of this study from design perspective. The study assists the designers to optimize DimensionM™ design by informing them about the required game components and resources from the educators and learners' views.

In addition, the results revealed issues related to the role of individual differences in term of computer experience, prior mathematics knowledge, and English skills on learning when using DimensionM™. Instructional and the game designers may improve the game design to support these differences in the games.

Researchers benefit from this study by learning about (a) the evolution of the instructional games and current state of the research in mathematics instructional games provided in Chapter two, literature review, (b) the procedure and implication of conducting a relatively large experimental study in the context of a formal K-12 setting, and (c) the future recommended studies that were generated as a result of this study.

Furthermore, this study is novel for all three groups of educators, instructional and game designers and researchers as it examined effect of a series of modern mathematics instructional games, DimensionM™. Although a number of empirical studies have examined effects of instructional mathematics games on learning (e.g., Ke & Grabowski, 2007; Klawe, 1998; Lopez-Moreto & Lopez, 2007; Rosas et al. 2003; Shaffer, 1997), none of them have examined the effect of a modern mathematics instructional game. A comprehensive description of the game, situation, and sample population are provided in Chapter three to make it possible to use the results of this study in other similar situations.

## Organization of Dissertation

This dissertation is organized into five chapters. Chapter one introduces the study with statement of problem, research questions and hypotheses, and research design. Chapter two provides a literature-based background for the study by presenting an overview of mathematics instructional games, state of literature reviews and empirical research, and conceptual framework for the study. Chapter three presents method of the study which includes research design, procedure, treatment, and procedure used for data collection and analysis. Chapter four presents the results of the study for the research hypotheses and post hoc questions. Chapter five provides discussion and conclusion for the study.

# CHAPTER TWO: REVIEW OF LITERATURE

The purpose of Chapter two is to review literature related to each of the major components within the study. Two literature reviews were conducted. The first review examined design and delivery of mathematics instructional games with focus on their learning effects. The second review characterized the empirical research and literature reviews on effectiveness of instructional games and established a theoretical foundation for the key issues that were examined in the study. This chapter begins by explaining the method used to conduct both reviews, follows by a presentation of each set of findings.

## Literature Review Method

Both literature reviews were formatted based on Cooper's (1985) framework which includes (a) goal, (b) coverage, (c) organization, and (d) audience. The goals of the reviews were to provide better understanding of the study treatment, justify the study, form variables for the study, and establish conceptual framework for the study. The reviews had exhaustive coverage with selection of sample of relevant works. They were organized conceptually and the relevant works were presented based on their relation to the topics of (a) instructional mathematics game, (b) literature reviews and empirical studies on effect of the mathematics instructional games, and (c) conceptual framework for conducting empirical studies on instructional games. These reviews provide insight for multiple audiences of educators, researchers, and designers in the field of instructional games.

In addition, the reviews were conducted using Cooper's (1988) research procedure that includes the following stages: (a) problem formulation, (b) data collection, (c) data evaluation, (d) analysis and interpretation, and (e) presentation of the results.

The following questions formulated problems for conducting the literature reviews:

- For the first review: what are design and delivery issues that influence effectiveness of mathematics instructional games?
- For the second review: (a) what are the variables, research designs, and results of empirical studies conducted on effect of mathematics instructional games?, and (b) what are conceptual frameworks for conducting empirical studies on effect of instructional games?

The data collection was conducted by searching numbers of resources, summarized in Table 1, including online journals, academic databases, information technology organization websites, academic institution websites, related conference websites and relevant publications with the following sets of criteria:

- For the first review, articles associated to design a delivery of Mathematics games were searched using the following keywords: "instructional mathematics games and K-12", "computer mathematics games and K-12", and "mathematics video games and K-12".
- For the second review, literature reviews and empirical studies associated with effectiveness of mathematics games were searched using the following keywords: "instructional games and effect", "instructional games and learning", "instructional games and empirical studies", "educational video games and learning", "literature review and game", "literature review and game", and "game and learning", "game and motivation", "instructional game theory", and "game and learning theory".

Table 1

The List of Searched Resources

| Type of Resource | Resource |
|---|---|
| Online Journals | • Game Studio, International journal of game research, (http://www.gamestudies.org/)<br>• British Journal of Educational Technology (http://www.sagepub.com/journal.aspx?pid=11113)<br>• Simulation & Gaming An International Journal of Theory, Practice and Research<br>• (http://www.sagepub.co.uk/journal.aspx?pid=105774)<br>• Journal of Educational Computing Research (http://baywood.com/journals/previewjournals.asp?id=0735-6331)<br>• Game Developer (http://www.gdmag.com/homepage.htm) |
| Academic Databases | • ERIC, Educational Resources Information Center (ERIC) (www.eric.ed.gov)<br>• Wilson Web (http://vnweb.hwwilsonweb.com.ucfproxy.fcla.edu)<br>• EBSCO HOST, Research Database (http://search.epnet.com/) |
| IT and Game Organization | • EDUCAUSE (http://www.educause.edu)<br>• Futurelab (http://www.futurelab.org.uk/)<br>• Gamusutra (http://www.gamasutra.com/)<br>• WRT: Writer Response Theory, Explorations in Digital Character Art (http://wrt.ucr.edu/wordpress/)<br>• Serious Game Initiative (http://www.seriousgames.org/index2.html)<br>• DiGRA, Digital Games Research Association (http://www.digra.org/)<br>• Idga, International Game Developers Association (http://www.igda.org/)<br>• Ludology, online resources for videogame researchers (http://ludology.org/index.php) |
| Academic Institution Websites | • The Education Arcade, an MIT-University of Wisconsin Partnership (http://www.educationarcade.org/)<br>• Simon Fraser University Institutional Repository, Dspace (http://ir.lib.sfu.ca/index.jsp)<br>• iCampus Projects, the MIT-Microsoft alliance<br>• (http://icampus.mit.edu/projects/)<br>• The MIT Press (http://mitpress.mit.edu/main/home/default.asp) |
| Conference Websites | • DiGRA 2005: Changing Views: Worlds in Play, 2005 International Conference, Dspace (http://ir.lib.sfu.ca/handle/1892/1318)<br>• NMC Online Conference on Educational Gaming (http://www.nmc.org/events/2005fall_online_conf/)<br>• Federation of American Scientists, FAS, Summit on Educational Game (http://www.fas.org/gamesummit/)<br>• Serious Games Summit, Washington DC, 2005 (http://www.cmpevents.com/GDsg05/a.asp?option=C&V=11&SessID=1018) |

As a result of applying the described search procedure, a large number of data were found that were evaluated as follow:

- For the first review with focus on design and delivery of mathematics instructional games, over 29 studies were located and a total of 17 studies met the criteria and were included in the analysis.
- For the second review with focus on literature reviews and empirical studies on instructional game effectiveness, 45 studies were located and a total of 8 literature reviews and 14 empirical studies met the criteria and were included in the analysis.

It is notable that only studies related to computer games exclusively made for educational purposes were included in the analysis reviews. The results of the literature reviews along with analysis and interpretation are provided in the following sections.

## Overview of Mathematics Instructional Games

This overview leads to a better understanding of (a) the research treatments, the instructional games DimensionM™, as compared to other mathematics instructional games, and (b) potential factors in design and delivery of the games that could influence the effectiveness of the game.

First, the summary of important mathematics instructional games for K-12, developed since 1970 and discussed by a numbers of authors (e.g., Egenfeldt-Nielsen, 2005; Habgood, Ainsworth & Benford, 2005), is provided in Table 2. Then, a review of highlighted mathematics games is presented. Finally, trends and issues in design and delivery of mathematics games are discussed.

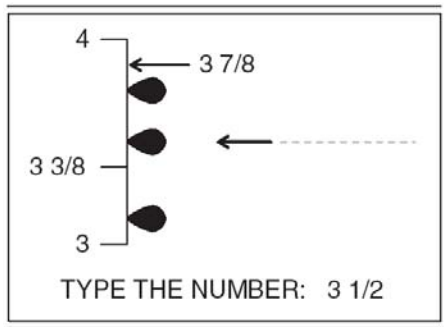
Table 2

Mathematics Instructional Games Developed in the Last Three Decades

| No | Mathematics Game | Year | Genre | Audience |
|---|---|---|---|---|
| 1 | Darts-Plato project | 1973 | Problem solving | Elementary school |
| 2 | Basic Mathematics or Fun with Numbers | 1977 | Problem solving | Elementary school |
| 3 | The Electric Company: Math Fun | 1979 | Strategy | Elementary school |
| 4 | Harpoon | 1981 | Strategy | Elementary school |
| 5 | Sonar | 1981 | Strategy | Elementary school |
| 6 | Lemonade Stand | 1985 | Strategy | Elementary school |
| 7 | Mathematics Blaster | 1986 | Action-Adventure | Elementary/Middle school |
| 8 | Millie's Math House | 1995 | Strategy | Elementary school PreK to First grade |
| 9 | Super Tangram-EGEMS | 1996 | Puzzle | Middle school |
| 10 | Zoombinis-Logical Journey | 1996 | Puzzle | Elementary school |
| 11 | Phoenix Quest-EGEMS | 1997 | Puzzle | Middle school |
| 13 | Freddi Fish 5: The case of Creature of Coral Cove | 2001 | Strategy-Adventure | Elementary school |
| 14 | Mathematics Missions | 2003 | Strategy | Elementary school K to second grade |
| 15 | Jumpstart Study Helper Math Booster | 2003 | Adventure | Elementary school |
| 16 | AquaMOOSE | 2003 | Strategy | High school students |
| 17 | ASTRA EAGLE | 2005 | Strategy | Elementary school |
| 18 | Zombie Division | 2005 | Action-Adventure | Elementary school |

## *Review of the Design and Effects of Mathematics Games*

The results of the literature review are presented in chronological order starting out with one of the earliest mathematics oriented project, Plato project. The Plato project, from 1973, produced positive results in relation to using instructional games for mathematics. These results supported initiation of later research in the field. One of the games created in Plato project was Darts game with the purpose of teaching fractions.




From “Toward a theory of intrinsically motivating instruction”, *Cognitive Science*, by T.W. Malone, 1981a, 5*(4)*, p. 349. Copyright 1981 by Cognitive Science Society. Adapted with permission from the publisher (see Appendix G).

Figure 1: The Screen Layout of the Darts Game

The game developed based on the conceptual framework of intrinsic fantasy by relating fantasy of balloons and arrows to the skill of estimating fractions (Malone, 1981a) (see Figure 1).

Two other instructional games of Harpoon and Sonar were made in 1981, based on the Darts game. They were intended to facilitate new understandings of arithmetic closer to everyday needs. They were proved to be successful in motivating and engaging players in learning planned mathematics concepts (Levin, 1981).

In the 1980’s the educational programming language Logo for designing mathematics games was popular. The basic approach was to teach mathematics by allowing learners design mathematics games (Egenfeldt-Nielsen, 2005). One of the advocators of such approach was Kafai (2001) who proposed the concept of using the games to learn by constructing the games as compared to using the games to teach (construction versus instruction). A number of studies indicated the effectiveness of this method in teaching mathematics (Kafai, 2001; Kafai & Resnick, 1996; Papert, 1996). The method of designing game by the learners was still used in 1998 by some researchers (Kafai, Frank, Ching, & Shih,1998).


Adapted with permission from the authors (see Appendix H)

Figure 2: The Screenshots of Super Tangrams and Phoenix Quest

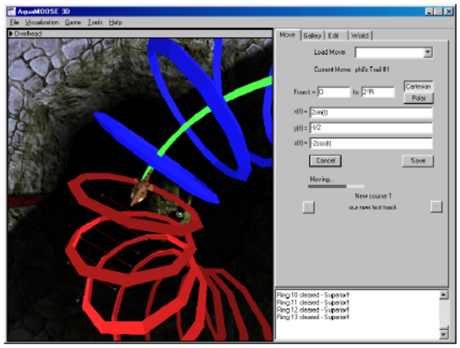
The 1990's were highlighted by two research projects in mathematics-oriented games, Electronic Games for Education in Math and Science (E-GEMS) and Through the Glass Wall. The E-GEMS project was conducted in the University of British Columbia. Two mathematics games were made in this project. The first game, Super Tangrams (ST), was made in 1996 to teach 2-dimensional transformation geometry to grade 6 students. The game was consisted of a series of puzzles which progressively became more difficult as shown in Figure 2. It was designed to provide a motivating, fun, and engaging learning environment (Sedighian & Sedighian, 1996). The second game in E-GEMS project, Phoenix Quest, was made in 1997 in an attempt to make the game attractive to both girls and boys. Both Super Tangrams and Phoenix Quest were designed based on basic concept of puzzles with different approaches. It is shown in Figure 2 that Super Tangrams was activity oriented while Phoenix Quest was story oriented.

The research project of Through the Glass Wall suggested that mathematics should be an integrated part of playing and encouraged mathematics-related reflection, thinking and discussion. In addition, this project emphasized the importance of the narrative frame and gender neutral approaches in designing games (Egenfeldt-Nielsen, 2005).

The 2000's were highlighted with emergence of 3-D instructional games. Iterative design with 3-D interface was used in a number of mathematics oriented virtual environments and games such as AquaMOOSE (Elliott & Bruckman, 2002) and Zombie Division (Habgood et al., 2005). However, other types of games with less complex interface were still designed and used such as series of games similar to Nintendo's Gameboy game (Rosas et al., 2003), web-based ASTRA EAGLE games (Ke & Grabowski, 2007) and Interactive Instructors of Recreational Mathematics (IIRM) (Lopez-Moreto & Lopez, 2007).

AquaMOOSE was a 3-D environment designed to help students learn about behavior of parametric equations. An underwater theme which allowed the players swim like a fish in 3 directions was used in the environment. The design was based on constructionism philosophy which advocates learning through design and construction activities. Iterative design was used to develop the environment. In this environment, students use mathematics to design interesting graphical forms and create mathematical challenges and games to share with others (Elliott & Bruckman, 2002). The environment included a number of games such as Ring game, in which students were presented a set of rings and challenged to swim through as many rings as possible with one mathematics function (see Figure 3). The results of a formative evaluation with 105 high school students indicated that the aesthetic qualities of the environment motivated students whereas lack of usability posed problems.

Zombie Division was a 3-D action-adventure game based on a combat mechanic in which the players divided numbered skeleton in hand-to-hand combats (see Figure 3) (Habgood et al., 2005). The emphasis was on creating a flow experience for players to increase the learning effectiveness of the game.



Ring Game [1] Zombie Division [2]

[1] From "Design of a 3-D Interactive Mathematics Learning Environment," by J. Elliott and A. Bruckman, 2002, Proceedings of DIS 2002 (ACM conference on Designing Interactive Systems). London, UK, p.6. Adapted with permission from the authors (see Appendix I).

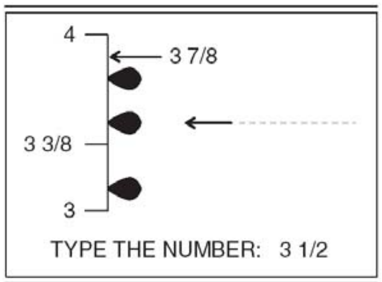
[2] From "Endogenous fantasy and learning in digital games", *Simulation & Gaming*, by M. P. J. Habgood, S. E., Ainsworth, & B. Benford, B. (2005), P. 495. Adapted with permission from the publisher (see Appendix I).

Figure 3: The Screenshots of Ring game in AquaMOOSE and Zombie Division

Flow experience refers to "feeling of total concentration, distorted sense of time, and extension of self that is the root of engagement power of digital games." (Habgood et al., 2005, p. 492). The designers suggested that an action adventure format with a strong emphasis on combat should ensure creation of a flow experience. In addition, it was suggested that the learning content should be presented in the most fun parts of the game and embodied within the structure of the gaming. Then, an external presentation of the content such as a quiz should be provided.

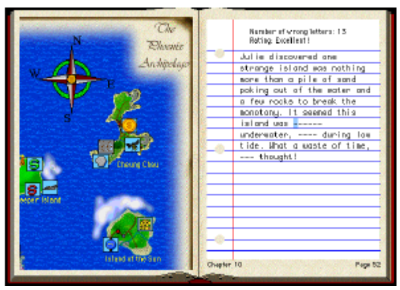
### *Edutainment and Modern 3-D Games*

A major trend that was revealed as a result of this literature review was the evolution of conceptual frameworks and technical aspects of the games during the last three decades (from 1970's to 2000's). As it is appeared, most of the early mathematics instructional games such as Darts in Plato project focused on drill and practice of simple number operations and concepts.



DARTS Game

Super Tangrams


Phoenix Quest


Zombie Division

Figure 4: Comparison of the screenshots of the Darts Game, Super Tangram, Phoenix Quest, and Zombie Division

These games were easy to develop and playing these game improved students' mathematics fluency.

However, drill and practice is one of the many ways of learning mathematics and it could be achieved through variety of non-game based learning (Klawe, 1998). The conceptual frameworks of the games have evolved from drill and practice (e.g., Darts), to construction versus instruction (e.g., game developed by Kafai, 2001), constructivism (e.g., AquaMOOSE), flow experience (e.g., Zombie Division), and collaborative community of learning (e.g., IIRM).

The similar progressive trend can be seen in technical aspects of the games. As technology advanced, the mathematics games became more complex in terms of graphic and interface. Such progression can be noticed by comparing simple interface of Darts to 2D environment of Super Tangram and Phoenix Quest, and 3-D environment of Zombie Division (see Figure 4).

Along with the evolution of conceptual and technical aspects of instructional games, edutainment products have been replaced with modern 3-D games. Edutainment is referred to the games that were produced mainly in 1980's and 1990's as combination of entertainment and education.

However, these games were not very successful as they did not completely incorporate the techniques and concepts of the computer games and education, consequently edutainment products were neither educational nor entertaining (Kirriemuir & McFarlane, 2003; Okan, 2003). As it is stated by Fabricatore (2000) edutainment combine two great things but come up with less than the sum of its parts, failing to meet the standards of high quality education or entertainment. As the conceptual and technical aspects of the games evolved, modern 3-D games, as a new generation of instructional games were emerged. Modern instructional games are significantly different from edutainment game generation as they may use advanced 3-D graphics and interface, multi-player options, high-speed telecommunication technologies (e.g., Quest Atlantis[tm]), immersive 3-D environments and visual storytelling (e.g., Zombie Division[tm]), and learner-centered and constructivist learning principles (e.g., AquaMOOSE, KM Quest[tm]) to engage learners and facilitate learning.

### *Effectiveness of the Games: Design Issues*

As a result of analysis of the evolution of mathematics instructional games, a number of design issues as factors that played roles in effectiveness of the instructional games were emerged.

*Motivation.* The relation between motivation and learning effectiveness of the games were frequently stressed by game designers (Elliott & Bruckman, 2002; Habgood et al., 2005; Lopez-Moreto & Lopez, 2007; Malone, 1981a; Rosas et al., 2003; Sedighian & Sedighian, 1996). The following factors for increasing motivation in the games are suggested (Sedighian & Sedighian, 1996): (a) situating mathematics learning in the games, (b) providing a set of goals to achieve (c) providing a balance amount of challenge to get excited but not overwhelmed, (d) making games cognitive artifact by incorporating two factors of interactivity and communication, (e) associating learning to pleasant memory, (f) providing a learning environment that allow students experience the joy of learning, and (g) providing sensory stimuli by including fancy graphics and animation.

*Gender neutral.* The games should be attractive to both genders. Including story and narrative frameworks was suggested as one of the ways to make the games female and male friendly (Egenfeldt-Nielsen, 2005; Klawe, 1998).

*Feedback and scaffolding.* The importance of providing elaborative feedback and scaffolding was stressed as a factor in increasing the effectiveness of the games for facilitating learning (Cameron & Dwyer, 2005; Klawe, 1998).

*Verbal and written reflection.* Mathematics-related reflection, thinking, and discussion, were suggested as critical factors in improving effectiveness of the mathematics games (Egenfeldt-Nielsen, 2005). In addition, challenge to produce verbal and written discourse in a purposeful, authentic context, not in an instruction context and only for teacher, may be a highly effective way for stimulating mathematics reflection for learners (Waywood, 1992).

*Game genre.* A genre pattern emerged from the findings indicates that the early mathematics games in 1970's and 1980's mostly were categorized as puzzle games followed by strategy in 1990's and adventure games in 2000 (see Table 1). However, this pattern was not followed by all the games. A numbers of games out of this pattern with various genres were identified throughout the three decades. It is notable that instructional action games which incorporated educational materials into fast-paced game environments and enforced the players to respond quickly to continual challenges, offered little time for reflection and were more appropriate for building skill fluency (i.e. speed and accuracy at exercising a skill) than for the acquisition of new and complex concepts (Baker, Habgood, Ainsworth, & Corbett, in press).

*Balance between the content and game.* To keep the instructional value of the game, the actual mechanics of play must always remain secondary to the instructional process (Habgood et al., 2005).

*Visual effect and usability.* The aesthetic qualities of the environment motivated students whereas lack of usability posed problems (Elliott & Bruckman, 2002; Kiili, 2005b; Shaffer, 1997).

## *Effectiveness of the Games: Delivery Issues*

The following delivery issues, which influence the learning effectiveness of the instructional games, were emerged as a result of analyzing the literature review findings:

*Curriculum issues.* The greatest difficulty facing the delivery of the educational mathematics games was the alignment of the game with the school curriculum and syllabus. (Gros, 2003; Rosas et al., 2003; Squire et al., 2005). Using principles and standards of the National Council of Teachers of Mathematics (2000) for developing the mathematics games was suggested as a method to address this issue (Lopez-Moreto & Lopez, 2007).

*Time and purpose of game implementation.* For delivery of the game, the teachers should consider: (a) when the game should be used in the classroom, and (b) whether game is designed to teach skill acquisition or to provide practice opportunities for previous learned skills (Van Etten & Watson, 1976).

*Outcome issues.* Educators' uncertainties about transferring of learned skills from games to the other contexts and real situations affected the delivery of mathematics games in the schools (Egenfeldt-Nielsen, 2005; Gros, 2003; Klawe & Phillips, 1995; Shaffer, 2006).

*Technical issues.* The adaptation of the multimedia materials in school with mathematics games was another important issue which affected the delivery of the games (Gros, 2003; Rosas et al., 2003).

### *Section Summary*

This overview provides a brief summary about technical and conceptual evolution of mathematics instructional games from edutainment to modern instructional games and highlights design and delivery factors that greatly influence effectiveness of the games. Based on the review, DimensionM™ instructional games are considered as modern games with 3-D interface and learning environment that encourage learning through interaction with environment and other learners.

In addition, the review indicates when examining the effectiveness of the games, a number of design and delivery factors should be considered, including (a) curriculum, (b) time and purpose, (c) desired outcomes, and (d) technical issues. In this study, each issue was addressed to optimize learning and minimize potential negative effects on the research results as noted in the description of the treatment in Chapter three.

## Research on Effect of Instructional Games

The purpose of this section is to provide an overview about research conducted on effects of instructional games. This overview indicated major concerns and needs for further research in the field of instructional games, thus, guided this study and formed major variables for this study. The findings revealed that research investigated learning effect of the games from various perspectives by using different research methods. The results are presented based on research methods in two sections of non-empirical or literature review and empirical research.

### *Literature Review on Instructional Games*

As a result of the literature review, a number of literature reviews or non-empirical studies were found that examined the effect of instructional games by using the results of reported research to analyze, compare and integrate the findings and reach a conclusion. The significance of the literature reviews is that they provide an overview about the effect of the games based on reviewing of a relatively large number of articles. Table 3 summarizes the literature reviews that were found along with the number of studies reviewed by them and their conclusions on the effect of instructional games on learning.

Table 3

Literature Reviews on Effect of Instructional Games

| Literature review | Number of reviewed studies | Results |
|---|---|---|
| 1. Dempsey et al. (1994) | 94 | Positive Effects |
| 2. Randel et al. (1992) | 67 | Mixed Effects |
| 3. Hays (2005) | 48 | Mixed Effects |
| 4. Vogel et al. (2006) | 32 | Positive Effects |
| 5. VanSickle (1986) | 26 | Weak Positive Effects |
| 6. Emes (1997) | 3 | No Effects |
| 7. Harris (2001) | 2 | No Effects |
| 8. Mitchell & Savill-Smith (2004) | Unclear | Mixed Effects |

As Table 3 shows, majority of the literature reviews, five of eight, reported mixed results (Hays, 2005; Mitchell & Savill-Smith, 2004; Randel et al., 1992), or no positive results (Emes, 1997; Harris, 2001) on effectiveness of instructional games.

Based on reviewing of 48 empirical studies, Hays (2005) found no evidence to indicate instructional games were a preferred method of instruction in all situations. He also concluded that empirical research on effectiveness of instructional games was fragmented and filled with ill-defined terms and methodological flaws.

Mitchell and Savill-Smith (2004) found instructional games had both negative and positive effects on students' school performances. Students who frequently played the game developed less positive attitude toward school. This was linked to the fact that students who were at a behavioral risk preferred to engage in non-directed time-consuming activities such as playing games or watching television. Frequent game playing also reduced homework time. In addition, instant satisfaction of playing the game reduced students' readiness to make required efforts for reading rewards. On the positive side, they reported that playing games made students ready for computer-oriented society and promoted spatial and cognitive skills.

Randel et al. (1992) reviewed 67 studies to compare the effectiveness of instruction games versus classroom setting. Majority of the studies, 38 of 67, indicated no differences between these two forms of instructions. The authors concluded that effects of instructional games varied depending on the subjects and the games were more effective when learning objectives were explicit and precisely defined. Finally, Emes (1997) and Harris (2001) found no clear causal relationship between academic performance and the use of computer games.

On the other hand, only three of eight literature reviews reported positive results (Dempsey et al., 1994; Vogel et al., 2006) and weak positive results (VanSickle, 1986). Based on reviewing of 91 empirical studies, Dempsey et al. (1994) concluded that instructional games were used in most of learning domains in Gagne's taxonomy (1985) including problem solving, cognitive strategy, and attitudes. In addition, they found that games functioned as tutoring, promoting self esteem, practicing skills, or changing attitudes. In another review based on 32 empirical studies, Vogel et al. (2006) reported that interactive simulation and games were more effective than traditional classroom instruction on learners' cognitive gains. Finally, according to reviewing 26 empirical studies, a slight improvement in learning and attitude of learners toward the subject matter was found as a result of using the games instead of traditional teaching methods (VanSickle, 1986).

A number of issues were emerged as a result of reviewing literature reviews. Two of the reviews found that the majority of articles on instructional games were opinionated and judgmental about the potential of games to provide effective instruction (Hays, 2005; Randel et al.,1992). Four of the reviews reported that numbers of articles provided empirical data in educational settings was scarce (Hays, 2005; Mitchell & Savill-Smith, 2004; Randel et al.,1992; Vogel et al. 2006). The results of literature reviews indicated empirical studies on mathematics instructional games in K-12 settings were far fewer. For example, of 270 articles obtained on effectiveness of games by Hays (2005), 48 provided empirical data, 16 focused on K-12 settings, and only 5 articles considered the learning effect of mathematics instructional games in K-12 settings.

Furthermore, it was observed that the literature reviews reviewed instructional games in a wide variety of subjects (e.g., mathematics, physics, health, military, science and social science) with variety of age group (K-12, college, and adult learners) (e.g., Hays, 2005; Mitchell & Savill-Smith, 2004). None of the literature reviews exclusively focused on mathematics instructional games in K-12 settings. However, mathematics games were included in all the literature reviews. There were indications that mathematics was a topic in which instructional games generated more effective results (Hays, 2005; Mitchell & Savill-Smith, 2004; Randel et al., 1992).

Finally, methodological flaws were found as major issues in empirical studies that impeded reaching a conclusion about effects of instructional games (Hays, 2005; Mitchell & Savill-Smith, 2004). A number of studies did not use experimental research design with a control group to compare the effect of the games on the players (Mitchell & Savill-Smith, 2004). Another group of studies used experimental research design but there were flaws in conducting their research (Hays, 2005). The reported methodology flaws included lack of (a) using instruments that accurately measure the game effects, (b) random sampling, (c) reporting validity and reliability, and (d) controlling interfering variables such as Hawthorn effect, selection effects, teacher bias, and time differences in treatment groups (Randel et al., 1992).

## *Empirical Research on Instructional Games*

As a result of literature review in this study, in addition to literature reviews, a number of empirical studies on effectiveness of the instructional games were found. Table 4 summarizes the results of the literature review on empirical studies along with their variables, research methods, and results.

Table 4

The Research Variables, Methods, and Results of 14 Empirical Studies

| Study | Research Variables | | | Research method, Game subject, Educational level | Results of facilitating learning with game |
|---|---|---|---|---|---|
| | Dependent variables | Individual differences | Other variables | | |
| 1. Rosas et al. (2003) | Achievement<br>Motivation | | Learning environment | Mixed method, Experimental<br>Mathematics & Reading<br>K-12 | Positive results |
| 2. Sedighian and Sedighian (1996) | Motivation | | | Qualitative<br>Mathematics<br>K-12 | positive |
| 3. Klawe (1998) | Achievement<br>Motivation | Gender | Game design | Qualitative<br>Mathematics<br>K-12 | Positive |
| 4. McDonald and Hanaffin (2003) | Achievement<br>Motivation | | | Qualitative<br>Quasi-Experimental<br>Social studies<br>K-12 | Mixed results |
| 5. Lopez-Moreto and Lopez (2007) | Motivation | Computer experience | | Quantitative<br>Mathematics<br>K-12 | Positive |
| 6. Ke and Grabowski (2007) | Achievement | Prior knowledge<br>computer experience<br>language background | | Quantitative<br>Experimental<br>Mathematics<br>K-12 | Positive results |
| 7. Moreno (2002) | Achievement | Prior knowledge<br>computer experience<br>Socio-status<br>language background | | Quantitative<br>Experimental<br>Mathematics<br>K-12 | Positive results |
| 8. Din and Caleo (2000) | Achievement | | | Quantitative<br>Experimental<br>Mathematics<br>K-12 | Mixed Results<br>No improve in Mathematics |
| 9. Laffey, Espinosa, Moore, and Lodree (2003) | Achievement | At risk behavioral problem | | Quantitative<br>Experimental<br>Mathematics<br>K-12 | Mixed results due to method flaw |

| Study | Research Variables | | | Research method, Game subject, Educational level | Results of facilitating learning with game |
|---|---|---|---|---|---|
| | Dependent Variables | Independent Variables/Individual Differences | Other variables | | |
| 10. Lim, Nonis, and Hedberg (2006) | Achievement | | Engagement | Mixed method Science K-12 | Mixed results |
| 11. Yip and Kwan (2006) | Achievement | | | Mixed method, Quasi-experimental Higher Ed | Positive results |
| 12. Cameron and Dwyer (2005) | Achievement | Field independent/dependent | | Quantitative Experimental Science Higher Ed | Positive results, More positive for field independent |
| 13. Halttunen and Sormunen (2000) | Achievement | | | Qualitative Higher Ed | Mixed results |
| 14. Corsi et al. (2006) | Achievement | | Decision making | Quantitative Higher Ed | Positive results |

As Table 4 shows, of fifteen empirical studies, eight focused on effect of mathematics instructional games on learning in K-12 settings, one study focused on science, and one focused on social science instructional games in K-12 settings. Five of fifteen studies focused on effect of instructional games with different subjects in higher education. This indicates mathematics in K-12 settings has received more research attention than other subjects in the field of instructional games. The focus of the following analysis is on these eight mathematics-oriented studies.

The findings indicate experimental research design was used by five of eight studies and non-experimental design with no control group was used by three of eight studies. In addition, the analysis shows that the empirical studies used three major groups of variables to examine the effect of games on learning: achievement used by seven of eight studies, motivation used by five of eight studies, and individual differences used by four of eight studies.

Furthermore, the findings reveal that as a result of using mathematics instructional games, six of eight studies found positive effects on learning achievement (Ke & Grabowski, 2007, Klawe, 1998; Lopez-Moreto & Lopez, 2007; Moreno, 2002; Rosas et al., 2003; Sedighian & Sedighian, 1996) and four of eight studies found positive effects on motivation (Klawe, 1998; Lopez-Moreto & Lopez, 2007; Rosas et al., 2003; Sedighian & Sedighian, 1996). One study found no difference in mathematics achievement and motivation of experimental versus the control group as a result of using mathematics instructional game (Din & Caleo, 2000). Another study had mixed or confounded results because the experimental group received more mathematics instruction than the control group (Laffey et al, 2003).

Finally, individual differences such as computer experience (Ke & Grabowski, 2007; Lopez-Moreto & Lopez, 2007; Moreno, 2002), prior knowledge and language background (Ke & Grabowski, 2007; Moreno, 2002), socio-status (Moreno, 2002), and gender (Klawe, 1998) were considered as research variables by four out of eight studies.

### *Section Summary*

The review of literature reviews indicates there is no consensus, based on empirical findings in the field, about the learning effects of instructional games. Particularly, there is a dearth of empirical studies on modern mathematics instructional game in K-12 settings. The literature review on empirical studies found only five experimental studies with focus on learning effects of mathematics instructional games in K-12 settings. All five studies examined the effects of non-modern instructional games. These results warrant conducting further experimental studies on learning the effectiveness of modern mathematics instructional game in K-12 settings.

In addition, the finding indicates achievement and motivation were two major concerns in the field of instructional games. These two factors were used as the indicators of effectiveness in the research. Finally, the results show that there is a need to consider the role of individual differences on learning effects of the games.

Therefore, this study uses achievement, motivation, and individual differences of computer experience, prior knowledge, and language background as research variables. Further descriptions about these variables and their associations with learning theories are provided in the next section.

## Conceptual Framework of the Study

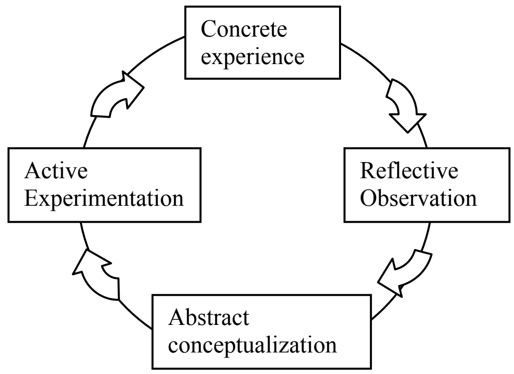
The review of the literature indicated that a variety of conceptual frameworks were used in studies related to the effect of instructional games including social constructivism (Halttunen, & Sormunen, 2000; Leemkuil, de Jong, de Hoog, Christoph, 2003; Lim, Nonis, & Hedberg, 2006), intrinsic motivation (Cameron & Dwyer, 2005; Rosas et al., 2003), and experiential theory with Kolb's learning cycle (Egenfeldt-Nielsen, 2005; Garris, Ahlers & Driskell, 2002; Isaacs & Senge, 1992; Kiili, 2005a; Lainema, 2003).

In this study, the experiential learning theory (Dewey, 1938; Kolb, 1984; Kolb & Kolb, 2005), which was closely related to the experiential nature of instructional games, was used to explain the DimensionM™ learning cycle and its effect on dependent variable of achievement. Additionally, ARCS model (Keller, 1987a) was used to explain and examine dependent variable of motivation which is a vital factor frequently associated to the effectiveness of the games and not elaborated by experiential learning theory. Both experiential theory and ARCS model were used to explain the role of independent variables of prior knowledge, computer experience, and language background on the game learning process.

### *Achievement: Experiential Learning Theory*

Experiential learning was used to explain how students learn in instructional games. In this philosophy, educators purposefully engage with learners in a direct experience and focused reflection in order to increase knowledge, develop skills and clarify values (Dewey, 1938). Experience is occurred as a result of interaction between human beings and the environment in forms of thinking, seeing, feeling, handling, and doing (Dewey, 1938). This experience may take place equally in real or artificial environment, as Egenfeldt-Nielsen (2005) stated, “In today’s computer games you are part of a living, breathing, simulated universe with very concrete self-sustaining experiences–getting still closer to reality” (p. 125). Computer games, which may be designed in the context of everyday life, can connect the players to everyday life experience. Such concrete experience is the heart of experiential learning approach in which knowledge is constructed, not transmitted, as a result of experiencing and interacting with environment.

In this approach, learning starts from concrete experience and continues to abstract thinking. Concrete experience is an experience that is very familiar for the players and does not need explanation such as experience of being in rush hour traffic in the SimCity game (Egenfeldt-Nielsen, 2005). According to Dewey (1910) “Concrete denoted a meaning definitely marked off from other meanings so that it is readily apprehended by itself” (p, 136).




From "Experiential Learning: Experience as the Source of Learning and Development," by D.A. Kolb, 1984, Englewood Cliffs, N.J: Prentice-Hall. Adapted with permission from the author.

Figure 5: Kolb's (1984) Circular Learning Model Based on Experiential Learning Theory

In an experiential learning cycle (Kolb, 1984), players can start from a familiar or concrete experience, construct knowledge, reflect on the learning experience, develop abstract concept, actively experiment the abstract concept, and move to the next experience (see Figure 5).

In this study, DimensionM™ instructional games allowed players interact with a familiar environment, an island, and perform simple tasks or missions, as concrete experiences, to develop abstract concept about Algebra I and achieve learning objectives. At the end of each mission, a quiz related to the mission topic is taken from players. These quizzes facilitate debriefing and reflection.

Kolb's stages in the learning cycle were consistent with the stages facilitated by the teachers using DimensionM™: the students learned through (a) completing a simple task or game mission, (b) debriefing by game and/or class quizzes, (c) developing abstract Algebra concepts, and (d) engaging with the class activities and moving to the next mathematics topic.

However, the problem with Kolb's learning cycle was that it was not clear why learners move to different stages in the learning cycle (Egenfeldt-Nielsen, 2005). There should have been a factor to stimulate learners to move to the next stage. Dewey (1938) as the founder of experiential learning theory emphasized the importance of motivation in learning (Bixler, 2006). However, motivation was not included in the Kolb's learning cycle. In this study, motivation was combined with Kolb learning cycle and considered as a factor to start the learning cycle and move it around. A modified version of Kolb's learning cycle which was used as conceptual framework of this study is provided in the Conclusion section. Further description on the motivation subject is provided in the next section.

### *Motivation: ARCS Model*

In the field of instructional games, motivation has been frequently referred as a vital factor in inspiring learning activities (Dweck, 1986; Keller, 1987a; Klawe, 1998; Malone, 1981a; Norman, 1993; Sedighian & Sedighian, 1996).

A number of theories in explaining underlying factors of motivation in instructional settings have been identified in the literature including ARCS model (Keller, 1987a), Intrinsic Motivations (Malone & Lepper, 1988), and Time Continuum Model of Motivation and Motivational Framework for Culturally Responsive Teaching (Wlodkowski, 1989, 1999). Among these theories, ARCS model (Keller, 1987a) and Intrinsic Motivations (Malone & Lepper, 1988) have been frequently referred and used in studies related to instructional games. Therefore, these models are discussed below.

Based on these theories, a number of factors should be adopted to create a motivated learning environment. ARCS model recommends four aspects of (a) attention, (b) relevance, (c) confidence, and (d) satisfaction, while Intrinsic Motivation theory suggests four main factors of

(a) challenge, (b) curiosity, (c) control, and (d) fantasy. The two models overlap in many aspects as describe in Table 5 (Bixler, 2006).

Table 5

The Comparison of Two Motivation Theories of ARCS Model and Intrinsic Motivation

| ARCS model<br>Keller (1987a) | Intrinsic Motivations<br>Malone and Lepper (1988) |
|---|---|
| • Attention: obtaining and sustaining | • Provide optimally challenging activities<br>• Change sensory conditions to arouse curiosity |
| • Relevance: Meet the needs of the learners.<br>• State goals. | • State goals or allow goals to emerge |
| • Confidence: Develop an expectancy for success. | • Provide an optimal level of challenge<br>• Provide performance feedback. |
| • Satisfaction: How good do people feel about their accomplishments?<br>• Give learners control over reaching goals that are intrinsically motivating | • Provide control over the learning environment |
| | • Use fantasy to help the student experience power, success, fame, and fortune. Also helps learners relate new learning to a past experience |

From "Motivation and Its Relationship to the Design of Educational Games," by B. Blixer, 2006, Paper presented at the NMC, Cleveland, Ohio, p.13. Adapted with permission from the author (see Appendix K).

As Table 5 shows fantasy is the only factor that differentiates the two models. However, the role of fantasy as a factor to motivate players in instructional games was subject of debate among the researchers (Habgood, Ainsworth, & Benford, 2005). In addition, it was suggested that Intrinsic Motivation theory hardly stimulate empirical studies because it was a prescriptive approach and did not provide measurable variables (Astleitner & Wiesner, 2004).

Therefore, ARCS model was considered as the preferred theory and used in this study to measure effect of DimensionM™ games on learners' motivation along four attributes of Attention, Relevance, Confidence, and Satisfaction (Keller, 1987a). This model has been used to evaluate motivations of learners in a variety of learning settings including E-learning environments and web-based distance settings (Keller & Suzuki, 2004), hypermedia contexts (Carson, 2006), and classroom face to face setting (Small, Zakaria & El-Figuigul, 2004).

Attention was referred to the gaining and sustaining learners' attention in a learning environment and can be reinforced through (a) perceptual arousal: gaining attention by offering novel and surprising activities, (b) inquiry arousal: stimulating learners by posing questions and problems, and (c) variability: maintaining students' interest by offering various activities (Keller, 1987a). The goal was situating learners in a proper learning state between boredom and hyperactivity.

Relevance was referred to the degree that instructions meet learners' needs and could be achieved through (a) familiarity: adapting instruction according to learners' background knowledge, (b) goal orientation: presenting instructional goal, and (c) motivation matching: providing instructional strategies according to learners' profiles (Keller, 1987a).

Confidence was the expectancy of the learners for success and could be achieved through (a) learning requirements: informing performance requirements, (b) success opportunities: providing different achievement levels, and (c) personal control: providing feedback and support (Keller, 1987a).

Satisfaction was referred to learners' feeling about their accomplishments and could be enhanced by providing (a) natural consequence: providing opportunities to use newly acquired knowledge in a real or simulating setting, (b) positive consequences: providing feedback and reinforcement, and (c) equity: maintaining consistence standards for task accomplishment and consequences (Keller, 1987a).

In this study, the effectiveness of DimensionM™ instructional games on learners' motivation was measured by using the Course Motivation Survey (see Appendix B) developed based on the four aspects of ARCS model.

### *Individual Differences: Experiential Learning Theory and ARCS Model*

Three individual differences of computer experience, prior knowledge, and language background were suggested based on the previous empirical studies (Ke & Grabowski, 2007; Moreno, 2002) as factors that influenced the effectiveness of instructional games. The experiential learning theory and ARCS model support such suggestion that these factors play an important role in effectiveness of games.

According to the Kolb's learning cycle, individuals with different abilities have different concrete experiences. Different concrete experiences affect the learning process and consequently the achievement of learners. Thus in this study, learners with different mathematics achievement levels, computer skills, and language backgrounds should have different experience in completing the game missions.

The relevance aspect of ARCS model suggests that the familiarity of game instructions to learners' background knowledge affects learners' motivation. Thus, learners with different prior knowledge, computer experience, and language background can be motivated differently depending on how close games relates to their background knowledge.

Therefore, three factors of prior knowledge, computer experience, and language background were considered independent variables that could affect motivation, achievement and consequently effectiveness of instructional games. Such hypothesis supported by empirical studies, experiential theory and ARCS model were tested in this study.

*Section Summary*

To build the conceptual framework of the study, experiential learning theory (Dewey, 1938; Kolb, 1984) and ARCS motivation model (Keller, 1987a) were combined. Figure 6 illustrates the conceptual framework and the relationships among the variables and adopted theories in this study. The framework included three main stages of learning input, game learning process, and learning outcome which was similar to three-stage game model proposed by Garris, Ahlers and Driskell (2002).

As Figure 6 shows, three independent variables of English language skill, prior mathematics knowledge, and computer skill were considered as factors that affected concrete experiences, motivation and consequently game learning cycle. These variables were input into the learning cycle.

| Learning Input (independent variables) | Revised Cyclical Experiential Learning Process with motivation in the heart of cycle | Learning outcome (dependent variables) |
|---|---|---|

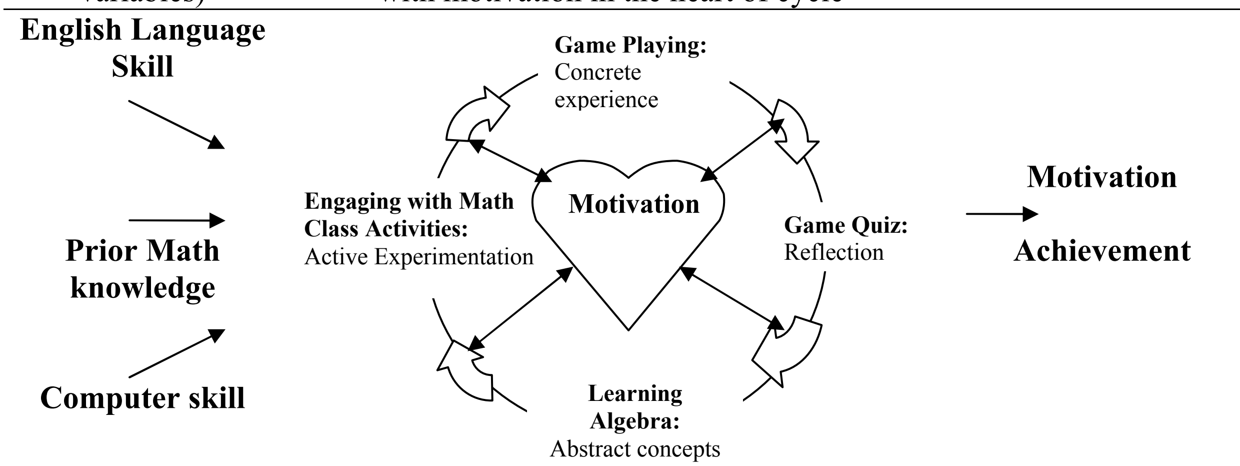



Figure 6: The Relations Among the Variables of Language Background, Prior Knowledge, Computer Experience, Motivation and Achievement with the Cyclical Learning Process of Experiential Learning Theory Extended from a Kolb's (1984) Circular Learning

In the game learning process, according to Kolb's learning cycle, learners (a) completed game missions or concrete experiences, (b) reflected on their learning experiences through game quizzes, (c) developed abstract Algebra concept, and (d) engaged in mathematics class activities and moved to the next experience.

Motivation, a dependent variable, was considered as heart and outcome of the cycle because on one hand, motivation inspired the game learning activity and on the other hand, it got affected by both the game activity and three independent variables of English language skill, prior mathematics knowledge, and computer skill. There was a two-way connection between the game learning cycle and motivation. Achievement, a dependent variable, was the outcome of a two-way function between cyclical game learning and motivation. This function was also influenced by the three independent variables.

In summary, this section provides theoretical foundation for this study variables and hypotheses. Experiential learning suggested that active engagement of the learners with the game environment coupled with debriefing through game quizzes produce achievement. This suggestion formed the foundation of the first hypothesis that searched for the effect of DimensionM™ on achievement. ARCS model proposed four attributes through which the second hypothesis were tested to identify effects of the games on motivation. Both experiential learning theory and ARCS model suggested that individual differences of computer experience, prior mathematics knowledge, and language background influenced the effectiveness of the game. This suggestion supported the third hypothesis that looked for the effect of the games on individuals with these three differences.

# CHAPTER THREE: METHOD

Chapter three presents the design and method of this study. The chapter is divided into seven main sections including: (a) participants, (b) research design, (c) treatments, (d) instruments, (e) procedure, (f) data analysis, and (g) limitations.

## Participants

The research participants were teachers and students at an urban high school at a southeast state in the United States of America. The school had the features of an ideal research site described by Rossman and Rallis (2003) which included: possible entry, possession of mix population, likelihood of developing positive relation between the participants and researchers, and ethical approval. The research was conducted in the school upon the principal's and the assistant principal's approvals. The high school had a rich mix of (a) ethnicity population of Spanish, Caucasian, and African American with different language backgrounds, and (b) students with low, average, and high achievement levels. The school's mixed population provided an opportunity to examine the effects of the games on participants with different language backgrounds and achievement levels. The teachers and students developed positive relationships with the researchers as they were interested in using the games as alternative tools of teaching and learning. The study was approved ethically. It was received the school district (see Appendix B) and the University of Central Florida Institute Review Board (IRB) (see Appendix C) approvals in the summer of 2007. In addition, the game treatment had not been previously used by the teachers or students. This feature controlled the conditions to better evaluate effectiveness of the games on the students.

The teachers were informed about the study and DimensionM™ games in an introductory training held in the summer of 2007. The teachers, who were interested in participating in the study, signed the teacher informed consents provided in Appendix D. The participated teachers introduced the study to their students and invited them to participate in the study. Then, the teachers requested their students to have their parent consents for participating in the study by reading the student scripts (see Appendix E) and distributing the parent consent forms (see Appendix F). A total of 10 Pre-Algebra and Algebra I teachers and 598 students were participated in this study.

## Research Design

This study used a mixed method of the combination of quantitative instruments and interviews. The mixed method was an appropriate method for this study because quantitative method allowed the researcher examined the effect of the game on a large number of students and therefore reach a conclusion with less error. In general, a larger sample generates a more accurate result (Cohen, 1992). On the other hand, interviews helped the researcher cross validated the quantitative results and explored the reasons that caused the game effects on the participants.

The study used experimental design described by Campbell and Stanley (1963). Teachers were randomly assigned to experimental and control groups. This approach was similar to the design of the study conducted by the U.S. Department of Education, Institute of Education (Dynarski et al., 2007) that examined the effectiveness of reading and mathematic software products.

Both the experimental groups and control groups attended Algebra I classes regularly. However, in addition to class attention, the experimental group used the treatment (X) which included (a) DimensionM™, (b) online teaching modules, and (c) lesson plans (see Table 6). At the beginning of the school year three sets of the instruments were used: (a) the demographic survey (O1) to identify the participants' demographic information, (b) the school district-wide benchmark exam (O2) and DimensionM™ game performance test (O3) to identify the participants' mathematics academic achievement level, and (c) the Course Motivation Survey to identify the participant's motivation toward mathematics (O4). To measure the effect of the treatment (X) on the mathematics achievement and motivation of the treatment group and compare the results with the test results of the control group, the similar set of survey and tests (O2, O3, O4) used at the beginning of the study were used at end of the second nine weeks. Furthermore, interviews (O5) were conducted with the teachers and students in the treatment group to gather data about the students' mathematics achievements and motivation. The interviews were conducted close to the end of the second nine weeks.

Table 6

The Research Design of Treatment and Control groups with Instruments and Treatment

| Participants' Groups | 1st Nine Weeks | | 2nd Nine Weeks | |
|---|---|---|---|---|
| | Beginning | During | During | End |
| Treatment Group | R O1O2O3O4 | X | X<br>O5 | O2O3O4 |
| Control Group | R O1O2O3O4 | | | O2O3O4 |

X = Treatment (DimensionM games, teaching modules and lesson plans)
O1 = Demographic Survey
O2= The School District-wide Benchmark Exams
O3 = DimensionM™ Game Tests
O4 = Course Motivation Survey
O5 = Interview

The independent variables in this study included participants' (a) game use/non use (b) prior mathematics knowledge determined by the participants' school record, (c) computer skills determined by the Demographic Survey provided in Appendix A, and (d) English fluency determined by the participants' school record.

The dependent variables in this study included (a) the participants' mathematics achievement, measured by the school district-wide benchmark exam, and the game performance tests provided in Appendix A, and (b) the participants' motivation measured by the Mathematics Course Motivation survey provided in Appendix A.

There were no anticipated risks, compensation or other direct benefits, and the participants were free to withdraw their consent and discontinue participation at any time without any consequence. The participants' responses were analyzed and reported anonymously to protect their privacy.

## Treatments

The research treatment included using a set of mathematics instructional games called DimensionM™, online teaching modules, and lesson plans. The DimensionM™ mathematics games include:

*SP (Single Player) Evolver*™. This game teaches Pre-Algebra by involving players in completing twenty mathematics related missions within a 3-D immersive environment designed with advanced graphics.

*SP (Single Player) Dimenxian*™. This game teaches Algebra I by involving players in completing five mathematics related missions within a 3-D immersive environment designed with advanced graphics.

*MP (Multi Player) Evolver™*. This game teaches Pre-Algebra and Algebra I by involving players in completing three individual 3-D games that allow players to play and compete with each other. The games are (a) Swarm, a team-based game in which players work together to compete against other groups by collecting points when solving mathematics problems, (b) Meltdown, a strategy game in which individual players compete against each other by gathering points using their calculation and speed skills, and (c) Obstacle Course, a strategy game in which players of a group compete against each other to complete five major stages with mathematics related obstacles.

According to the findings of the literature review in Chapter two, when examining effectiveness of instructional games a number of design and delivery issues should be addressed to optimize game learning effects. The game design issues included providing the components of: motivation, gender neutral, feedback and scaffolding, verbal and written reflection, game genre, balance between content and game, visual appeal and friendly usability. A number of suggested components (Sedighian & Sedighian, 1996) to increase motivation were incorporated in DimensionM™ games. The games were gender neutral as the main avatar of the game was designed to look unisex. Feedback and scaffolding were provided by a vocal guidance throughout the game. Verbal and written reflection was presented at the end of each mission in the form of a quiz. The games had an action-adventure genre which was aligned with the genre of the recent modern games (e.g, Zombie Division). Balance between the content and game-playing was maintained. The players got involved in the games while they had mathematics oriented missions to accomplish. The games were designed with appealing visual effects and were user friendly.

Game delivery issues discussed in Chapter two included curriculum issues, the time and purpose of the game implementation, outcome issues, and technical issues. These issues were addressed for the delivering of DimensionM™ games by providing the participated teachers with the online teaching modules, lesson plans, and resources. The online teaching modules taught relevant mathematics skills. Lesson Plans, which included guidance in two versions of teacher-directed and inquiry-based approaches, helped the teachers to integrate the games into the school curriculum. In addition, a number of resources were provided to help the teachers use the games including (a) correlation of the game mission objectives to the school district and National Standards, (b) practice tests, and (c) quizzes.

## Instruments

Data were collected through quantitative instruments of the motivation surveys, the school district-wide tests, and the game performance tests. In addition, a series of interviews were conducted. The instruments are described below.

*Demographics survey.* Information regarding participants' demographics was collected through a demographic survey provided in Appendix A.

*Motivation surveys.* Pre and post surveys were used for collecting students' motivation. The survey was developed based on Keller's ARCS Model (1987a). This model measures the motivation along four major attributes of Attention, Relevance, Confidence, and Satisfaction (ARCS). Attention refers to whether students' interest is gained and maintained during educational activities. Relevance refers to whether a student perceives the activity as a personal need. Confidence refers to whether a student expects to succeed at the activity. Satisfaction refers to the rewards that the student anticipates from the activity. Further information related to the survey and the actual questions are provided in Appendix A.

As shown in Table 7, the reliability of the Course Motivation survey has been estimated based on Cronbach's alpha measure for the total scale and subscale with 20 items for the motivation pretests and posttests. The total scales and all the subscales except for the relevance and the confidence have met the requirement of higher than .7 cut-off point suggested by Nunnaly (1978). The validity of the Motivation survey was confirmed by the experts who developed and modified the motivation survey.

Table 7

The Reliability of the Course Motivation Survey with 20 Questions

| | | Reliability (pretest) | | Reliability (posttest) | |
|---|---|---|---|---|---|
| | | Cronbach's alpha (α) | N | Cronbach's alpha (α) | N |
| Total Scale | | 0.87 | 499 | 0.86 | 641 |
| Subscale | Attention | 0.72 | 518 | 0.73 | 662 |
| | Relevance | 0.6 | 513 | 0.62 | 672 |
| | Confidence | 0.59 | 515 | 0.59 | 668 |
| | Satisfaction | 0.7 | 519 | 0.69 | 665 |

*Academic achievement tests.* The following tests were used to collect students' mathematics achievement:

- The school district-wide benchmark exam
- The DimensionM™ game performance tests provided in Appendix A

The reliability and validity of the school district-wide benchmark exams have been determined by the school district. The benchmark test reliabilities were moderate to good and ranged from .73 (Grade 9) to .82 (Grade 10) for the pretest and from .84 (Grade 9) to .86 (Grade 10) for the posttest (Princeton Review, 2008).

The reliability of the game performance tests have been estimated based on Cronbach's alpha as $\alpha = .9$, $N = 490$, for the pretest and $\alpha = .91$, $N = 649$, for the posttest. The validity of the game performance tests have been confirmed by the mathematics experts who developed the tests in the game company.

*Interviews.* In addition to the surveys and tests that collected quantitative data, interviews with open-ended questions were used to gather qualitative data to: (a) cross validate quantitative results on effects of the games on achievement and motivation of the participants, and (b) identify the reasons that cause such game effects on the participants. The interviews were conducted based on predefined protocol and questions provided in Appendix A. All the experimental teachers were interviewed about their perspectives on the effects of the games on the students. To select students for interview, stratified sampling were used to sample three students of low achiever, average and high achiever from the students of each participated teacher. In stratified sampling, sample is taken from each sub-group of the population. This strategy is useful when the members of a population are dissimilar and, therefore, measurements of interests vary among sub-groups of the population. Using this sampling technique helped the researcher select the representative of different students and identify the effect of the games on the participants with different levels of achievement.

## Procedure

This study was conducted for 2 nine-week school periods or a total of eighteen school weeks from August 2007 to January 2008. The selection of the school as the research site for this study was conducted in the summer of 2007 based on the criteria described in the Participants section. Then, an introductory training was held before the beginning of the school to inform and recruit the teachers. The teachers, who were interested in participating in the study, have signed the teacher informed consents provided in Appendix D. The students of the participated teachers who were interested in participating in this study have returned the signed parent consent forms provided in Appendix F.

After collecting the teacher and student consent forms, the instruments were administered in both the experimental and control groups. The study treatments were used only by the treatment group as explained in the Research Design section. The surveys and tests were answered in Scantrons. The Scantrons were run through the readers and prepared for analysis in January 2008. The results were summarized and reported in March 2008.

## Data Analysis

Data were input into SPSS and statistical tests of multivariate analysis of covariance (MANCOVA) were used to test the study hypotheses. MANCOVA is a useful test to compare two or more groups when there are covariates and two or more dependent and independent variables. A covariate is an independent variable that is not controlled by researchers but affects dependent variables. To have a statistical control of the pre-existed difference, MANCOVA with pretest scores as covariates is recommended as a preferable analysis method in an experimental study (Campbell & Stanley, 1963).

In this study, to test the first and second hypotheses about the game effects on achievement and motivation, MANCOVA were used with the following variables. The results of the achievement tests and motivation surveys were used as dependent variables, while teaching method (game use or non-use) were considered as independent variable. The results of achievement and motivation pretests conducted at the beginning of the school were considered as covariates to control the effect of the participants' variance.

As discussed in the Conceptual Framework section of Chapter two, a number of studies used the individual differences of computer skills, prior mathematics knowledge, and language backgrounds as independent variables that influenced the game effectiveness. Computer skills was considered as an independent variable by three studies (i.e., Ke & Grabowski, 2007; Lopez-Moreto & Lopez, 2007; Moreno, 2002) while prior mathematics knowledge was considered by Ke and Grabowski (2007) and language background was considered by Moreno (2002) as an independent variable.

To examine the third hypothesis about the game effects on achievement and motivation of learners with different computer skills, English language skills, and prior mathematics knowledge, MANCOVA was used with the following variables. Achievement and motivation were used as dependent variables while teaching method (game use and non-use) computer skills, English language skills, and prior mathematics knowledge were used as independent variables. The pretest results of achievement and motivation tests were considered as covariates.

To analyze the interview results, Charmaz's (2000) grounded theory was used. The grounded theory refers to a qualitative methodology which explains an under study phenomenon by developing a theory grounded on the collected qualitative data. In this method, the data are compared, coded and categorized to explicit an implicit belief system (Moghaddam, 2006). To identify the effect of the DimensionM™ games on the participants and the reasons that cause such effects, the interview data were refined, compared, and categorized. Based on the categorized data, explanations about the effects of the games on the participants' learning were drawn.

## Limitations

The results of this study were indications of effects of DimensionM™ games on students in an urban high school in a southeastern state in the United States of America. The generalization of the results is limited to the similar population using the same or similar instructional games. A description of the games, situation, and the sample population are provided in this Chapter and Chapter four to make it possible to use the results of this study in other similar situations.

Furthermore, the game usage time and location varied among the experimental classes. This variation might have affected the achievement and motivation results. Finally, it is notable that there was 55% missing data mainly because from the pretests taken in August to the posttests taken in December, a number of participants changed their classes or withdrew from the school. However, the missing data might not have affected the results because they were Missing Completely At Random (MCAR) as discussed in Chapter four.

# CHAPTER FOUR: RESULTS

Chapter four presents the results of testing the research hypotheses through quantitative methods and interview responses from the participated teachers and students. In addition, the results of the post hoc questions are provided. The chapter is divided into four main sections including: (a) introduction, (b) the research hypotheses, (c) the interviews, and (d) the post hoc questions.

## Introduction

The following three research hypotheses were proposed in this study:

1. There is no significant difference between learners' achievement of the experimental group, who received the pre-Algebra and/or Algebra I instructional games, versus the control group, who did not receive the games.
2. There is no significant difference between the learners' motivations of the experimental group, who received the pre-Algebra and/or Algebra I instructional games, versus the control group, who did not receive the games.
3. There is no significant difference between effects of the games on students with differences in (a) prior mathematics knowledge, (b) computer skills, and (c) English language skills.

To test these hypotheses an experimental study was conducted using the design described in Chapter three and depicted in Table 6. As shown in Table 6, demographic survey was used at the beginning of the 18 week period and three sets of tests and surveys including the school district benchmark test, the motivation surveys, and the game performance mathematics tests were used at the beginning (pretests) and end of (posttests) the 18 weeks school period. In addition, the experimental teachers and students were interviewed close to the end of the 18 weeks period.

A total of 981 students and 10 teachers were recruited from a high school in the southeast of the United States of America to participate in this study. As a result, 598 students were participated in this study. Of 598 students, 430 permitted the researchers access to their grades. The sample of 430 cases was input into SPSS. Of 430 cases, the total of 193 cases had valid data on all the dependent variables and 237 cases had one or more missing data on the dependent variables. The six dependent variables of this study included: (a) the motivation pre-survey (Motivation1), (b) the motivation post-survey (Motivation2), (c) the benchmark pre-exam (Benchmark1), (d) the benchmark post-exam (Benchmark 2), (e) the game mathematics performance pre-test (GameMath1), and (f) the game mathematics performance posttest (GameMath2). Three dependent variables of Motivation1, Benchmark1, and GameMath1 were considered as covariates.

To find a proper technique to handle the missing data, the distribution and effects of the missing data on the dependent variables were analyzed using descriptive and correlation tests as recommended by a number of scholars (e.g., Schafer & Graham, 2002; Widaman, 2006). The descriptive test was used to find a possible missing pattern based on the participants' demographic variables including teacher, gender, ethnicity, computer skills, prior mathematics achievement, and English language skills. The descriptive analysis indicated that the missing data were randomly distributed among all aforementioned criteria except for teacher. As depicted in Table 8, two of the ten teachers had more than 50% missing data which was larger than the missing data percentage of the other teachers.

Table 8

The Percentage of Valid and Missing Data of the Participants Per Teacher (N = 430)

| Teacher | Participants' data | | | | |
|---|---|---|---|---|---|
| | Valid | | Missing | | Total |
| | n | Percent | n | Percent | n |
| 1 | 37 | 67.3% | 18 | 32.7% | 55 |
| 2 | 9 | 64.3% | 5 | 35.7% | 14 |
| 3 | 26 | 40.6% | 38 | 59.4% | 64 |
| 4 | 59 | 71.1% | 24 | 28.9% | 83 |
| 5 | 25 | 80.6% | 6 | 19.4% | 31 |
| 6 | 12 | 57.1% | 9 | 42.9% | 21 |
| 7 | 19 | 36.5% | 33 | 63.5% | 52 |
| 8 | 26 | 72.2% | 10 | 27.8% | 36 |
| 9 | 36 | 78.3% | 10 | 21.7% | 46 |
| 10 | 21 | 75.0% | 7 | 25.0% | 28 |
| | Total =193 | | Total = 237 | | Total = 430 |

The two teachers were contacted to find out if there was any relationship between the large missing data and the dependent variables of this study. The teachers explained that the data were missing mainly due to: the students' moving from their classes to the other non-participating teachers' classes, absences, and withdrawals from school.

In addition, the correlation test was conducted to identify if there were any relationships between the missing data of one variable and outcomes of other variables. To achieve this purpose, the recommended method by Widaman (2006) was used in which an index was generated for each dependent variable with missing data by dummy coding the variable's missing data as 0 and valid data as 1, then the correlation of this index with other variables was examined using SPSS correlation test. As shown in Table 9, there were no statistically significant correlations ($p > .05$) between the missing data of one variable and other posttest variables.

Table 9

The Correlation between the Missing Data of One Dependent Variable and of the Other Dependent Variables

| Variable with Missing data | | Dependent Variables | | | | | |
|---|---|---|---|---|---|---|---|
| | | M1 | M2 | GM1 | GM2 | BM1 | BM2 |
| Motivation2, posttest (M2) | *p* | 0.10 | 0.00 | 0.06 | 0.87 | 0.69 | 0.58 |
| | n | 357 | 302 | 345 | 296 | 336 | 368 |
| Game Math2, posttest (GM2) | *p* | 0.27 | 0.59 | 0.01 | 0.20 | 0.39 | 0.07 |
| | n | 357 | 302 | 345 | 296 | 336 | 368 |
| Benchmark2, posttest (BM2) | *p* | 0.31 | 0.35 | 0.47 | 0.87 | 0.96 | 0.00 |
| | n | 347 | 291 | 336 | 290 | 325 | 357 |

M1 = Motivation1 (pretest)
M2 = Motivation2 (posttest)
GM1 = Game Mathematics Test1 (pretest)
GM2 = Game Mathematics Test2 (posttest)
BM1 = Benchmark Exam1 (pretest)
BM2 = Benchmark Exam2 (posttest)

A set of missing data can be classified as Missing Completely at Random (MCAR) if the probability of missing data of a variable is unrelated to the value of the variable itself or to the values on any variables in the study (Widaman, 2006). In addition, the unpredictability of missingness was considered as an important indicator for MCAR data (Schafer & Graham, 2002). Therefore, missing data in this study were considered as the MCAR type of missing data because they were randomly distributed, there was no correlation between the missing data and outcomes of other variables, and missingness was unpredictable. List-wise case delete was used to remove cases with one or more missing data on the dependent variables.

As a result, a sample size of 193 with valid data on all six dependent variables was used for testing the research hypotheses. As described in Chapter three, 10 teachers were randomly assigned to the experimental and control groups. Of the 193 participants, 117 participants were assigned to the experimental and 76 to the control group. The teachers' demographics are shown is Table 10.

Table 10

The Demographics of the Participated Teachers (N = 10)

| Demographic | | Number of Teachers |
|---|---|---|
| Gender | Male | 4 |
| | Female | 6 |
| Ethnicity | Caucasian | 4 |
| | African American | 3 |
| | Hispanic | 3 |
| Age | Gen X (1961-1979) | 7 |
| | Baby Boomers (1945-1960) | 3 |
| Education | Bachelors degree | 5 |
| | Masters degree | 5 |
| Experience | Over 10 years | 5 |
| | Over 6 years | 4 |
| | About 2 years | 1 |
| Computer Skill | Proficient-Regular User | 7 |
| | Awesome-Power User | 3 |
| Game-Playing | Not at all | 4 |
| | Not often | 3 |
| | About 3-4 time per week | 2 |
| | Everyday | 1 |

The demographics of the 193 research participants on their gender, ethnicity, prior mathematics knowledge, English language skills, and computer skills are provided in Table 11. The information about gender, ethnicity and computer skill were obtained from the demographic survey while prior mathematics knowledge and English language skills were obtained from the students' school records.

Table 11

The Demographics of the Participated Students (N = 193)

| Demographic | | Percent |
| --- | --- | --- |
| Gender | Male | 52.9 |
| | Female | 47.1 |
| Ethnicity | Caucasian | 16 |
| | African American | 5.9 |
| | Hispanic | 73.4 |
| | Other | 4.8 |
| Prior Mathematics Knowledge | Very low | 33.7 |
| | Low | 29.7 |
| | Intermediate | 32.6 |
| | High | 4.1 |
| | Professional | 0 |
| English Language Skill | Low | 25.6 |
| | Intermediate | 5.8 |
| | High | 15.1 |
| | Proficient | 10.5 |
| | Native | 43 |
| Computer Skill | Non-User | 3.1 |
| | Beginner- Just Started User | 5.2 |
| | Novice-Infrequent User | 14.5 |
| | Proficient-Regular User | 44.6 |
| | Awesome-Power User | 29.5 |

Figure 7 depicts the demographics of the 193 research participants on their gender, ethnicity, prior mathematics knowledge, English language skills, and computer skills.

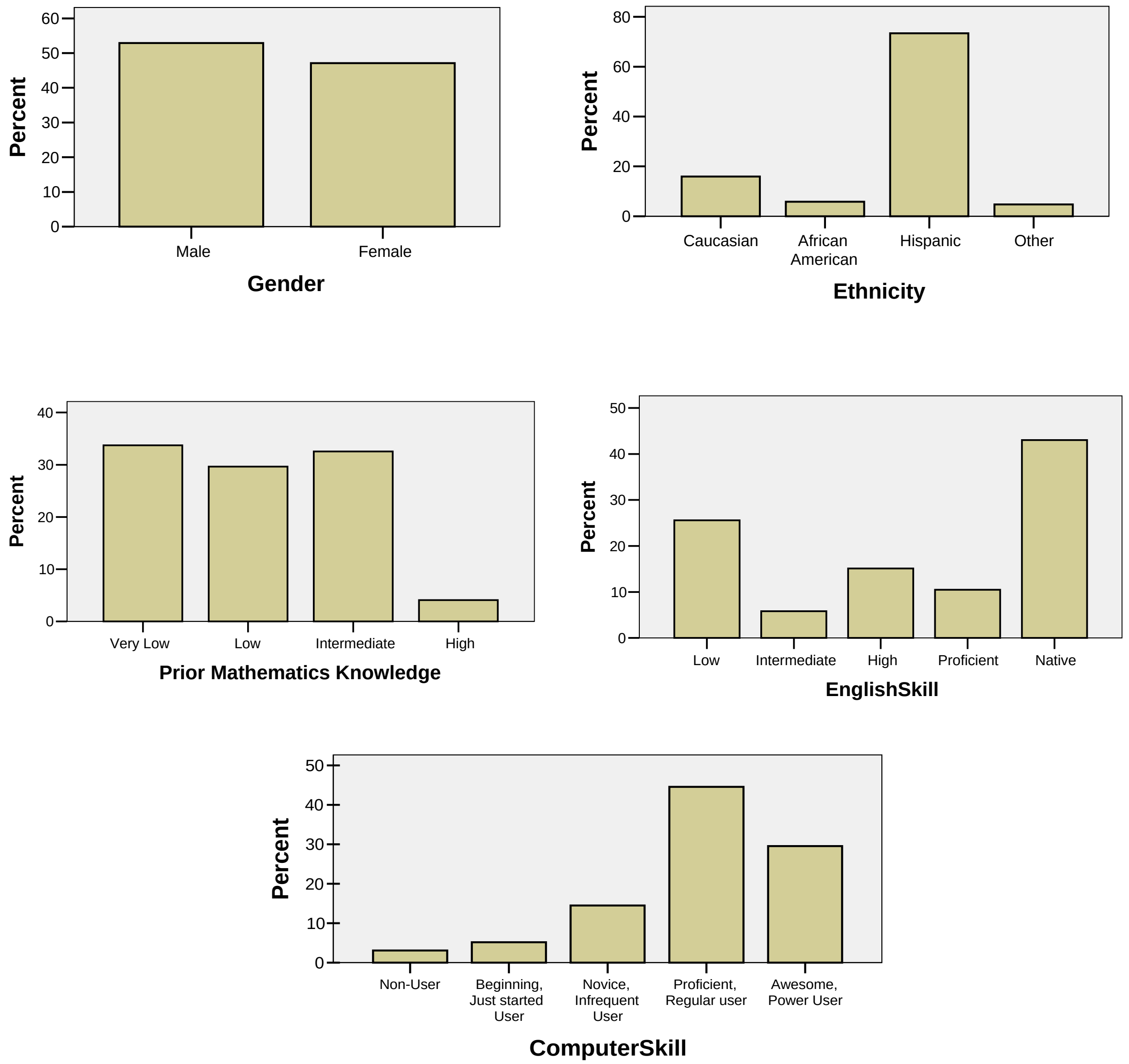



Figure 7: The Demographics of the 193 Research Participants on Their Gender, Ethnicity, Prior Mathematics Knowledge, English Language Skills, and Computer Skills

The mean and standard deviation of scores of 193 participants on the three sets of pretest and posttest that formed six dependent variables across the two groups of experimental and control are provided in Table 12. It is notable that the benchmark scores are presented in percentage while the motivation and game mathematics performance are provided in raw scores. The benchmark test difficulty was generally moderate, with the district-wide average percentage of correct tests ranging from 40 (Grade 9) to 48 (Grade 10) percent for pretest and from 51 (Grade 9) to 55 (Grade 10) for posttest (Princeton Review, 2008). Given the fact that the school's population was mostly low achievers (63%), the school benchmark means were in normal range as they were slightly lower than the district averages (experimental $M_{pretest} = 37.64$, $M_{posttest} = 45.71$, control $M_{pretest} = 28.26$, $M_{posttest} = 32$, of total 100%).

Table 12

The Mean and Standard Deviation of Six Dependent Variables for Experimental and Control Group (N=193)

| Variable | Total Score | Mean | | Std. Deviation | |
|---|---|---|---|---|---|
| | | Control (n=76) | Experimental (n=117) | Control (n=76) | Experimental (n=117) |
| Motivation1 (pretest) | 100 (raw) | 67.99 | 70.58 | 13.11 | 13.48 |
| Motivation2 (posttest) | 100 (raw) | 68.53 | 68.20 | 11.38 | 13.17 |
| GameMath1 (pretest) | 47 (raw) | 18.92 | 27.52 | 7.99 | 9.18 |
| GameMath2 (posttest) | 47 (raw) | 21.99 | 24.58 | 7.73 | 11.67 |
| Benchmark1 (pretest) | 100 (percent) | 28.26 | 37.64 | 12.09 | 14.30 |
| Benchmark2 (posttest) | 100 (percent) | 32.00 | 45.71 | 13.65 | 17.55 |

## Testing the Research Hypotheses

To test the research hypotheses a multivariate analysis of covariance (MANCOVA) was conducted to determine the effect of the mathematics games on the participants' mathematics achievement and motivation. MANCOVA is a useful test to compare two or more groups when there are covariates and two or more dependent and independent variables. Two MANCOVA tests were run separately. The first MANCOVA tested the first and second hypotheses. The second MANCOVA tested the third hypothesis. All tests for significance were set at the .05 level.

*The First and Second Research Hypotheses*

To test the first and second hypotheses on effect of the games on achievement and motivation MANCOVA was planned to conduct. Achievement was measured using the game mathematics performance posttest, shown as GameMath2 variable, and the district benchmark post-exam, shown as Benchmark2 variable. The motivation was measured using motivation post-survey, shown as Motivation2 variable. The pretests scores of GameMath1, Benchmark1, and Motivation1 were considered as covariates.

Before conducting MANCOVA, the homogeneity of the slopes assumption was tested. The test evaluated interaction between the covariates and the group factor in the prediction of the dependent variables. If the interaction is significant, the interpretation of main effect of a MANCOVA will not be helpful. As shown in Table 13, the results of the test were not significant on the interaction of group factor of Group (control and experimental) with covariates of Benchmark1, GameMath1, and Motivation1. The multivariate $\eta^2 =< 0.01$ suggested that there was small or no relation between the groups and covariates. The results for Group*Motivation1 on dependent variable of Motivation2 was $F$ (1, 185) = 1.12, $p > .05$, $\eta^2 = .01$, for Group*GameMath1 on GameMath2 was $F$ (1,185) =.56, $p > .05$, $\eta^2 < .001$, and for Group*Benchmark1 on Benchmark2 was $F$ (1, 185) = .22, $p > .05$, $\eta^2 < .001$. Thus, the assumption of homogeneity of the slopes was met and MANCOVA was conducted.

Table 13

The Results of Tests of Between-Subjects Effects for Testing Homogeneity of Slopes

| Source | Dependent Variable | *df* | *F* | $\eta^2$ | *p* |
|---|---|---|---|---|---|
| Group | Motivation2 | 1 | .310 | .002 | .578 |
| | GameMath2 | 1 | .078 | < .001 | .781 |
| | Benchmark2 | 1 | .007 | < .001 | .933 |
| Group * Motivation1 | Motivation2 | 1 | 1.121 | .006 | .291 |
| | GameMath2 | 1 | .410 | .002 | .523 |
| | Benchmark2 | 1 | .485 | .003 | .487 |
| Group * GameMath1 | Motivation2 | 1 | 1.718 | .009 | .192 |
| | GameMath2 | 1 | .561 | .003 | .455 |
| | Benchmark2 | 1 | .136 | .001 | .713 |
| Group * Benchmark1 | Motivation2 | 1 | .006 | < .001 | .939 |
| | GameMath2 | 1 | 2.174 | .012 | .142 |
| | Benchmark2 | 1 | .222 | .001 | .638 |
| Error | Motivation2 | 185 | | | |
| | GameMath2 | 185 | | | |
| | Benchmark2 | 185 | | | |

MANCOVA results indicated that the assumption of equality of covariance among the dependent variables across groups was violated because Box's M Test of Equality of Covariance Matrices that tested equality of covariance matrices of the dependent variables across control and experimental groups was significant, $F$ (6, 172265) = 5.02, $p < .001$. Therefore the results of Pillai's Trace test, which is the most robust of the multivariate tests in face of the assumption violation (Olson, 1976) were used.

The results showed a significant difference on achievement but an insignificant difference on motivation across experimental and control group. As depicted in Table 14, Pillai's Trace test of .01 was significant, $F$ (3, 186) = 6.48, $p < .001$, and rejected the hypotheses that population means on the dependents were the same for control and experimental groups. The multivariate $\eta^2 = 0.1$ indicated 10% of multivariate variance of the dependent variables was associated with the group factor. The partial $\eta^2$ value is the proportion of variance of the dependent variables related to the group factor where 0.1 is considered medium effect size (Green & Salkind, 2005).

Table 14

The Multivariate Analysis of Covariance for Achievement and Motivation of Control and Experimental Group

| Effect | | Value | $F$ | Hypothesis *df* | Error df | $\eta^2$ | Observed Power[a] | $p$ |
|---|---|---|---|---|---|---|---|---|
| Group | Pillai's Trace | .095 | 6.484 | 3.000 | 186.000 | .095 | .97 | < .001 |

a. Computed using alpha = .05

As shown in Table 15, the tests of between-subjects effects indicated significant difference between the scores of the control group versus the experimental group, after controlling the existing differences by using the pretest as covariance, on the game mathematics posttest (GameMath2) test $F(1, 188) = 8.37$, $p < .001$, and the benchmark posttest (Benchmark2) $F(1, 188) = 6.93$, $p < .05$, however, no significant differences were found between the two group scores on the motivation post-survey (Motivation2), $F(1, 188) = 2.85$, $p > .05$.

Table 15

The Results of Tests of Between-Subjects Effects for Achievement and Motivation of Control and Experimental Group

| Source | Dependent Variable | *df* | *F* | $\eta^2$ | Observed Power[a] | *p* |
|---|---|---|---|---|---|---|
| Group | Motivation2 | 1 | 2.845 | .015 | .389 | .093 |
| | GameMath2 | 1 | 8.363 | .043 | .820 | .004 |
| | Benchmark2 | 1 | 6.928 | .036 | .745 | .009 |
| Error | Motivation2 | 188 | | | | |
| | GameMath2 | 188 | | | | |
| | Benchmark2 | 188 | | | | |

a. Computed using alpha = .05

As depicted in Table 12, the experimental group produced significantly superior performance on the benchmark post-exam (Benchmark2) (*M* = 45.71, *SD* =17.55) and the game mathematics post-exam (GameMath2) (*M* = 24.58, *SD* = 11.67) compared to the control group performance on the benchmark post-exam (Benchmark2) (*M* = 32, *SD* = 13.65) and the game mathematics post-exam (GameMath2) (*M* = 21.99, *SD* = 7.73). No significant differences between motivation post-survey (Motivation2) of experimental (*M* = 68.20, *SD* = 13.17) and control group (*M* = 68.53, *SD* = 11.38) were found.

### *The Third Research Hypothesis*

The third hypothesis proposed that there is no significant difference between effects of the games on students with differences in (a) prior mathematics knowledge, (b) computer skills, and (c) English language skills. To test this hypothesis, MANCOVA was conducted using Motivation1, Benchmark1, and GameMath1 as covariate, Motivation2, Benchmark2, and

GameMath2 as dependent variables and group, mathematics achievement, computer skill, and English language skill as independent variables.

The homogeneity of the slopes assumption was met. No significant interaction were found among fixed factors of group (control and experimental), prior mathematics knowledge, English language skills, computer skills and the covariates of Benchmark1, GameMath1, and Motivation1. The multivariate $\eta^2 =< 0.01$ suggested that there was small or no relation between the fixed factors and covariates. As shown in Table 16, the results for Group * ComputerSkill * Mathachievement * EnglishSkill * Motivation1 on dependent variable of Motivation2 was $F$ (1, 36) = .52, $p > .05$, for Group * ComputerSkill * Mathachievement * EnglishSkill * GameMath1 on Gamemath2 was $F$ (1, 36) = 1.03, $p > .05$, and for Group * ComputerSkill * Mathachievement * EnglishSkill * Benchmark1 on Benchmark2 was $F$ (1, 36) = 0.71, $p > .05$. Thus, the assumption of homogeneity of the slopes was met and MANCOVA was conducted.

Table 16

The Results of Tests of Between-Subjects Effects for Homogeneity of Slopes

| Source | Dependent Variable | *df* | *F* | $\eta^2$ | *p* |
|---|---|---|---|---|---|
| Group | Motivation2 | 1 | .122 | .003 | .729 |
| | GameMath2 | 1 | .135 | .004 | .715 |
| | Benchmark2 | 1 | .322 | .009 | .574 |
| Group * ComputerSkill * Mathachievement * EnglishSkill * Motivation1 | Motivation2 | 17 | .523 | .198 | .923 |
| | GameMath2 | 17 | 1.366 | .392 | .211 |
| | Benchmark2 | 17 | .990 | .318 | .490 |
| Group * ComputerSkill * Mathachievement * EnglishSkill * GameMath1 | Motivation2 | 17 | .754 | .263 | .729 |
| | GameMath2 | 17 | 1.034 | .328 | .448 |
| | Benchmark2 | 17 | .832 | .282 | .649 |
| Group * ComputerSkill * Mathachievement * EnglishSkill * Benchmark1 | Motivation2 | 17 | .660 | .238 | .819 |
| | GameMath2 | 17 | 2.130 | .502 | .028 |
| | Benchmark2 | 17 | .707 | .250 | .776 |

| Source | Dependent Variable | *df* | *F* | $\eta^2$ | *p* |
|---|---|---|---|---|---|
| | Motivation2 | 36 | | | |
| Error | GameMath2 | 36 | | | |
| | Benchmark2 | 36 | | | |

The assumption of the equality of covariance among the dependent variables across groups was violated as Box's M Test of Equality of Covariance Matrices tested was significant, $F$ (78, 2292) = 1.397, $p < .05$. Therefore, the results of Pillai's Trace test were used.

The MANCOVA test indicated no significant differences on achievement and motivation of the control group versus the experimental group with different prior mathematics knowledge, computer skills, and English language skills. As shown in Table 17, the Pillai's Trace of 0.05 is not significant, $F$ (3, 94) = 1.49, $p > .05$, and failed to reject the hypothesis that population means on the dependent variables were the same for control and experimental groups. The multivariate $\eta^2 = .05$ indicated 5% of multivariate variance of the dependent variables of achievement and motivation was associated with the group factor, prior mathematics, computer skills, and English language skills. In addition, no significant interaction was found among control and experimental groups, computer skill, prior mathematics achievement, and English language skill, $F$ (3, 94) = .86, $p > .05$.

Table 17

The Multivariate Analysis of Covariance for Achievement and Motivation of Control and Experimental Groups When Interacting with Computer Skill, Mathematics Achievement, and English Language Skill

| Effect | | Value | *F* | Hypothesis *df* | Error df | $\eta^2$ | Observed Power[a] | *p* |
|---|---|---|---|---|---|---|---|---|
| Group | Pillai's Trace | .045 | 1.490 | 3.000 | 94.000 | .045 | .382 | .222 |
| Group * ComputerSkill * Mathachievement * EnglishSkill | Pillai's Trace | .027 | .858 | 3.000 | 94.000 | .027 | .23 | .466 |

a. Computed using alpha = .05

Because no interaction effects were presented, the interaction of group (control and experimental) with the computer skills, prior mathematics knowledge, English language skills were removed from the model while the four fixed factors still kept in the model and MANCOVA ran again. As shown in Table 18, the results indicated non-significant differences between the mean scores of the control and experimental group, $F\ (3,153) = 187$, $p > .05$.

Table 18

The Multivariate Analysis of Covariance for Achievement and Motivation of Control and Experimental Groups without Interacting with Computer Skill, Mathematics Achievement, and English Language Skill

| Effect | | Value | *F* | Hypothesis *df* | Error *df* | $\eta^2$ | Observed Power[a] | *p* |
|---|---|---|---|---|---|---|---|---|
| Group | Pillai's Trace | .035 | 1.866 | 3.000 | 153.000 | .035 | .48 | .138 |

a. Computed using alpha = .05

The tests of between-subjects effects, shown in Table 19, indicated a non-significant mean difference between the experimental and control groups on the motivation post-survey (Motivation2), $F$ (1,155) = 0.81, $p > .05$, the Game mathematics performance posttest (GameMath2), $F$ (1,155) = 3.87, $p > .05$, and the Benchmark post-exam (Benchmark2), $F$ (1,155) = 0.49, $p > .05$, when there were no interaction effect among group and the three factors of computer skills, prior mathematics knowledge and English language skills.

Table 19

The Results of Tests of Between-Subjects Effects without Interaction of Independent Variables

| Source | Dependent Variable | *df* | *F* | $\eta^2$ | Observed Power[a] | *p* |
|---|---|---|---|---|---|---|
| Group | Motivation2 | 1 | .806 | .005 | .145 | .371 |
| | GameMath2 | 1 | 3.874 | .024 | .499 | .051 |
| | Benchmark2 | 1 | .489 | .003 | .107 | .485 |
| Computer Skill | Motivation2 | 5 | 2.093 | .063 | .683 | .069 |
| | GameMath2 | 5 | 1.171 | .036 | .409 | .326 |
| | Benchmark2 | 5 | .664 | .021 | .236 | .651 |
| Math prior achievement | Motivation2 | 3 | .580 | .011 | .168 | .629 |
| | GameMath2 | 3 | 4.044 | .073 | .834 | .008 |
| | Benchmark2 | 3 | 4.713 | .084 | .891 | .004 |
| English Skill | Motivation2 | 4 | 2.051 | .050 | .602 | .090 |
| | GameMath2 | 4 | 1.295 | .032 | .398 | .274 |
| | Benchmark2 | 4 | .718 | .018 | .228 | .581 |
| Error | Motivation2 | 155 | | | | |
| | GameMath2 | 155 | | | | |
| | Benchmark2 | 155 | | | | |

a. Computed using alpha = .05

## The Interviews

In addition to quantitative data collected through the tests and surveys, interviews with the 5 experimental teachers and 15 selected experimental students were conducted. The interview purpose was to cross validate quantitative results on effects of the games on mathematics achievement and motivation of the participants and to identify the causes of such effects on the participants.

All the experimental teachers had proficient computer skills and native English language fluency. Three of the teachers played computer games occasionally, one of them played games regularly, and the other one did not play computer games at all. The 15 interviewed students were selected based on their mathematics achievement levels of low, average and high from each experimental teacher. These students had mixed computer skills: one was beginner, six were novice, five were proficient, and three were power user. They also had mixed English language skills: six were low, three were average, and seven were advance. The interview results are provided in the following sections: (a) the first and second hypotheses, (b) the third hypothesis, (c) the causes of the game effects, and (d) additional emergent issues.

### *The First and Second Research Hypotheses*

The results of the interviews indicated that both teachers and students believed that the mathematics games had positive effects on achievement. In addition, the teachers reported that the games had a positive impact on the students' motivation. The students reported that they liked playing the games more than doing other school activities such as homework, class assignments, and working on worksheets. The details on interview responses are provided below.

Table 20 shows the total number of responses of the teachers on the effects of the games on the students' achievements and motivation. Dimenxian™ and Evolver™ games were played by the five teachers. The majority of the teachers reported that these two games had some to great positive effects on students' achievement (3 of 5 for Evolver™, 4 of 5 for Dimenxian™) and motivation (4 of 5 for Evolver™, 5 of 5 for Dimenxian™). Teacher1 reported that Evolver™ had no impact on students' achievement and motivation because of the game topics were not already taught to the students. Teacher 2 suggested that Obstacle Course™ had no impact on achievement and motivation because it was too complicated to play. Finally teacher 3 reported no impact of Evolver™, Dimenxian™ and Swarm™ on achievement because her students played the game only three times, each time for 30 minutes.

Table 20

The Teachers' Number of Responses on the Effects of the Games on Students' Achievement and Motivation (n = 5)

| | | Not Played | Achievement | | | | | Motivation | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | GN | SN | NI | SP | GP | GN | SN | NI | SP | GP |
| Numbers of the Teachers' Responses | Evolver™ | | | | 2 | 3 | | | | 1 | 3 | 1 |
| | Dimenxian™ | | | | 1 | 4 | | | | | 3 | 2 |
| | Swarm™ | 3 | | | 1 | | 1 | | | | 1 | 1 |
| | Obstacle Course™ | 4 | | | 1 | | | | | 1 | | |
| | Meltdown™ | 4 | | | | | 1 | | | | | 1 |

GN = Great Negative
SN = Some Negative
NI = No Impact
SP = Some Positive
GP = Great Positive

Table 21 shows the total responses of the students on effects of the games on their mathematics achievement and their motivation. All of the 15 students reported somewhat positive to very positive impact of the games on their achievement. In addition 13 of 15 students reported that they were more interested in playing the games than doing other school activities such as homework, assignments, and worksheets.

Table 21

The Students' Responses on the Effects of the Games on Students' Achievement and Motivation (n = 15)

| | Achievement | | | | | Interested in playing the games as compared to other school works | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Not at all | No Impact | Somewhat Positive | Positive | Great Positive | A lot less | Less | About the Same | More | A lot more |
| Numbers of the Students' Responses | | | 5 | 5 | 5 | | | 2 | 6 | 7 |

## *The Third Research Hypothesis*

The results of interviews indicated that both teachers and students had a consistent view on the impact of students' mathematics prior knowledge, but inconsistent perspectives on the impacts of computer skills and English language skills on students' mathematics achievement and motivation when they played the games.

As shown in Table 22, majority of the interviewed teachers (4 of 5) reported that students' prior mathematics knowledge and English language skill had some to great positive effect on students' achievement and motivation when they played the games, while less than half of the teachers (2 of 5) suggested a positive effect of students' computer skills on their mathematics achievements and motivations.

Table 22

The Teachers' Numbers of Responses on the Effects of Prior Mathematics Knowledge, Computer Skill and English Language Skill on the Game Playing (n = 5)

| | Preexisting math knowledge | | | | | Computer skill | | | | | English language skill | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GN | SN | NI | SP | GP | GN | SN | NI | SP | GP | GN | SN | NI | SP | GP |
| Numbers of the Teachers' Responses | | | 1 | 3 | 1 | | | 3 | | 2 | | | 1 | 3 | 1 |

GN = Great Negative
SN = Some Negative
NI = No Impact
SP = Some Positive
GP = Great Positive

Table 23 shows that 14 of 15 students believed prior mathematics knowledge played some to great role on achievement, 10 of 15 reported computer skill had some to great impact on achievement, and only 5 of 15 suggested English language skill had some to great impact on their achievement.

Table 23

The Students' Numbers of Responses on the Effects of the Games on Students' Achievement with Different Prior Mathematics Knowledge, Computer skill, English Language Skill (n = 15)

| | Achievement | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Preexisting math knowledge | | | | | Computer skill | | | | | English language skill | | | | |
| | NE | LE | SE | SIE | GE | NE | LE | SE | SIE | GE | NE | LE | SE | SIE | GE |
| Numbers of the Students' Responses | 1 | | 4 | 6 | 4 | 3 | 2 | 5 | 1 | 4 | 8 | 2 | 2 | 1 | 2 |

NE = No Effect
LE = Little Effect
SE = Some Effect
SIE = Significant Effect
GE = Great Effect

The similar trend is shown in Table 24 that 13 of 15 students believed prior mathematics knowledge played some to great impact on their motivation when they played the games, 10 of 15 reported computer skill had some to great impact on motivation, and only 6 of 15 suggested English language skill had some to great impact on their motivation when they played the games.

Table 24

The Students' Numbers of Responses on the Effects of the Games on students' Motivation with Different Prior Mathematics Knowledge, Computer Skill, English Language Skill (n = 15)

| | Motivation | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Preexisting math knowledge | | | | | Computer skill | | | | | English language skill | | | | |
| | NE | LE | SE | SIE | GE | NE | LE | SE | SIE | GE | NE | LE | SE | SIE | GE |
| Numbers of the Students' Responses | 1 | 1 | 6 | 3 | 4 | 3 | 2 | 2 | 5 | 3 | 7 | 2 | 2 | 2 | 2 |

NE = No Effect
LE = Little Effect
SE = Some Effect
SIE = Significant Effect
GE = Great Effect

### *The Causes of the Game Effects*

All of the five treatment teachers reported that the DimensionM™ game series had a positive effect on learning mathematics. The teachers suggested the following reasons as primary causes of positive game effects:

- The game motivated the students because it was an alternative way of teaching, a positive change that got the students away from pencils and paper and engaged them in mathematics activities. As one of the teachers stated, "This is definitely the way that we have to go to teach mathematics in the future."

- The games made students more interested in learning mathematics. When students played the game, they wanted to learn more and pay more attention because they liked to pass the game missions. One of the teachers stated: "It (the games) makes them want to learn."
- The game could change students' state of mind about mathematics. Their mathematics phobia was changed by playing the game. The students could see the relationship between mathematics and real life.
- The mathematics concepts stayed with the students longer when they saw the concepts in the game.

All of the 15 treatment students, who were interviewed, reported that they liked playing the games for various reasons including:

- The game took them out of class and changed their mood and it was entertaining.
- The adventure and exploration aspect of the game made it interesting.
- The mathematics challenging aspect of the game was interesting.
- The combination of shooting, solving problems, and learning mathematics in the games made them very attractive.
- The way that games combined fun and learning mathematics was interesting.
- The games showed students different way of learning mathematics. This was very attractive for students who liked to see different way of learning mathematics.

### *Additional Emergent Issues*

The following issues emerged as a result of interviewing the teachers.

*Training.* Using the computer games for teaching mathematics was a positive change in mathematics education. This was an innovation that the teachers needed to have to improve teaching mathematics. However, to better use the games, there should be a training program for students to teach them how to play the games. Or the teachers should be trained completely and learned how to play the games before offering the games to the students.

*Logistics.* The game was a useful tool that could improve students' mathematics skills. However, the logistics issues should be addressed before using the games. There should be more time and available computers so that students could play the game more often.

*Educating the school and district administrators.* The school and district administrators should be educated about using the mathematics games in teaching mathematics. A number of administrators evaluated the teachers based on using their class time effectively. Playing the games was not considered as an effective way of using the class time.

*Correlating with the school district benchmarks*. The mathematics of the games was in a lower level than that of the school and district benchmarks. In order to significantly increase students' mathematics skills and scores by using the games, the level of the games should be increased and correlated with the school district benchmark. In addition the sequence of topics offered in the games should be sorted based on the district order of topics.

*Focusing on learning.* The games should be modified in a way that students cannot progress in the game without solving mathematics problems. In the current games, students could still play the games by passing the mathematics problems through try and error. Thus, students mainly played the games instead of learning the mathematics offered by the games.

*Providing more excitement.* This generation of students get used to violation in the commercial games. Therefore, some of them found these mathematics games “boring” as they do not offer as much violation and excitement as commercial games.

## The Post Hoc Questions

To further examine the results and reach to better conclusions the following five post hoc questions were proposed.

1. Did participants in either the experimental or control group demonstrate significant gains in the achievement test, as measured by the district benchmark exams?
2. Did participants in either the experimental or control group demonstrate significant gains in the achievement test, as measured by the game mathematics performance test?
3. Did participants who played the mathematics games demonstrate greater gains in the achievement tests (in either or both the district benchmark exam or the game mathematics performance test) than participants who did not play the game?
4. Did participants in either the experimental or control group demonstrate significant gains in the motivation subscales of attention, relevance, confidence, and satisfaction, as measured by the motivation survey?
5. Did participants in the experimental group report different achievement scores based on the amount of time and location that they played the mathematics games?
6. Did participants in the experimental group report different motivation scores based on the amount of time and location that they played the mathematics games?

To answer the first four questions, paired-samples *t* tests were conducted to compare gain scores of experimental versus control groups from pretest to posttest for benchmark exams

(Benchmark1 and Benchmark2), game mathematics preparation (GameMath1 and Gamemath2), and four subscales of motivation survey (Attention1 and Attention1, Relevance1 and Relevance2, Confidence1 and Confidence2, Satisfaction1 and Satisfaction2) (see Table 25).

Table 25

The Comparison of the Gain Scores of Experimental and Control Group

| | | Paired Differences | | *t* | *df* | *p* |
|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | | | |
| Experimental | Benchmark1 - Benchmark2 | -8.07 | 17.91 | -4.87 | 116 | < .001 |
| Control | Benchmark1 - Benchmark2 | -3.74 | 13.83 | -2.36 | 75 | .02 |
| Experimental | GameMath1 - GameMath2 | 2.94 | 10.03 | 3.17 | 116 | < .001 |
| Control | GameMath1 - GameMath2 | -3.07 | 5.77 | -4.63 | 75 | < .001 |
| Experimental | Attention1 - Attention2 | 0.18 | 4.77 | 0.41 | 116 | .68 |
| Control | Attention1 - Attention2 | -0.58 | 4.13 | -1.22 | 75 | .23 |
| Experimental | Relevance1 - Relevance2 | 0.82 | 3.74 | 2.38 | 116 | .02 |
| Control | Relevance1 - Relevance2 | 0.42 | 4.21 | 0.87 | 75 | .39 |
| Experimental | Confidence1 - Confidence2 | 0.85 | 4.05 | 2.28 | 116 | .02 |
| Control | Confidence1 - Confidence2 | -0.09 | 4.75 | -0.17 | 75 | .87 |
| Experimental | Satisfaction1 - Satisfaction2 | 0.53 | 4.38 | 1.31 | 116 | .19 |
| Control | Satisfaction1 - Satisfaction2 | -0.29 | 4.75 | -0.53 | 75 | .60 |

Table 25 shows the participants in both experimental, $t$ (116) = - 4.87, $p < .05$, and control, $t$ (75) = - 2.36, $p < .05$, groups achieved significant gains from pretests to posttests in the district benchmark exams. The experimental group reported a greater gain in the benchmark exams as the mean difference between pretest and posttest of experimental group is 8.07 as compared to the mean difference of 3.74 for the control group. For the game mathematics tests, the experimental group reported dropped of mean scores of 2.94 from pretests to posttests, $t$ (116) = 3.17, $p < .05$, while control group gained mean scores of 3.07 from pretest to posttests, $t$ (99) = - 4.63, $p < .05$.

In addition, Table 25 shows that for the four subscales of motivation including attention, relevance, confidence, and satisfaction, there was no significant change in attention of experimental, $t$ (116) = 0.41, $p$ > .05, and control group, $t$ (75) = -1.22, $p$ > .05 or satisfaction of experimental $t$ (116) = 1.31, $p$ > .05 and control group $t$ (75) = - 0.53, $p$ > .05. Furthermore, there was no significant differences between the pretest and posttest scores of the control group on relevance $t$ (75) = 0.87, $p$ > .05 and confidence $t$ (75) = - 0.17, $p$ > .05. But there were significant difference between pretests and posttest of experimental group in relevance, $t$ (116) = 2.38, $p$ < .05, with 0.82 reduction in the mean and confidence, $t$ (116) = 2.28, $p$ < .05, with 0.85 mean reduction.

To answer the fifth and sixth post hoc question related to the game-use time/location, achievement and motivation, three analyses of variance (ANOVA) tests were conducted in which game-use was an independent variable with six levels. The control groups were categorized as zero and the experimental groups were categorized from 1 with the lowest level of game-use time to 6 with highest game-use time. The game-use time/location was reported by the teachers. In the first ANOVA test, achievement measured by game performance posttest was considered as dependent variable. In the second ANOVA test, achievement measured by benchmark posttest was considered as dependent variable. In the third ANOVA test motivation measured by motivation post-survey was considered as dependent variable.

The result of the first ANOVA test indicated no significant differences in game performance scores based on game time/location. For the benchmark posttest, as depicted in Table 26, the experimental participants who played the games often in the school computer lab and class ($M$ = 52.38, $SD$ = 19.76) scored significantly higher than the ones who played the games only three times in total in the school lab ($M$ = 41.47, $SD$ = 13.68). The results of the second ANOVA test shown in Table 27 indicated that game-use time/location had a significant effect on the benchmark posttest scores, $F$ (5,186) = 5.61, $p < .05$. The game-use time/location accounted for 13% of the variance in score ($\eta^2 = 0.13$).

Table 26

The Descriptive Statistics on Benchmark Posttest (Benchmark2)

| Gameuse | Mean | Std. Deviation | n |
|---|---|---|---|
| No Game Use | 32.00 | 13.66 | 76 |
| LateNov_Dec,3 Times- 60min,Lab | 41.47 | 13.68 | 30 |
| LateNov-Dec,4 Times-30-40 min, Lab,Special Education | 32.00 | 7.16 | 6 |
| LateSep-Dec,Once a week, 30-40min, Lab | 37.25 | 18.86 | 16 |
| MidSep-Dec, Once a week, 30-40Min, Lab | 50.36 | 16.85 | 44 |
| Oct-Dec, Once a week 30-40Min, Lab And Class | 52.38 | 19.76 | 21 |
| Total | 40.31 | 17.435 | 193 |

Table 27

The Results of Tests of Between-Subjects Effects on Benchmark Posttest (Benchmark2)

| Source | df | F | $\eta^2$ | $p$ |
|---|---|---|---|---|
| Gameuse | 5 | 5.604 | .131 | < .001 |
| Error | 186 | | | |

The estimated marginal means of the benchmark posttest score (Benchmark2) based on the amount of the game-playing time and location are depicted in Figure 8.

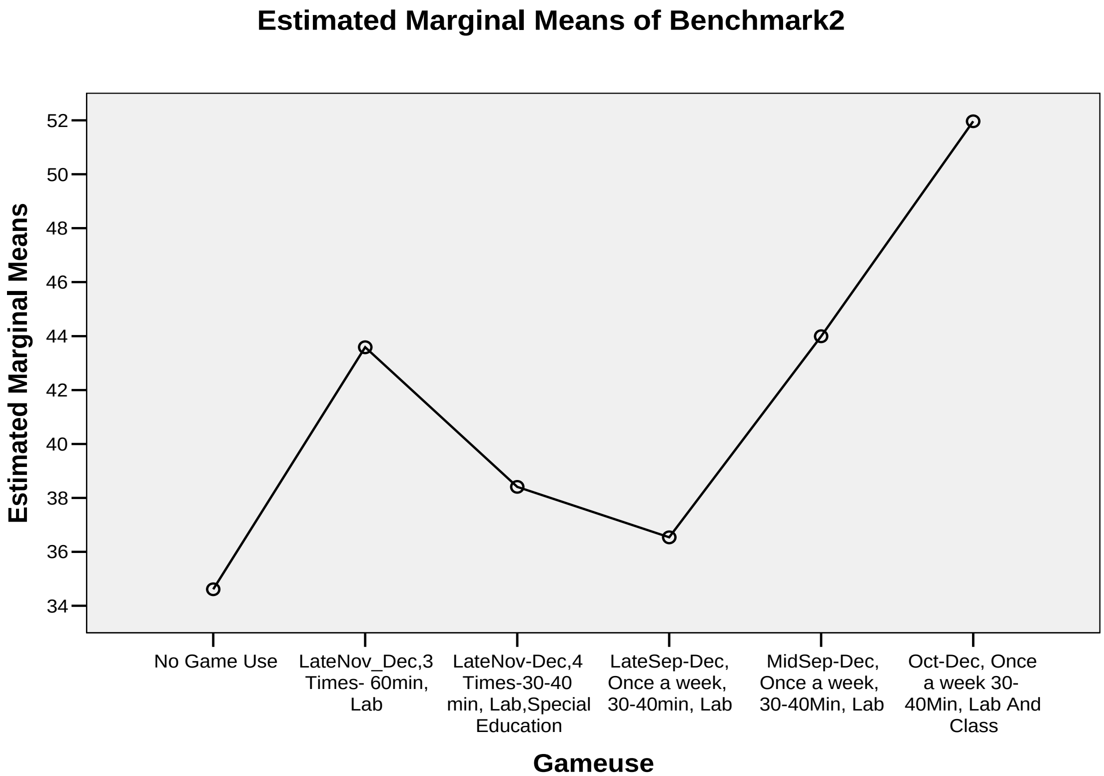



Figure 8: The Distribution of Benchmark Posttest Mean Scores Across Groups with Different Total Time and Location of Playing the Games

For motivation post-survey, as depicted in Table 28, the experimental participants who played the games often in the school computer lab and class ($M$ = 75.86, $SD$ = 14.64) scored significantly higher than the ones who played the games only three times in total in the school lab ($M$ = 62.53, $SD$ = 11.60). The results of third ANOVA shown in Table 29 indicated that game-use time/location had a significant effect on the motivation scores, $F$ (5,187) = 2.98, $p <$ .05. The game-use time/location accounted for 7% of the variance in score ($\eta^2 = 0.07$).

Table 28

The Descriptive Statistics on Motivation Post-survey (Motivation2)

| Game Use | Mean | Std. Deviation | n |
|---|---|---|---|
| No Game Use | 68.53 | 11.38 | 76 |
| LateNov_Dec,3 Times- 60min,Lab | 62.53 | 11.60 | 30 |
| LateNov-Dec,4 Times-30-40 min, Lab, Special Education | 68.33 | 10.91 | 6 |
| Late Sep-Dec, Once a week, 30-40min, Lab | 68.25 | 10.73 | 16 |
| Mid Sep-Dec, Once a week, 30-40Min, Lab | 68.36 | 13.13 | 44 |
| Oct-Dec, Once a week 30-40Min, Lab And Class | 75.86 | 14.64 | 21 |
| Total | 68.33 | 12.46 | 193 |

Table 29

The Results of Tests of Between-Subjects Effects on Motivation Post-survey (Motivation2)

| Source | *df* | *F* | $\eta^2$ | *p* |
|---|---|---|---|---|
| Game use | 5.00 | 2.98 | 0.074 | 0.01 |
| Error | 187.00 | | | |

The estimated marginal means of the motivation post-survey (Motivation2) score based on the amount of the game-playing time and location are depicted in Figure 9.

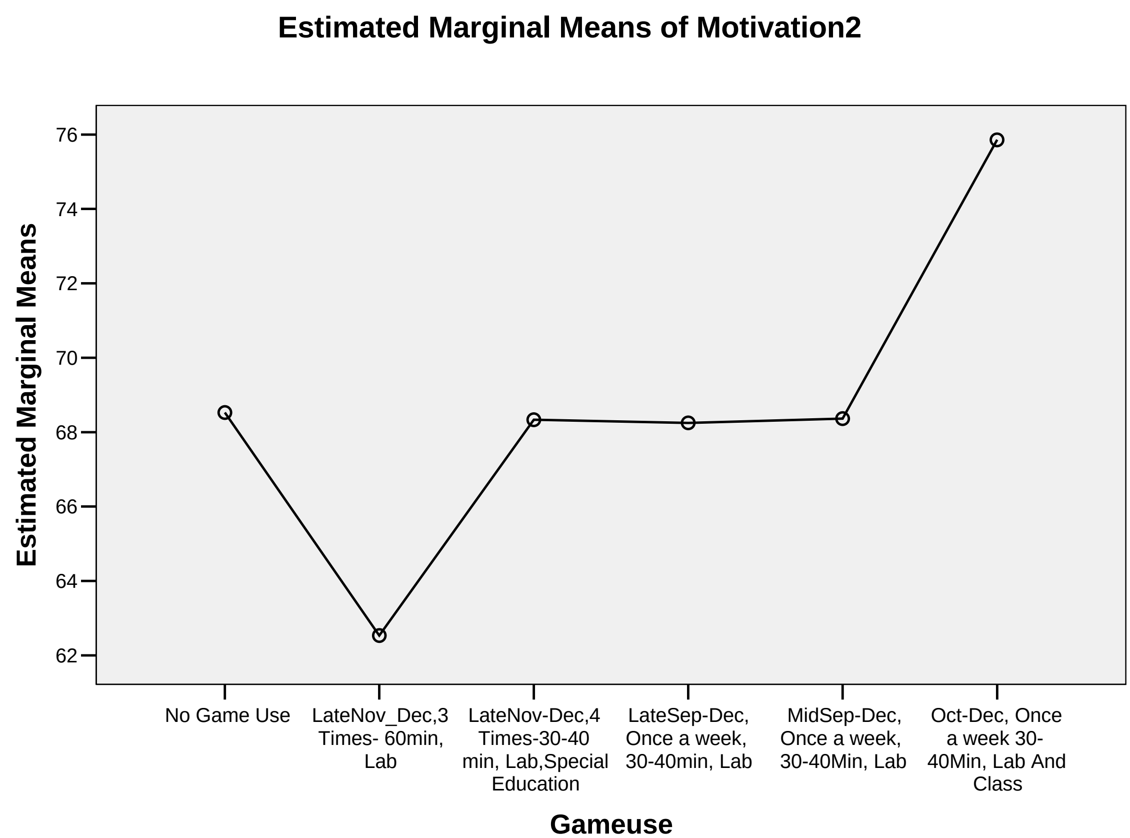



Figure 9: The Distribution of Motivation Mean Scores Across Groups with Different Total Time and Location of Playing the Games

# CHAPTER FIVE: DISCUSSION

Chapter five discusses the research findings presented in Chapter four. It is divided into three major sections (a) mathematics achievement and motivation, (b) individual differences, and (c) conclusions. The first section discusses results related to the two primary hypotheses on participants' mathematics achievement and motivation together because one Multivariate Analysis of Covariance (MANCOVA) test was run to test both hypotheses. The first section is then subdivided to discuss mathematics achievement and motivation separately along with related post hoc analyses. The second section discusses the effects of individual differences (i.e., prior mathematics knowledge, English language skill, and computer skill) on achievement and motivation of the participants when they played the games. The last section summarizes the conclusions and forwards recommendations for future research.

## Mathematics Achievement and Motivation

The first research hypothesis proposed that there is no significant difference between learners' achievement of the experimental group, who receive the pre-Algebra and/or Algebra I instructional games, versus the control group, who do not receive the games. The second hypothesis proposed that there is no significant difference between learners' motivations of the experimental group, who receive the pre-Algebra and/or Algebra I instructional games, versus the control group, who do not receive the games. To test these hypotheses, a MANCOVA test was conducted using the results of posttests on benchmark exams and the game mathematics performance tests as two dependent variables to measure the achievement and the result of the motivation post-survey as a dependent variable to measure motivation. The pretest results of benchmark exams, the game mathematics performance tests and the motivation surveys were considered as covariates to control the initial differences among the participants. The result of MANCOVA was significant, $F$ (3, 186) = 6.48, $p < .001$, Observed Power = .97, and rejected the hypotheses that population means on the dependents were the same for control and experimental groups. In other words, students who played the mathematics games scored significantly higher than students who did not play the mathematics games on mathematics achievement or motivation measures.

To further investigate the effect of playing the games on the individual dependent variables of benchmark exam, the game mathematics performance tests, and the motivation survey across control and experimental groups, test of between-the-subjects was conducted.

### *Achievement Measurements*

The results of between-the-subjects test indicated that the experimental group scored significantly higher on the benchmark exam, $F$ (1, 188) = 6.93, $p < .05$, Observed Power = .75, and the game mathematics performance test, $F$ (1, 188) = 8.37, $p <.001$, Observed Power = .82, than the control group. It appears that the mathematics games had a positive effect on mathematics achievement of the participants. These results are further examined and explained by interviews and post hoc analyses.

The majority of the interviewed teachers (4 of 5) and students (15 of 15) reported that the participants' mathematics understandings and skills improved as a result of playing the mathematics games. According to those interviewed, the effectiveness of the games was mostly related to: the combination of fun and learning, the interactive feature of the games, and experiential nature of the games. Therefore, the teachers and students' interview responses were consistent with the quantitative results.

To further explore the achievement results, three post hoc questions were proposed as follow.

1. Did participants in either the experimental or control group demonstrate significant gains in the achievement test, as measured by the district benchmark exams?
2. Did participants in either the experimental or control group demonstrate significant gains in the achievement test, as measured by the game mathematics performance test?
3. Did participants who played the mathematics games demonstrate greater gains in the achievement tests (in either or both the district benchmark exam or the game mathematics performance test) than participants who did not play the game?
4. Did participants in the experimental group report different achievement scores based on the amount of time and location that they played the mathematics games?

To answer the first three post hoc questions paired-samples *t* tests were conducted. The result of paired-samples *t* test for the first question indicated that participants in both experimental and control groups achieved significant gains from pretest to posttest on the district benchmark exams, $t\ (116) = -4.87$, $p < .05$, and $t\ (75) = -2.36$, $p < .05$, respectively. These results suggest that both groups scored significantly higher after attending the school for 18 weeks. However, the experimental group with the mean increase of 8.07 ($M_{pretest} = 37.64$, $M_{posttest} = 45.71$, of total score of 100), who played the games, reported greater gain from pretest to posttest on the benchmark exams than the control group with the mean increase of 3.74 ($M_{pretest} = 28.26$, $M_{posttest} = 32$ of total score of 100).

To test the fourth post hoc question two ANOVA tests were conducted. The test results indicated no significant differences in game performance scores based on game time/location. However, significant differences in benchmark posttest scores of experimental group based on game time/location, $F$ (5,186) = 5.61, $p < .05$, were found. The experimental participants who played the games often in the school computer lab and class scored significantly higher ($M$ = 52.38, $SD$ = 19.76) than the ones who played the games only three times in total in the school lab ($M$ = 41.47, $SD$ = 13.68). The game-use time/location accounted for 13% of the variance in score ($\eta^2 = 0.13$).

The benchmark test difficulty was generally moderate, with district-wide average percent correct ranging from 40 (Grade 9) to 48 (Grade 10) percent for pretest and from 51 (Grade 9) to 55 (Grade 10) for posttest (Princeton Review, 2008). Given the fact that the school's population were mostly low achievers (63%), the school benchmark means were in normal range, which were slightly lower than the district averages (experimental $M_{pretest} = 37.64$, $M_{posttest} = 45.71$, control $M_{pretest} = 28.26$, $M_{posttest} = 32$, of total 100 percent).

The comparison of the results of the first post hoc question and the first hypothesis on the benchmark exam indicates that experimental group had greater gain scores and showed significantly higher mean posttest scores than the control group. This comparison is more evidence to the positive effect of playing the mathematics games on the improvement of participants' achievement on the district benchmark exams.

The result of paired-samples $t$ test for the second question on the game mathematics performance test indicated that from pretests to posttests the experimental group mean decreased by 2.94 ($M_{pretest} = 27.52$, $M_{posttest} = 24.58$, of total score of 47), $t$ (116) = 3.17, $p < .05$, while the control group mean increased by 3.07 ($M_{pretest} = 18.92$, $M_{posttest} = 21.99$, of total score of 47), $t$

(99) = - 4.63, $p < .05$. Because the mean scores are low as compared to the total score, the statistically significant differences in gain or drop scores may not have practical significance. In addition, the mean gain or drop maybe explained by the timing of taking the game mathematics tests. The pretests were taken during the week three after beginning of the school when the participants were focused on learning, while the posttest were taken in a week before holiday season when the participants most likely were excited about the holiday. It is notable that although the difference in mean scores of the game mathematics performance tests and benchmark exams are statistically significant ($p < .05$), the results should be interpreted with some caution due to relatively low mean scores by both groups in the game mathematic performance test (Experimental $M_{posttest} = 24.58$, control $M_{posttest} = 21.99$ of total score of 47).

Furthermore, the comparison of the results of the second post hoc question and the first hypothesis on the game mathematics performance test shows that the experimental group had a significantly higher mean on posttests than the control group despite the fact that they had a drop of mean from pretests to posttests. While the results of the second post hoc question raises some questions, the results of the original first hypothesis and the first and third post hoc evidence seems compelling that the game playing had a positive effect on mathematics achievement.

These positive results are consistent with the prior empirical research such as those reported by Ke and Grabowski (2007), Klawe (1998), Moreno (2002), Rosas et al. (2003), and Sedighian and Sedighian (1996) indicating that using the games has improved mathematics achievement. Particularly, the results of two studies, Ke & Grabowski, (2007) and Rosas et al. (2003), with experimental design in formal schools settings are comparable with the results of the current study. Ke and Grabowski (2007) found that game-playing was more effective than drills in promoting mathematics performance of fifth grade students in the state of Pennsylvania.

They used four mathematics single-user strategy games that relied on thinking and problem solving. Rosas et al. (2003) found positive effects of a series of single-player games similar to the commercial Nintendo's Gameboy on mathematical skills of first and second grade students in Chile. The comparison of these two studies and the current study indicate that game-playing is a useful tool for promoting learning within the classrooms with students in different grades and different types of games.

The current study contributes further insights on the existing literature of the computer game effectiveness as it differs from the previous studies with regards to the type of game used as treatment, the research method and design, and the students' level. This study tested the effects of modern computer games, as described in Chapter three, with 3-D graphics, single and multiple players, and mission-based, strategy approaches. While pervious empirical studies used single player games with basic 2-D graphic. In addition, the present study used quantitative and interview data to cross validate the results of quantitative tests. Rosas et al. (2003) used quantitative tests with observation while Ke and Grabowski (2007) used only quantitative tests. The findings of this study indicated that a combination of quantitative exams and interviews provided invaluable insights on the effects of the games that could not have been discovered through quantitative tests alone. Finally, the present study focused on effects of the games on a group of high school students (N = 193) in the United States. A high school population was not previously used in the experimental studies in the context of formal school settings. Ke & Grabowski (2007) focused on middle school students (N = 125) in the United States and Rosas et al. (2003) examined elementary students (N = 1274) in Chile.

Furthermore, the results of achievement improvement of the experimental versus control groups support the conclusions of the two meta-analysis studies discussed in chapter three. In the first study, Vogel et al. (2006) based on reviewing 32 empirical studies reported that interactive simulations and games were more effective than traditional classroom instruction on learners' cognitive gains. Similarly, the results of this study indicated that the experimental group who played the games and attended the traditional classrooms achieved higher mathematics score than the control group who only attended traditional classrooms. In the second study, Dempsey et al. (1994) based on reviewing 94 empirical studies concluded that instructional games could be used in most of learning domains in Gagne's taxonomy (1985) including problem solving, cognitive strategy, and attitudes. Likewise, the results of this study indicated that the games helped the participants recall verbal information, apply concepts and rules, and develop mathematics problem solving skills.

In addition, the positive achievement results partially support the learning effectiveness of the experiential nature of the treatment activities which can be related to the experiential learning theory developed by Dewey (1938), and elaborated by Kolb (1984). Although the mathematics games did not provide authentic mathematics problems, issues and experiences as required by experiential theory, they did provide hands-on activities and simulated missions that engaged students in learning by doing and experiencing. Thus, the participants' score improvement may be attributed to the effectiveness of learning through interacting with the game missions. Further investigation may better test the effectiveness of the experiential theory with a game that is closely designed based on the experiential theory and Kolb's (1984) learning cycle.

It appears that various reasons made the mathematics games used in this study effective learning tools. The majority of the teachers and students related the positive learning effects of the games to the experiential, interactive, and hands-on nature of the game activities. In addition, positive learning effects of the games were related to some other factors including (a) the playful and entertaining aspect of the games, (b) the combination of fun and learning together, as frequent comments were received from students such as " I like playing and learning at the same time" or "I like the way that I can have fun and being able to learn at the same time", and (c) the innovative teaching and learning through the games which was different from traditional classroom settings as one of students suggested, "I like to see different ways of learning math. It helps me learn math almost as effective as my teacher". Furthermore, it was suggested that the games made students learn better in the classrooms by changing their mood, stimulating, and keeping their attentions. One of the students reported the game is effective because "it [the game] takes me out of class, changes my mood and it is entertaining". In addition, one of the teachers suggested that the games transformed students' attitude toward mathematics, removed their mathematics phobia, and showed them the relationship between mathematics and real life.

Because various reasons were suggested as the cause of effectiveness of the games and participants' personal preferences influenced their views, future investigation is warranted to further identify the cause of effect of the mathematics games on the learners' achievement.

### *Motivation Measurement*

The results of between-the-subjects test indicated that the differences of the motivation survey scores between the participants in experimental group and control were not significant, $F(1, 188) = 2.85$, $p > .05$, Observed Power = .39. This result suggests that the mathematics games did not improve the participants' motivation toward mathematics. This finding is further examined and explained by interviews and post hoc analyses.

The majority of the interviewed teachers (5 of 5) reported that the participants' motivation increased toward mathematics as a result of playing the mathematics games. In addition, the majority of the interviewed students (13 of 15) reported that they liked playing the games better than doing other schools activities such as homework, assignments, and worksheets. This result contradicts the quantitative results which indicated no game effects on the participants' motivation.

Therefore, to further explore the effects of playing the games on the participants' motivation, two post hoc questions were proposed as follow.

1. Did the participants in either the experimental or control group demonstrate significant gains in the motivation subscales of attention, relevance, confidence, and satisfaction, as measured by the motivation survey?
2. Did the participants in experimental group have different motivation scores based on the amount of time and location that they played the mathematics games?

To answer the first post hoc question, paired-samples *t* test was conducted. The results of the test indicated that the experimental group did not gain scores on motivation subscales of attention, $t\ (116) = 0.41$, $p > .05$ and satisfaction, $t\ (116) = 1.31$, $p > .05$, and their scores dropped on relevance $t\ (116) = 2.38$, $p < .05$, and confidence $t\ (116) = 2.28$, $p < .05$ subscales. The control group means did not change significantly on motivation subscales of attention, $t\ (75) = -1.22$, $p > .05$, relevance, $t\ (75) = 0.87$, $p >. 05$, confidence $t\ (75) = -0.17$, $p > .05$, and satisfaction $t\ (75) = -0.53$, $p > .05$. These results suggest that the mathematics games had no effect on the attention and satisfaction but they had a negative effect on the relevance and confidence subscales of motivation of the participants who played the games. Therefore, the negative reduction in the experimental group motivation subscales of relevance and confidence accounted for their total score reduction on the overall motivation score found in the results of the second hypothesis.

However, the drops in subscales scores do not explain why the majority of teachers and students reported greater level of motivation during interviews but not on the motivation survey.

To answer the second post hoc question related to the game use time/location and motivation, Analysis of Variance (ANOVA) was conducted. The results indicated that game use time had a significant effect on the motivation scores, $F(5,187) = 2.98$, $p < .05$. Within the experimental group, the participants who played the games for two months and half in the school lab and in their class scored significantly higher ($M = 75.86$, $SD = 14.64$) than the ones who played the games only three times in total in the school lab ($M = 62.53$, $SD = 11.60$). In addition, the participants who played the games in both the school lab and in their class had higher mean motivation ($M = 75.86$, $SD = 14.64$) than groups who played the games for the same amount of time only in the school lab ($M = 68.36$, $SD = 13.13$). These results suggest that the mathematics games improved the participants' motivations when they played the game for a long enough period of time (i.e., at least two months) in both the school lab and in their classrooms.

The results of the second post hoc question help explain the non-significant motivation differences between the control and experimental group. The participants in the experimental group associated the games to their mathematics class when they played the games in their classrooms. Otherwise, they considered playing the games as a separate activity and reported, perhaps, their motivation about their mathematics classes without game-playing. If this is true, it explains why no significant differences were found between the experimental and control mean scores on the motivation surveys.

The possibility that the participants reported their motivation toward mathematics classes separate from game-playing can help explain the negative effects of the games on relevance and confidence subscales as revealed by the first post hoc question. One potential explanation is that the students, who played the games, probably compared learning mathematics in two distinct ways (traditional classroom and interactive game settings). As a result they reported that the learning mathematics in the classroom setting was less related to their personal needs and decreased their confidence as compared to the learning mathematics in the game settings. Meanwhile, the control group who did not play the games did not report any motivation changes toward their mathematics classes.

Another potential explanation for the mixed motivation results is that although the motivation survey was designed based on the ARCS motivation model (Keller, 1987a), the mathematics games used in this study were not designed based on the ARCS model to systematically address the four components of attention, relevance, confidence, and satisfaction. Therefore, no significant results were measured by the motivation survey as there was little or no correspondence between the game effects and the measured items in the motivation survey.

Finally, an alternative plausible explanation for the non-significant motivation results is the presence of Hawthorn’s effect, which has also been observed by previous experimental study conducted by Rosas et al. (2003). Hawthorn’s effect refers to the fact that behaviors may be altered when people know they are being studied. In Rosas et al. (2003) study, the effects of the games on students’ learning and motivation were examined on three groups: an experimental group, an internal control group who were in the same school, and an external control group who were in another school but in the same achievement level. Rosas et al. (2003) found non-significant difference on the achievement of experimental versus internal control group but significant difference on the achievement of experimental versus external control group. They concluded that the internal control group teachers were aware of the study and they made special efforts to accomplish an adequate performance of their students. Similarly, it can be concluded that the control group teachers in this study tried to make their students more interested in mathematics as they were aware of the experiment, therefore, no significant difference between motivation of experimental versus control group were found in the motivation survey.

Although three meta-analyses conducted by Hays (2005), Mitchell and Savill-Smith (2004), and Randel et al. (1992) reported mixed or non-significant effects of the games on learning, no meta-analysis or empirical study was identified that reported non-significant effect of the games on motivation. The empirical studies conducted by Klawe (1998), Lopez-Moreto and Lopez (2007), Rosas et al. (2003), and Sedighian and Sedighian (1996) found positive effect of the games on motivation. These positive results are supported by teachers and students' interviews but contradicted by the motivation survey results.

Such contradicting results necessitate further investigation, controlling for three variables to achieve consistent results. First, the games should be used in the classrooms so that the students consider the games as part of their mathematics classes. Second, the games and the motivation survey should be designed based on the same motivation theory so that the survey measurements will be correlated to the components offered in the game environment. For example, if the survey is designed based on the ARCS model to measure the effects of the game on attention, relevance, confidence, and satisfaction, the games should address these four components to properly stimulate the participants' motivation. Third, Hawthorn's effect should be controlled so that the possible altered behavior of the control group will not affect the experimental results. Such study can be conducted by examining the motivation of experimental group versus external control group who are not aware of using games as treatment in the experimental study.

## Individual Differences

The third research hypothesis proposed that there is no significant difference between effects of the games on students with differences in (a) prior mathematics knowledge, (b) computer skills, and (c) English language skills. To test this hypothesis, MANCOVA was conducted. The results indicated no significant differences on achievement and motivation of control group versus experimental with different prior mathematics knowledge, computer skills, and English language skills, $F$ (3, 94) = 0.86, $p > .05$, Observed Power = .48. In other words, prior mathematics knowledge, computer skills and English language skills did not affect achievement and motivation scores of students who played the games versus the ones who did not play the games. The findings are further examined and explained by interview analyses.

The interviewed teachers and students had consistent views on the impact of prior mathematics knowledge but different views on the impacts of English language skills and computer skills on mathematics achievement and motivation of the participants when they played the games. The majority of teachers (4 of 5) and students (13 of 15) reported prior mathematics knowledge played important role on achievement and motivation. The majority of teachers (4 of 5) but less than half of students (6 of 15) believed on effects of English language skills on achievement and motivation. Less than half of the teachers (2 of 5) but the majority of students (10 of 15) reported important effects of computer skills on students' achievement and motivation. These mixed results are partially consistent with the quantitative results which indicated that the three individual differences did not have significant effect on the students' achievement and motivation when they played the games.

The teachers' further explanations on their interviews revealed that they helped students who did not have required levels of prior mathematics knowledge, English language skills, and computer skills to gain the skills and play the games. Therefore, such differences were not detected in the achievement and motivation tests taken at the end of the 18-weeks semester because by the time the students took the tests they had already overcome with their difficulties and gained required skills to play the games. Thus, it can be concluded that the prior mathematics knowledge, English language skills, and computer skills played a temporary role on the student achievement and motivation when they played the games. The effect of these individual differences decreased and eventually disappeared as the players gained required game playing skills.

Parts of the interview results support the pervious empirical studies conducted by Lopez-Moreto and Lopez (2007), Moreno (2002), and Moreno and Duran (2004) who found significant impact of computer skills, prior mathematics knowledge and language background on students' achievement and motivation when they played the games. The students' views on importance of the computer skills support Lopez-Moreto and Lopez's (2007) findings who reported that participants with low computer skills were less motivated in playing computer games. Both teachers and students' responses on importance of prior mathematics knowledge support Moreno's (2002) results. The study reported that students with low prior knowledge and computer skills were helped most by the visual representations in the gaming situation. Finally, teachers' views on importance of English language skills on mathematics achievement support Moreno and Duran's (2004) study who found students preferred to follow the mathematics instruction in their native language.

However, the quantitative results in this study that indicated no significant impact of individual differences on achievement and motivation do not support the findings of the aforementioned studies.

In addition, the individual differences results partially support the role of prior knowledge, computer skills, and English language skills on achievement based on Dewey (1938) and Kolb's (1984) experiential theory and Keller's (1987a) ARCS model. According to the Kolb's learning cycle, individuals with different abilities have different concrete experiences. Different concrete experiences affect the learning process and consequently the achievement of learners. Furthermore, based on ARCS model, these differences were supposed to affect the learners' relevance and confidence subscales in ARCS model. In this study, the learners with different mathematics achievement levels, computer skills, and English language skills had different experiences in completing the game missions but these differences diminished as they played the games. This is an interesting discovery deserving further investigation. A possible future study can be conducted in different stages of playing the games to test the trend of impact of these individual differences on the achievement and motivation of the learners when they play the games.

## Conclusion

The purpose of this study was to examine the effects of a series of mathematics computer games on mathematics achievement and motivation of high school students. In addition, the role of prior mathematics knowledge, computer skills, and English language skills of the participants on their mathematics achievement and motivation when they played the games were investigated. The total of 598 students and 10 teachers from an urban high school in the southeast of the United States of America were asked to participate in this study. Due to the lack of consent and missing data, the scores of 193 participants were used to test the research hypotheses. The study applied an experimental design with additional qualitative information gathered for further investigation and helped to explain results. The data were collected through the school district benchmark exams, the game mathematics performance tests, and the motivation surveys. The test of MANCOVA was conducted to analyze the data. In addition, interviews were conducted to cross validate the results of the quantitative data.

The results indicated significant improvement of the mathematics achievement of the participants who played the games as compared to the ones who did not play the game. However, the results should be interpreted with some caution due to relatively low mean scores by both groups in the game mathematic performance test and benchmark exams. A number of reasons for positive learning effects of the games were reported by the participated teachers and students. According to the teachers, the games were effective teaching and learning tools because (a) they had an experiential nature, (b) they were an alternative way of teaching and learning, (c) they gave the students reasons to learn mathematics to solve the game problems and progress in the games, (d) the games transformed students' mathematics phobia and showed them the relationship between mathematics and real life, and (e) the game provided an environment through which students played with mathematical concepts and therefore the concepts stayed longer with them. According to the students, the games were effective because they (a) combined learning and fun together, (b) offered mathematics in adventurous and exploration context, and (c) challenged students to learn mathematics. The overall results indicated that the mathematics games used in this study were effective teaching and learning tools to improve the mathematics skills of the students. Using the games in mathematics education was suggested by the teachers as an appropriate alternative way of teaching. As one of the teachers stated: "This is definitely the way that we have to go to teach mathematics in the future."

No significant improvement was found in the motivation of the participants who played the games as compared to the ones who did not play the games. The non-significant difference in reported mathematics class motivation is primarily attributed to the fact that students may have disassociated game-playing from their mathematics class. The motivation survey only referred to mathematics class, not the integration of game-playing and classes. Such conclusion was made for two reasons. First, the teachers and students reported in their interviews that the games improved the participants' motivation toward mathematics. Second, it was found that there was significant improvement on the motivation scores of the students who played the games in their school lab and classrooms as compared to the ones who played the games only in the school labs. These results suggest that mathematics games should be integrated with classroom activities if teachers want to increase mathematics class motivation.

In addition, the findings indicated that prior mathematics knowledge, computer skills, and English language skills did not play a significant role in achievement and motivation of the participants who played the games. However, the teachers' interviews revealed that these individual differences had indeed played significant roles in game-playing at the beginning of using the games but the impacts seemed to gradually diminish as the students gained the required skills. Evidently, the teachers' help and support is vital in using the games effectively in a population with different prior mathematics knowledge, computer skills, and English language skills.

Furthermore, a number of important issues regarding designing and using the games in school settings emerged from the teachers and students' interviews that deserve the attention of educators, instructional designers, and game designers. To use the games effectively in school setting: (a) a comprehensive training program should be offered for students and teachers to teach them how to play the games before using them in the school settings, (b) the logistical issues including providing more time and available computers for students to play the games should be addressed, (c) the school and district administrators should be educated about using the mathematics games in teaching mathematics so that they consider playing the games as an effective way of using the class time (According to some teachers in this study, a number of administrators did not consider playing the games an effective way of using the class time), (d) mathematics topics taught by the games should be correlated to the school district benchmarks and the sequence of the topics should be sorted based on the district order of topics, (e) the games should be designed in a way that students cannot progress in the games without solving mathematics problems so that the students focus primarily on learning mathematics not playing the games, (f) the games should provide clear game objective and guidance to help students play the games, (g) the extra game activities should not distract the game players from mathematics learning, and (h) the game should allow the players save their progressive activities so that the players will be able to continue their play each time that start the game.

It is notable that the Observed Powers of the statistics tests should be considered in interpreting the results. The results of the tests with Observed Powers lower than .8 should be interpreted with some caution. The effects of the games on combined mathematics achievement and motivation had strong Observed Power of .97. However, effect of the games on the individual achievement and motivation measurements had different Observed Powers. The game performance test had Observed Power = .82, Benchmark exam had Observed Power = .75, and motivation had Observed Power = .39. In addition, the Observed Power for the effects of the games on mathematics achievement and motivation of the learners with individual differences was .48.

This study sheds light on effectiveness of a series of 3-D single and multiple player mathematics computer games on an urban high school students who were mostly Hispanic (73%), low achievers (63%), fluent in English (68%), and proficient in computer skill (64%). Generalization of the results is limited to the situations with similar games and population. The learning effectiveness of educational computer games have been subject of discussion and debate by a number of scholars such as Hays (2005), Mitchell and Savill-Smith (2004), and Randel et al. (1992). The results of the current study may help educators and instructional designers to reach better conclusions on the effectiveness of educational computer games.

To further explore the effect of mathematics computer games on student learning and motivation, the following issues should be considered. First, it is helpful to examine the effects of the same or similar games used in this study with different population. Second, various findings for the effectiveness of the games in this study, justify further investigation to better identify the cause of the game effects on achievement and motivation. Third, the mixed results on motivation in this study necessitate further investigation on effects of the games on motivation. To ensure achieving reliable results (a) both computer games and motivation survey should be designed based on the same motivation theory, (b) the games should be integrated into classroom activities, and (c) external control group should be used to control Hawthorn’s effects. Fourth, a possible future study can be conducted in different stages of playing the computer games to test the trend of impact of the individual differences of prior knowledge, computer skill, and English language skill on participants’ achievement and motivation.

# APPENDIX A: INSTRUMENTS

This appendix includes the following sections:

- Demographic Survey (Administrated in the pre-tests)
- Motivation Survey (Administrated in both pre-tests and post-tests)
- Game Preparation and Performance Test #1 (Administrated in the pre-tests)
- Game Preparation and Performance Test #2 (Administrated in the post-tests)
- Interview Protocol and Questions

## Demographic Survey

*Please fill in the appropriate circle on the* ***BACK*** *of the SCANTRON,* ***starting with #51***

**51. Are you male or female?**
A. Male
B. Female

**52. What is your ethnicity?**
A. Caucasian
B. African American
C. Hispanic
D. Asian
E. Other

**53. Approximately how often do you play *entertaining* video games each week?**
A. Every day
B. 3-5 times per week
C. 1-2 times per week
D. Not very often
E. Not at all

**Approximately how much of each of the following games have you played?**

| | All of it | Most of it | Some of it | Very little | Have not played |
|---|---|---|---|---|---|
| **54. Evolver (Single Player Pre-Algebra Game)** | A | B | C | D | E |
| **55. Dimenxian (Single Player Algebra Game)** | A | B | C | D | E |
| **56. Swarm (Multi-Player Game)** | A | B | C | D | E |
| **57. Obstacle Course (Multi-Player Game)** | A | B | C | D | E |
| **58. Meltdown (Multi-Player Game)** | A | B | C | D | E |

**59. Do you have a computer connected to the Internet at home?**

A. Yes
B. No

**60. Approximately how often do you use the computer to do school work at home?**

A. Every day
B. 4-6 times per week
C. 1-3 times per week
D. Not very often
E. Not at all

**61. How would you rate your computer skills (NOT considering game playing skills)?**

A. Awesome, power user
B. Proficient, regular user
C. Novice, infrequent user
D. Beginning, just started user
E. Non-user

# Course Motivation Survey (CMS)

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# Course Motivation Survey (CMS)

Instructions

1. There are 20 statements in this questionnaire. Please think about each statement in relation to the mathematics class that you are about to participate in and indicate how true the statements are using the scale provided after each statement. Give the answer that truly applies to you and not what you would like to be true, or what you think others want to hear.

2. Think about each statement by itself and indicate how true it is. Do not be influenced by your answers to other statements.

3. Circle the number that best indicates your response, and follow any additional instructions that may be provided in regard to the answer sheet that is being used with this survey. Be sure to circle a number. DO NOT circle any space between the numbers.

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

## Course Motivation Survey (CMS)

Name: ______________________________ Teacher: ____________________________ Class: _________________

Please remember to circle a number. DO NOT circle any space between numbers.

1. I think this mathematics class will be challenging, but neither too easy, nor too hard for me.

1--------------------2--------------------3--------------------4--------------------5
Not true Slightly true Moderately true Mostly true Very true

2. There is something interesting about this mathematics class that will capture my attention.

1--------------------2--------------------3--------------------4--------------------5
Not true Slightly true Moderately true Mostly true Very true

3. This mathematics class seems more difficult than I would like for it to be.

1--------------------2--------------------3--------------------4--------------------5
Not true Slightly true Moderately true Mostly true Very true

4. I believe that completing this mathematics class will give me a feeling of satisfaction.

1--------------------2--------------------3--------------------4--------------------5
Not true Slightly true Moderately true Mostly true Very true

5. It is clear to me how this mathematics class is related to things I already know.

1--------------------2--------------------3--------------------4--------------------5
Not true Slightly true Moderately true Mostly true Very true

6. I believe this mathematics class will gain and sustain my interest.

1--------------------2--------------------3--------------------4--------------------5
Not true Slightly true Moderately true Mostly true Very true

7. I believe that the information contained in this mathematics class will be important to me.

1--------------------2--------------------3--------------------4--------------------5
Not true Slightly true Moderately true Mostly true Very true

8. As I learn more about this mathematics class, I am confident that I could learn the content.

1--------------------2--------------------3--------------------4--------------------5
Not true Slightly true Moderately true Mostly true Very true

9. I believe that I will enjoy this mathematics class so much that I would like to know more about this topic.

1--------------------2--------------------3--------------------4--------------------5
Not true Slightly true Moderately true Mostly true Very true

10. The mathematics class seems dry and unappealing.

1--------------------2--------------------3--------------------4--------------------5

Not true Slightly true Moderately true Mostly true Very true

11. The mathematics class is relevant to my interests.

1--------------------2--------------------3--------------------4--------------------5
Not true Slightly true Moderately true Mostly true Very true

12. It is apparent to me how people use the information in this mathematics class.

1--------------------2--------------------3--------------------4--------------------5
Not true Slightly true Moderately true Mostly true Very true

13. I will really enjoy completing assignments for this mathematics class.

1--------------------2--------------------3--------------------4--------------------5
Not true Slightly true Moderately true Mostly true Very true

14. After working on this mathematics class for awhile, I believe that I will be confident in my ability to successfully complete all class assignments and requirements.

1--------------------2--------------------3--------------------4--------------------5
Not true Slightly true Moderately true Mostly true Very true

15. I think that the variety of materials, exercises, illustration, etc., will help keep my attention on this mathematics class.

1--------------------2--------------------3--------------------4--------------------5
Not true Slightly true Moderately true Mostly true Very true

16. The technology that will be used to deliver this mathematics class may be frustrating/irritating.

1--------------------2--------------------3--------------------4--------------------5
Not true Slightly true Moderately true Mostly true Very true

17. It will feel good to successfully complete this mathematics class.

1--------------------2--------------------3--------------------4--------------------5
Not true Slightly true Moderately true Mostly true Very true

18. The contents of this mathematics class does not include information that will useful to me.

1--------------------2--------------------3--------------------4--------------------5
Not true Slightly true Moderately true Mostly true Very true

19. I do NOT think that I will be able to really understand the information in this mathematics class.

1--------------------2--------------------3--------------------4--------------------5
Not true Slightly true Moderately true Mostly true Very true

20. I do not think that this course will be worth my time and effort.

1--------------------2--------------------3--------------------4--------------------5
Not true Slightly true Moderately true Mostly true Very true

# Overview of the ARCS Model

## Summary of the ARCS Model

The ARCS model, developed by Keller (1987a, 1987b), provides a systematic process for analyzing student motivation and designing motivationally effective instruction. It also helps to organize knowledge of human motivation. He argues that the plethora of constructs related to human motivation makes it difficult for practitioners to transfer theory into practice. To develop a comprehensive measure of learners' motivation, educators would have to apply a battery of tests which is not practical in most instructional situations. By synthesizing the various theories of human motivation, Keller has constructed a model, with related instruments that allow researchers and practitioners to form a comprehensive profile of learners' situational motivation.

Keller posits that theories of human motivation may be subsumed under four general categories: A--Attention, R--Relevance, C-Confidence, and S--Satisfaction. In order to motive students to learn, instruction must: (1) gain and sustain learners attention; (2) be relevant to their needs; (3) promote learners confidence in their ability to succeed; and (4) satisfy learners (e.g., results were worth time and effort). There are a number of concepts related to each major category. The following is a list of concepts related to each category, along with corresponding theories of human motivation.

**Attention** - To motivate students to learn, instruction must gain and sustain attention.

A1. Perceptual Arousal - Stimulate senses
A2. Inquiry Arousal - Stimulate curiosity
A3. Variability - Vary stimulus

*Theoretical Foundations*
- Curiosity
- Perceptual Arousal
- Inquiry Arousal

**Relevance** - To motivate students to learn, instruction must be relevant to their needs.

R1. Goal Orientation - Help students create and achieve goals
R2. Motive Matching - Address specific needs
R3. Familiarity - Relate to learners' past experiences

*Theoretical Foundations*
- Drive Theories
- Needs Hierarchy
- Need for Achievement

**Confidence** - To motivate students to learn, they must have confidence in their ability to succeed.

C1. Learning Requirements - Awareness of expectations and evaluation criteria.
C2. Success Opportunities - Opportunities to experience success.
C3 Personal Control - Link success or failure to student effort and abilities.

*Theoretical Foundations*

- Self-efficacy
- Locus of Control
- Learned Helplessness

**Satisfaction -** To motivate students to learn, learners must be satisfied that the results of instruction were worth their time and effort.

S1. Natural Consequences - Meaningful opportunities to apply learned skills
S2. Positive Consequences - Positive reinforcement
S3. Equity - Consequences perceived to be fair by all students

*Theoretical Foundations*

- Conditioning Theory
- Cognitive Evaluation Theory

**Purpose of the CMS**

The Course Motivation Survey is intended to be a situational measure of students' perceived levels of motivation toward a course. It is based on Keller's' Instructional Materials Motivation Survey (IMMS) that assess learners' motivation reaction to specific instructional materials.

The CMS and IMMS are designed in accordance with the theoretical foundation represented by the ARCS Model (Keller, 1987a, 1987b). This theory is derived from the current literature on human motivation, hence, many of the items in the CMS are similar in intent (but not in wording) to items established measures of psychological constructs such as need for achievement, locus of control, and self-efficacy, to mention three examples.

**CMS Scoring Guide**

The response scale ranges from 1 to 5. This means that the minimum score on the 20 item survey is 20, and the maximum score is 100 with a midpoint of 60. The minimums, maximums, and midpoints for each subscale are comparable because they have the same number of items.

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

There are no norms for the survey. As it is a situation specific measure, there is no expectation of a normal distribution of responses. As data become available form a variety of applications of the scales, descriptive statistical information will be published.

Scores are determined by summing the responses for each subscale and the total score. Please note that the items marked *reverse* are stated in a negative manner. The responses have to be reversed before they can be added into the response total. That is for these items, 5=1, 4=2, 3=3, 2=4, and 1=5.

Attention items

| | | |
|---|---|---|
| 2 | 10 (reverse) | 16 (reverse) |
| 6 | 15 | |

Relevance items

| | | |
|---|---|---|
| 5 | 11 | 18 (reverse) |
| 7 | 12 | |

Confidence items

| | | |
|---|---|---|
| 1 | 8 | 19 (reverse) |
| 3 (reverse) | 14 | |

Satisfaction items

| | | |
|---|---|---|
| 4 | 13 | 20 (reverse) |
| 9 | 17 | |

Game Preparation and Performance Test #1

1. Which of these is a prime number?

   A. 15
   B. 16
   C. 39
   D. 47

2. Given the values **12** and **40**, find the greatest common factor (GCF).

   A. 4
   B. 8
   C. 120
   D. 10

3. Which of these numbers is a perfect square?

   A. 11
   B. 42
   C. 63
   D. 81

4. What is the least common multiple (LCM) of **9** and **12**?

   A. 3
   B. 12
   C. 36
   D. 108

5. When the expression **12 ▪ 6** is reorganized, which of these expressions represents the Commutative Property?

   A. 8▪9
   B. 4▪3▪2▪3
   C. 6▪12
   D. 12▪2▪3

6. Given the following expression **6(3 + 9)**, which of the expressions below is an equivalent expression?

   A. (6 ▪ 3) +9
   B. 3 + (9 ▪ 6)

C. 9 + 9
D. 6(3 ) + 6(9)

7. Using the order of operations what is the first step when calculating the value of this expression **8(4 ▪ 3) − 3 + 4**?

   A. 3+4
   B. (4 ▪ 3)
   C. 8(4 ▪ 3)
   D. (4 ▪ 3) − 3

8. Which of the following fractions is the smallest?

   A. 2/6
   B. 5/10
   C. 2/18
   D. 3/12

9. How could you express **60% as a fraction**?

   A. 2/6
   B. 3/5
   C. 6/20
   D. 5/3

10. A garden is planted with **8 red rose bushes** and **10 yellow rose bushes**. What is the ratio of red rose bushes to yellow rose bushes?

    A. 8:10
    B. 10:18
    C. 10:8
    D. 8:18

11. During a marathon, participants were clocked at different points throughout the race. Here is some of the data: (hint: the equation for speed = distance / time)

| Participant | Distance (miles) | Time (minutes) |
|---|---|---|
| Smith | 5 | 45 |
| Allen | 10 | 80 |
| Jones | 18 | 180 |
| Bryant | 22 | 154 |

Which participant ran at the greatest rate finishing the race before the others?

A. Jones
B. Allen
C. Smith
D. Bryant

12. Find the product of the proportion **5:9**, when its value is increased by a **9:3** ratio.

A. 15:81
B. 81:15
C. 45:27
D. 27:45

13. The numbers **27, 10, 0, -2, -45, 13, 7** and **-11** are to be placed on a number line. Which arrangement shows these numbers ordered correctly?

A. 0, -2, 7, 10, -11, 13, 27, -45
B. -2, -11, -45, 0, 7, 10, 13, 27
C. -45, 27, 13, -11, 10, 7, -2, 0
D. -45, -11, -2, 0, 7, 10, 13, 27

14. Which two values can be added together to reach a value of **−21**?

A. -24 and -3
B. -7 and 3
C. -24 and 3
D. 24 and -3

15. Which two values multiplied together give you a value of **−63**?

A. -9 and -7
B. -56 and -7
C. -66 and -3
D. -9 and 7

16. What value for **p** makes the expression **3p ▪ 2p + p = 100** true?

A. p = 4
B. p = 8
C. p = 10
D. p = 20

17. Translate "**the product of 3 and a number decreased by 5**" into a numerical expression.

A. 3n/5

B. 3 + n/5
C. 3n − 5
D. 3 + n − 5

18. When like terms in the expression **3x + 2x − 6x** are combined, what is the result?

A. 0
B. x
C. -9x
D. -x

19. Distribute the terms correctly across the expression **6(3x + 2 – 9).**

A. 18x + 12 −3
B. 9x + 8 −15
C. 18x + 12 − 54
D. 3x. + 4 −3

20. Which of the following fractions is the largest?

A. 5/6
B. 3/4
C. 9/10
D. 3/9

21. A garden is planted with **8 red rose bushes** and **10 yellow rose bushes**. What is the ratio for the number of yellow rose bushes to the total number of bushes?

A. 18:10
B. 10:8
C. 10:18
D. 8:10

22. Which is the value of **x** in the expression **108/x = −12** true?

A. 9
B. 1/9
C. -9
D. -1/9

23. A piece of information is missing from this equation **42/x = 6/3**. Find the value of **x**.

A. x = 3
B. x = 8
C. x = 21

D. x = 7

24. When using the numbers below to create a number line, where is the zero placed?

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **-12** | **-9** | **-6** | **-3** | **3** | **6** | **9** | **12** |

A. Between -9 and -6
B. Between -6 and -3
C. Between -3 and 3
D. Between 3 and 6

25. When calculating the value of the expression.

$$\frac{\mathbf{50 + (6+4)}}{\mathbf{12}}$$

What is the second step using the order of operations?

A. (5 ▪ 10)
B. 50 + 10
C. 60/12
D. (6 + 4)

26. What is the value of the expression **108 – (x)** when **x = −13**

A. 95
B. 105
C.-95
D. 121

27. Convert the expression “**45 is 5 times some number**” into an equation.

A. 5n = 45
B. 5/n = 45
C. 5 + n = 45
D. 5/45 = n

28. Looking at the values below, find the missing number to complete the pattern.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **-49** | **-38** | | **-16** | **-5** | **6** | **17** | **28** |

A. -11
B. -27
C. -13
D. -12

29. Translate “**the quotient of a number and 2**” into a numerical expression.

A. y + 2
B. y − 2
C. y/2
D. y ▪ 2

30. Evaluate the expression **3y ▪ 7y − 6y** when **y = −2**.

A. -32
B. 96
C. 72
D. 1008

31. Find the product of the proportion **10:15**, when its value is reduced by a **2:3** ratio.

A. 30:30
B. 2:3
C. 20:45
D. 150:6

32. What is the resulting expression when the following terms are combined: **3 ▪ 2y + 15y/5**?

A. 3y
B. 9y
C. 21y/5
D. 10y

33. Would the following values from a number line fall to the right or left of the zero?

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **-256** | **-248** | **-240** | **-232** | **-224** | **-216** | **-208** | **-200** |

A. Right
B. Left
C. Impossible to determine
D. Neither

34. Given the values **a = 3, b = -7,** and **c = 4**, what is the value of the expression **−2a + 3b – 4c**?

A. −18
B. 54
C. −54
D. −43

35. Which two values can be multiplied together to reach a value of −**56**?

A. 9 and −7
B. –7 and −8
C. 9 and 7
D. −7 and 8

36. Find the missing value in the function table below.

| x | y |
|---|---|
| **6** | **13** |
| **7** | **15** |
| **8** | |
| **9** | **19** |
| **10** | **21** |

A. 16
B. 11
C. 17
D. 20

37. Using the order of operations, what is the last step when calculating the value of the expression **8/(4▪2) + 3 − 4**?

A. 8/4
B. 8+3
C. 4▪2
D. 4-4

38. What is the value of the expression **–(x) + 34** when **x = 11**?

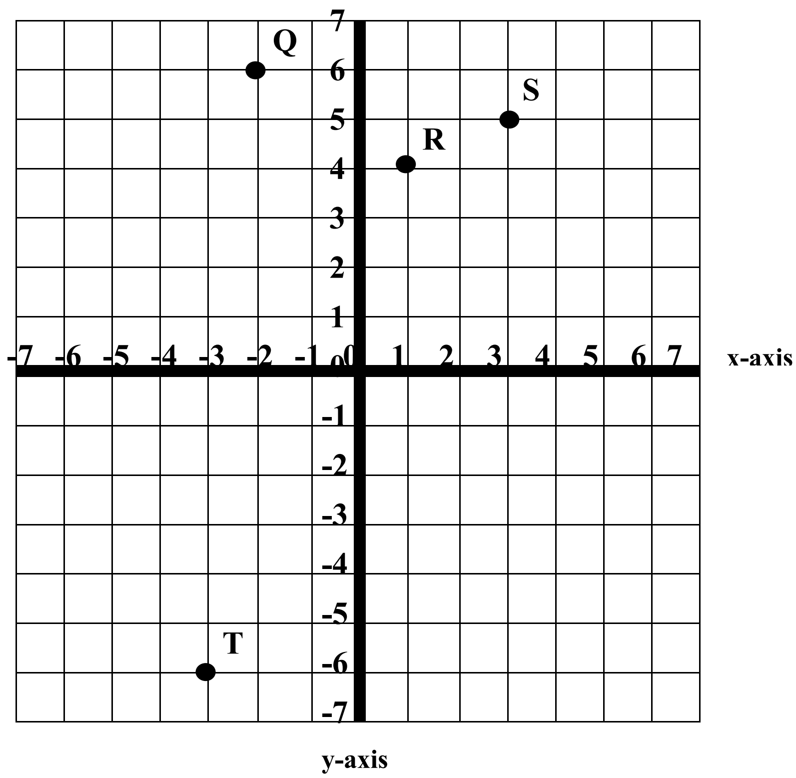
A. 45
B. 23
C. 65
D.-23

39. Given the equation **n/15 = 6**, solve for **n**.

A. n = 9
B. n = 45
C. n = 30
D. n = 90

40. Given the equation **y = 2x** which point on the graph has coordinates that fit this

equation to make it true?

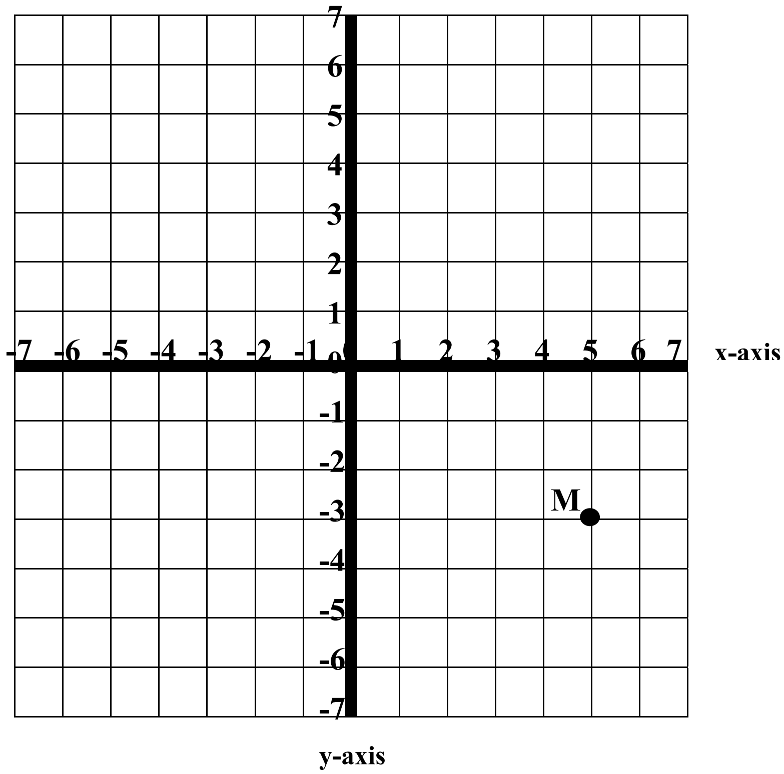



A. T
B. R
C. Q
D. S

41. Translate the expression "**the sum of 25 and 3 times some number**" into a numerical expression.

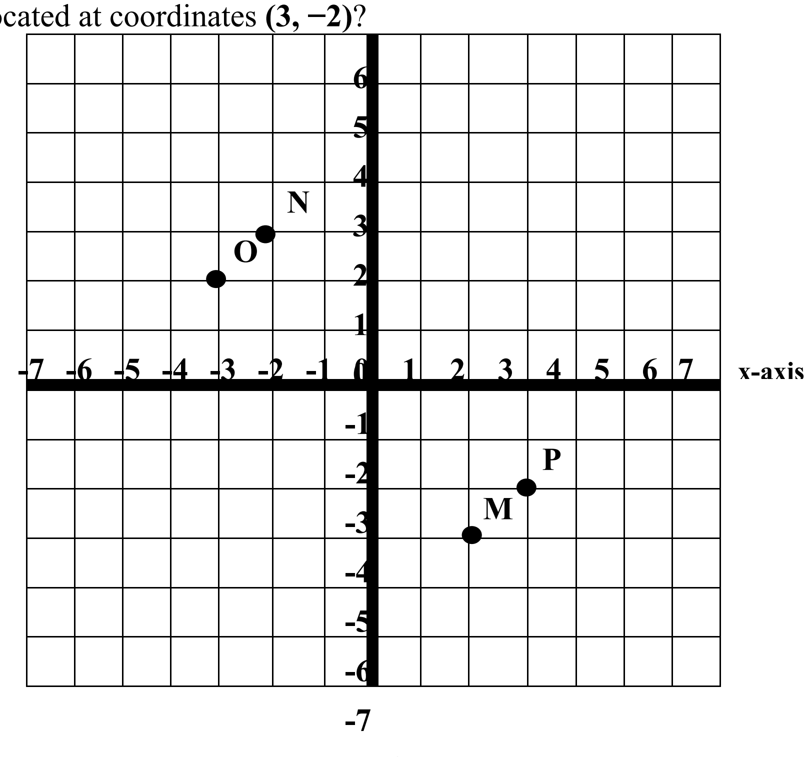
A. 25 + 3x
B. 25(3x)
C. 25 + 3 - x
D. 25/3x

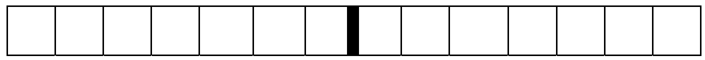
42. What are the coordinates for point **M** on the graph below?




A. (-5, -3)
B. (5, -3)
C. (3, -2)
D. (-3, 5)

43. What point is located at coordinates **(3, −2)**?





A. N
B. P
C. O
D. M

44. Solve for **y** in the equation **4y – 12 = 48**.

A. y = 3
B. y = 15
C. y = 9
D. y = 12

45. What function does this table represent?

| x | y |
|---|---|
| **1** | **5** |
| **2** | **10** |
| **3** | **15** |
| **4** | **20** |
| **5** | **25** |

A. y = x + 5
B. y = 5/x
C. y = 5x
D. y = x/2

46. Convert the expression “**twice a number divided by 3 is 8**” into an equation.

A. 2x ▪ 3 = 8
B. 2x/3 = 8
C. 2x ▪ 8 = 3
D. 2 ▪ 3/x = 8

47. Look at the pattern below:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **-11** | **-8** | **-5** | **-2** | **1** | **4** | **7** | **10** |

Which expression best describes this pattern?
A. 3n
B. n/3
C. 3n + 1
D. n − 3

Game Preparation and Performance Test #2

**Instructions**

- Enter your 7 digit code under the label "ID Number" on the scantron: __ __ __ __ __ __ __ __
- Fill-in the appropriate circle for all math answers on the scantron using a No. #2 pencil.

1. When the expression **24 ▪ 7** is rewritten, which of these expressions represents the Commutative Property?

   A. 2 ▪ 84
   B. 2 ▪ 2 ▪ 2 ▪ 3 ▪ 7
   C. 7 ▪ 24
   D. 7 ▪ 2 ▪ 3 ▪ 2 ▪ 2

2. Which of these is a prime number?

   A. 17
   B. 18
   C. 39
   D. 45

3. Given the values **15** and **30**, find the greatest common factor (GCF).

   A. 5
   B. 10
   C. 15
   D. 30

4. Convert the expression "**half a number plus 4 is 10**" into an equation.

   A. x/2 + 4 = 10
   B. 2x + 4 = 10
   C. 4x + 2 = 10
   D. 4/x + 4 = 10

5. What is the least common multiple (LCM) of **5** and **8**?

   A. 20
   B. 40
   C. 45
   D. 80

6. Look at the pattern below:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **-18** | **-12** | **-6** | **0** | **6** | **12** | **18** | **24** |

Reading from left to right, which expression best describes this pattern?

A. n + 6
B. n/6
C. n ▪ 6
D. None of the above

7. Find the equivalent value of the proportion **20:24**.

A. 10:12
B. 10:8
C. 8:10
D. 40:72

8. Using the order of operations what is the first step when calculating the value of this expression **8 ▪ 2 − 2 + 5/2**?

A. 2 – 2
B. 2 + 5
C. 8 ▪ 2
D. 5/2

9. A class has **7 boys and 13 girls**. What is the ratio of boys to girls?

A. 7:13
B. 7:20
C. 13:20
D. 20:20

10. When calculating the value of the expression:

$$\frac{\mathbf{12 + (8 - 4)}}{\mathbf{3}}$$

What is the second step using the order of operations?

A. 12/3
B. 4/3
C. 12 + 4
D. 8 – 4

11. Find the missing value in the function table below.

| x | y |
|---|---|
| **4** | **7** |
| **6** | **11** |
| **8** | **15** |
| **10** | |
| **12** | **23** |

A. 18
B. 19
C. 20
D. 21

12. Given the following expression **9(22 + 4)**, which of the expressions below is an equivalent expression?

A. (11 ▪ 2) + 9
B. 9 + (22 ▪ 4)
C. 9 + 22 + 9 + 4
D. 9(22) + 9(4)

13. During a car race, cars were clocked at different points throughout the race. Here is some of the data: (hint: the equation for speed = distance / time)

| Participant | Distance (miles) | Time (minutes) |
|---|---|---|
| Car 43 | 120 | 6 |
| Car 52 | 147 | 7 |
| Car 8 | 132 | 6 |
| Car 17 | 180 | 15 |

Which car ran the fastest when it was timed?

A. Car 8
B. Car 17
C. Car 43
D. Car 52

14. What is the resulting expression when the following terms are combined: **7 ▪ 3y - 10y/2**?

A. y
B. 5y
C. 16y
D. 21y

15. The numbers **-17, -21, 1, -2, 14, -7 and 11** are to be placed on a number line. Which arrangement shows these numbers ordered correctly from least to greatest?

A. -17, -21, 1, -2, 14, -7, 11
B. -21, -17, -7, -2, 1, 11, 14
C. 14, 11, 1, -2, -7, -17, -21
D. -2, -7, -17, -21, 1, 11, 14

16. Looking at the values below, find the missing number to complete the pattern.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **8** | **11** | **14** | **17** | **20** | | **26** | **29** |

A. 5
B. 23
C. 25
D. 32

17. Which of the following fractions is the largest?

A. 6/7
B. 3/4
C. 7/10
D. 3/12

18. Which two values can be added together to reach a value of **14**?

A. -24 and 10
B. -7 and 21
C. -10 and -4
D. -4 and 10

19. Which of these numbers is a perfect square?

A. 8
B. 15
C. 16
D. 24

20. Which two values multiplied together give you a value of **35**?

A. 7 and 5
B. -7 and 5
C. 7 and -5
D. 15 and 3

21. Translate "**the product of 4 and 7 increased by a number**" into a numerical expression.

A. n – 7 ▪ 4
B. (4 ▪ 7) + n
C. 4n – 7n
D. 7n – 4n

22. Distribute the terms across the expression **4(8x + 4 – 12)**.

A. 32x + 16 - 48
B. 2x + 1 – 3
C. 16x -16
D. x + 1 -3

23. A farm is planted with **3 acres of corn** and **7 acres of wheat**. What is the ratio for the number of acres of wheat to the number of acres of corn?

A. 3:10
B. 7:7
C. 7:10
D. 7:3

24. What value for **r** makes the expression **7r ▪ 2r + r = 129** true?

A. r = 14
B. r = 10
C. r = 8
D. r = 3

25. Which is the value of **x** in the expression **16x = −48**?

A. 8
B. -4
C. -1/3
D. -3

26. Given the values **r = -11, s = 0,** and **t = 2**, what is the value of the expression **r – 3s + 9t**?

A. -7
B. -4
C. 2
D. 7

27. What function does this table represent?

| x | y |
|---|---|
| 2 | 1 |
| 4 | 5 |
| 6 | 9 |
| 8 | 13 |
| 10 | 17 |

A. y = 3x - 5
B. y = 3x
C. y = 2x - 3
D. y = x/4

28. Given the equation **n/7 = 5**, solve for **n**.

A. n = 2
B. n = 12
C. n = 24
D. n = 35

29. Convert the expression "**4 less than a number is 18**" into an equation.

A. 4 – x = 18
B. 18 – x = 4
C. x – 4 = 18
D. 22 – x = 4

30. Looking at the values below, find the missing number to complete the pattern.

| -19 | -16 | | -10 | -7 | -4 | -1 | 2 |
|---|---|---|---|---|---|---|---|

A. -15
B. -14
C. -13
D. 5

31. A piece of information is missing from this equation **32/x = 8/2**. Find the value of **x**.

A. x = 2
B. x = 4
C. x = 8
D. x = 16

32. Translate "**the quotient of a number and 9**" into a numerical expression.

A. x/9
B. x − 9
C. x + 9
D. x ▪ 9

33. Evaluate the expression **r ▪ 4r + 2r** when **r = −3**.

A. 30
B. -21
C. -30
D. -42

34. When like terms in the expression **8x - x + 4x** are combined, what is the result?

A. -5x
B. 0
C. 11x
D. 13x

35. Would the following values on a number line fall to the right or left of the zero?

| -25 | -24 | -20 | -2 | 4 | 14 | 24 | 25 |
|---|---|---|---|---|---|---|---|

A. Right
B. Left
C. Neither
D. Both

36. Given the values **a = 7, b = -4,** and **c = -6**, what is the value of the expression **4a - 3b + 2c**?

A. 4
B. 8
C. 16
D. 28

37. Which of the following fractions is the smallest?

A. 3/8
B. 1/2
C. 1/16
D. 6/7

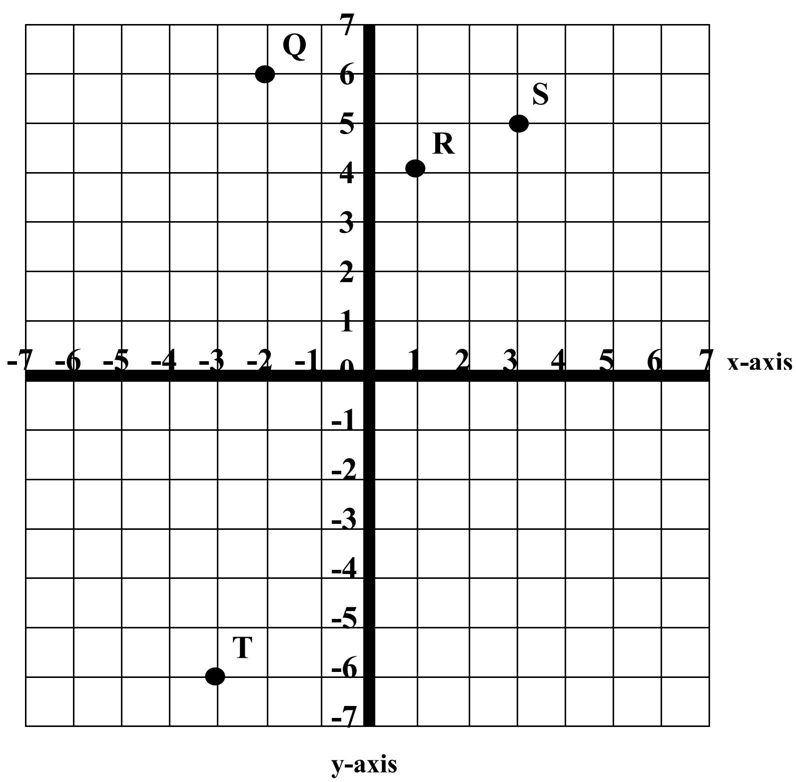
38. Given the equation **x ▪ 6 = 30**, solve for **x**.

A. x = 2
B. x = 5
C. x = 8
D. x = 24

39. Which two values can be multiplied together to reach a value of **−24**?

A. 2 and 12
B. -4 and 6
C. -4 and -6
D. -2 and -12

40. Given the equation **y = x + 2** which point on the graph has coordinates that fit this equation to make it true?

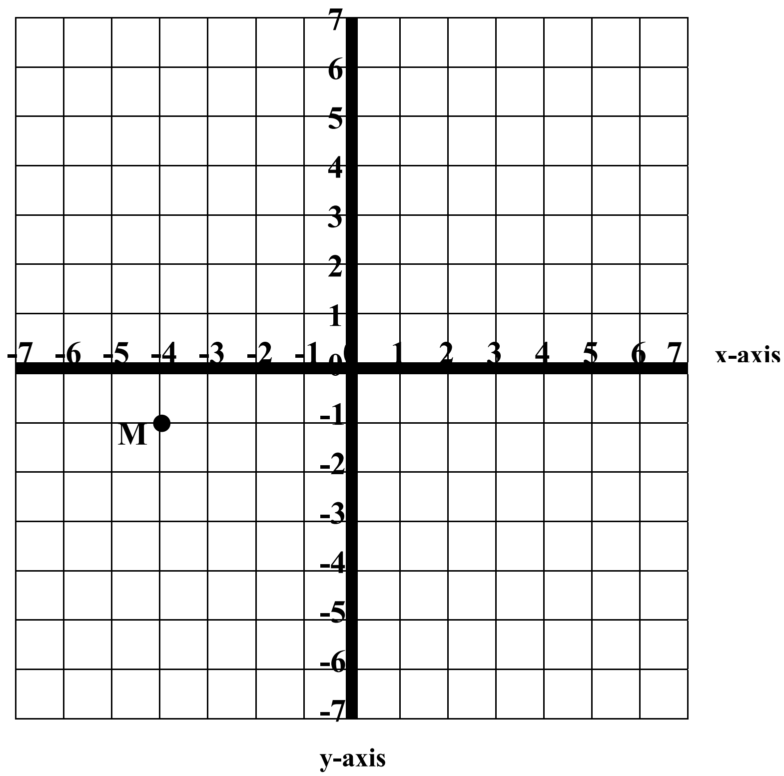


A. Q
B. R
C. S
D. T

41. What is the value of the expression **–14 + p** when **p = -7**?

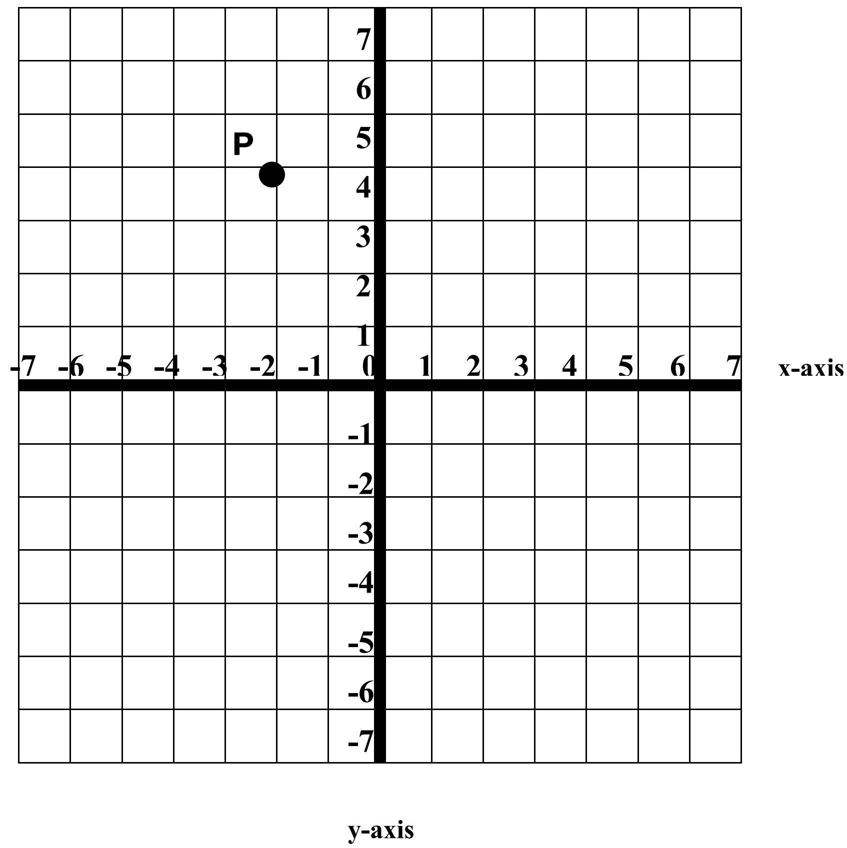
A. 7
B. 14
C. 21
D. -21

42. What are the coordinates for point **M** on the graph below?



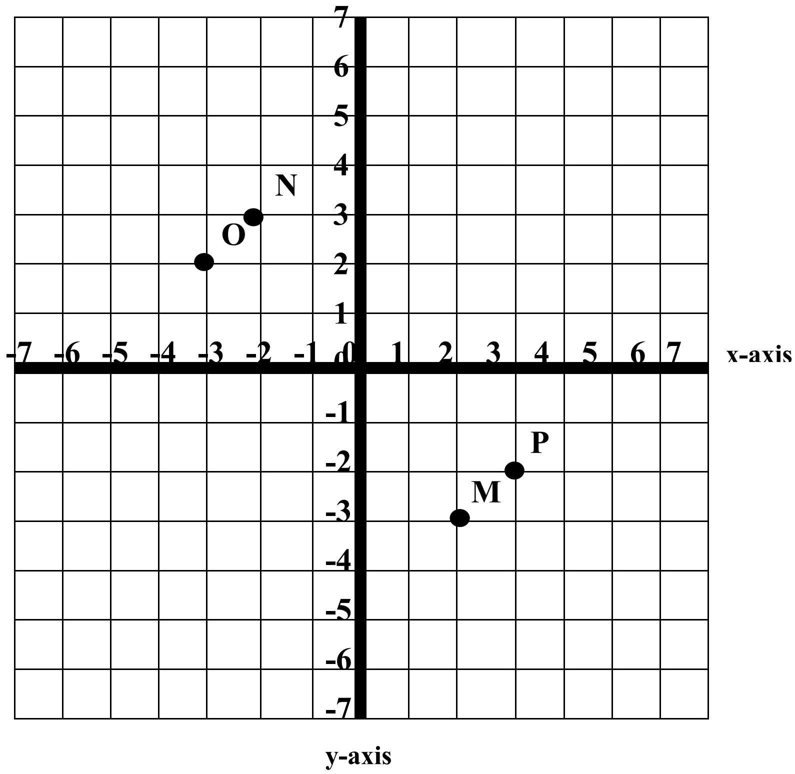

A. (-4, -1)
B. (4, 1)
C. (-4, 1)
D. (1, -4)

43. What are the coordinates for point **P** on the graph below?




A. (-4, -3)
B. (4, -2)
C. (-2, 4)
D. (3, -4)

44. What point is located at coordinates **(-2, 3)**?




A. M
B. N
C. O
D. P

45. How could you express **24% as a fraction**?

A. 24/50
B. 12/24
C. 6/25
D. 12/25

46. Solve for **y** in the equation **6y – 10 = -4**.

A. y = -2
B. y = -1
C. y = 1
D. y = 2

47. What function does this table represent?

| x | y |
|---|---|
| **2** | **7** |
| **4** | **13** |
| **6** | **19** |
| **8** | **25** |
| **10** | **31** |

A. y = 3x + 1
B. y = 3x
C. y = 2x + 3
D. y = x/2

Interview Protocol and Questions

The following information is to be used by the researcher before, during, and after the interview. The researchers follow these steps:

**Before the interview**

- Schedule interview with student during lunch period. Be sure to schedule room where there is another adult/teacher present.
- Request permission ahead of time to tape the interview.
- Assure the participant that results will be kept confidential.
- Make sure to test recording equipment, including the microphone and volume.
- Have all materials organized and ready for the interview.
- Take extra batteries or an extension cord for your recording equipment.
- Make sure to bring a recorder and tape of high quality. (60-90 minute tape)

**During the interview**

- Before beginning the formal questions, the researcher records students' name, date, and school.
- Ask the questions as written, but if the participant seems to misinterpret the question or to get "off track" with his/her response, asks probing questions to clarify his/her response.
- Try to avoid a dialogue during the interview – lets the participant do the talking.
- In conclusion, asks the participant if she/he have any questions or comments.

**After the interview**

- Write up (or verbally attach) a brief report as soon as possible after the interview. Make sure to clarify any unusual occurrences (such as an interruption in the interview), or her impressions of strange responses from the participant. (e.g., Were there any questions that he/she seemed to find offensive or threatening? Were there any questions that seemed unusually difficult to answer?).
- Supplement notes by defining any special terms or explanations used that might not be known by the other universities.
- Describe any insights that may not have registered through the audio medium, or any other unusual occurrences during the meeting.

**Interview Guide for Use by Researcher**

Interviewer initials: _______ Date: _________ Time begin:_________ Time end:______
Folder #: __________

**Introduce yourself and the purpose of the interview:**
After I introduce myself and have the recorder started, I will read the following.
"Thank you for allowing me to come in today to talk about mathematics class. The purpose of our interview is not to grade or rank you, but to look at the factors that affect you as a student learning mathematics. The interview will run about 60 minutes.
Please be assured that the information you provide will be kept in strict confidentiality. Do you have any questions before we begin?"

**Confidentiality:**
What you say will be confidential. I won't connect your name with anything you say.
Please say what you really think - it's not a test:
Please remember, there is no right or wrong answers. It's not a test.
I didn't design the game, and you won't hurt my feelings, no matter what you say about it. So please feel free to say what you think.

**Student Interview Questions**

1. Name: ____________________________ 2. Teacher: ___________________________

3. Class/Period_________________________ 4. School: _____________________________

Please think about your current mathematics class(es). Think about your teacher and how she or he teaches the class, as well as the programs and other materials you use in class.

**For students in both treatment and control groups**

5. What specific parts of your mathematics class catches and keeps your attention?
6. What specific parts of your mathematics class do you think are important/relevant to your personal life and/or interests?
7. What specific parts of your mathematics class increased your confidence to do mathematics and do well in mathematics class?
8. What specific parts of learning mathematics and of your mathematics class do you think are worth your time and effort?

9. What specific parts of your mathematics class do you think helps you learn mathematics in general, and do better on the mathematics section of the FCAT test?

10. What specific parts of your mathematics class either motivates you to learn or has a bad effect on your motivation to learn?

**For students in treatment group only**

11. Which game did YOU play and about how much of the each game did YOU play?

| | All of it | Most of it | Some of it | Very little | Did not play |
|---|---|---|---|---|---|
| O N/A (Not Applicable) | | | | | |
| Not sure which game(s), but I did play… | O | O | O | O | O |
| Evolver (Single Player Pre-Algebra Game) | O | O | O | O | O |
| Dimenxian (Single Player Algebra Game) | O | O | O | O | O |
| Swarm (Multi-Player Game) | O | O | O | O | O |
| Obstacle Course (Multi-Player Game) | O | O | O | O | O |
| Meltdown (Multi-Player Game) | O | O | O | O | O |

12. Compared to other forms of mathematics school work (e.g., worksheets, home work assignments), do you like playing the game designers' mathematics Games?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| A lot Less | Less | About the same | More | A lot More |

13. Compared to other entertaining video games, do you like playing the game designers' mathematics Games?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| A lot Less | Less | About the same | More | A lot More |

14. What did you like or dislike about the game(s)?

15. Do you feel that playing the mathematics video game(s) helped you understand mathematics concepts and increase your mathematics skills?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Not, not at all | No | Somewhat | Yes | Yes, very much |

16. Did any of the following effect your desire to play the mathematics games?

| | No effect | Little effect | Some effect | Significant effect | Great effect |
|---|---|---|---|---|---|
| Your mathematics skills | O | O | O | O | O |

| | | | | | |
|---|---|---|---|---|---|
| Your computer skills | O | O | O | O | O |
| Your English skills | O | O | O | O | O |

17. Did any of the following effect your learning from the mathematics games?

| | No effect | Little effect | Some effect | Significan t effect | Great effect |
|---|---|---|---|---|---|
| Your Mathematics skills | O | O | O | O | O |
| Your computer skills | O | O | O | O | O |
| Your English skills | O | O | O | O | O |

18. Did you play the single player AND multi-player games? If not, skip this question and go to question #11. If yes, which one did you prefer and why? Which one increased your mathematics skills more and why?

19. Was it easy for you to learn how to play the mathematics game(s)?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| No, they were very difficult to learn | No | Somewhat | Yes | Yes, they were very easy to learn |

20. What specific problems, if any, did you have in learning how to play the game?

21. What specific aspects of the game did you enjoy the most?

22. What specific aspect of the game did you dislike the most?

24. How would you improve the games?

25. Do you have any additional questions or comments?

Thank you for your time and comments!

**Teacher Interview Questions**

1. Name: ________________     2. Gender: a. Male | b. Female

3. Ethnicity: a. White | b. African American | c. Hispanic | d. Asian | e. Other _____________

4. Birthday:
   O before 1945 (Silent Generation)
   O 1945-1960 (Baby Boomers)

O 1961-1979 (Gen X)
O 1980 (Digital Natives)

5. Highest Degree and Area:
   O Associates in ___________________________
   O Bachelors in ____________________________
   O Masters in ______________________________
   O Specialization in _________________________
   O Doctorate in ____________________________

6. Math Certification
   O None
   O Temporary
   O Professional

7. Certification Level
   O N/A
   O Grades 5-9
   O Grades 6-12

8. How many years have you been teaching Math?
   O This is my first year
   O One year
   O Two-Five years
   O Six-Ten years
   O Over Ten years

9. Which math subjects do you teach and to what extent do you enjoy teaching each subject?

| | One of my favorites | | It's OK | | Really do not enjoy it |
|---|---|---|---|---|---|
| O $7^{h}$ Grade (Regular) | O | O | O | O | O |
| O $7^{h}$ Grade (Advanced) | O | O | O | O | O |
| O Pre-Algebra | O | O | O | O | O |
| O Algebra | O | O | O | O | O |
| O Algebra (Honors) | O | O | O | O | O |
| O Geometry | O | O | O | O | O |
| O Other _________________________ | O | O | O | O | O |
| O Other _________________________ | O | O | O | O | O |

10. On a scale from 1-5, How would you characterize your teaching method (circle a number)?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Directed Teacher-Centered | | | | Inquiry/Investigative Student-Centered |

11. In your opinion, what distinguishes Inquiry/Investigative Student Centered instructional methods from Directed, Teacher-Center methods?

12. Other than the Math games used in the current study, what innovative programs are you currently using in your class (if any)? How often do you use each program?

13. Approximately how often do you play video games each week?
   - O Every day
   - O 3-5 times per week
   - O 1-2 times per week
   - O Not very often
   - O Not at all

14. How would you rate your computer skills (NOT considering your video game playing skills)?
   - O Awesome, power user
   - O Proficient, regular user
   - O Novice, infrequent user
   - O Beginning, just started user
   - O Non-user

**Treatment Group**

15. Which of the following Math Games did you use with students prior to Fall 2007?
   - O None
   - O Evolver (Single Player PreAlgebra)
   - O Dimenxian (Single Player Algebra)
   - O Swarm (Multi-Player)
   - O Obstacle Course (Multi-Player)
   - O Meltdown (Multi-Player)

16. Which game did YOU play and approximately how much of the each game did YOU play?

| | Did not play | Very little | Some of it | Most of it | All of it |
|---|---|---|---|---|---|
| O N/A (Not Applicable) | | | | | |
| Not sure which game(s), but I did play… | O | O | O | O | O |
| Evolver (Single Player Pre-Algebra Game) | O | O | O | O | O |
| Dimenxian (Single Player Algebra Game) | O | O | O | O | O |
| Swarm (Multi-Player Game) | O | O | O | O | O |
| Obstacle Course (Multi-Player Game) | O | O | O | O | O |
| Meltdown (Multi-Player Game) | O | O | O | O | O |

17. Which of the following DimensionM math games did you use WITH STUDENTS?

| | Did not use | Very little of it | Some of it | Most of it | All of it |
|---|---|---|---|---|---|
| O N/A (Not Applicable) | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Evolver (Single Player Pre-Algebra Game) | O | O | O | O | O |
| Dimenxian (Single Player Algebra Game) | O | O | O | O | O |
| Swarm (Multi-Player Game) | O | O | O | O | O |
| Obstacle Course (Multi-Player Game) | O | O | O | O | O |
| Meltdown (Multi-Player Game) | O | O | O | O | O |

18. Please rate the impact of each game on student math achievement?

| | Great Negative | Some Negative | No Impact | Some Positive | Great Positive |
|---|---|---|---|---|---|
| O N/A (Not Applicable) | | | | | |
| Evolver (Single Player Pre-Algebra Game) | O | O | O | O | O |
| Dimenxian (Single Player Algebra Game) | O | O | O | O | O |
| Swarm (Multi-Player Game) | O | O | O | O | O |
| Obstacle Course (Multi-Player Game) | O | O | O | O | O |
| Meltdown (Multi-Player Game) | O | O | O | O | O |

19. Please rate the impact of each game on student motivation to learn?

| | Great Negative | Some Negative | No Impact | Some Positive | Great Positive |
|---|---|---|---|---|---|
| O N/A (Not Applicable) | | | | | |
| Evolver (Single Player Pre-Algebra Game) | O | O | O | O | O |
| Dimenxian (Single Player Algebra Game) | O | O | O | O | O |
| Swarm (Multi-Player Game) | O | O | O | O | O |
| Obstacle Course (Multi-Player Game) | O | O | O | O | O |
| Meltdown (Multi-Player Game) | O | O | O | O | O |

20. Please rate the impact of each factor on student learning from gameplay.

| | Great Negative | Some Negative | No Impact | Some Positive | Great Positive |
|---|---|---|---|---|---|
| O N/A (Not Applicable) | | | | | |
| Students' math preexisting knowledge | O | O | O | O | O |
| Students' computer skills | O | O | O | O | O |
| Students' English skills | O | O | O | O | O |

21. How often did you use each of the following DimensionM supplemental products?

| | Not at all | A few times | Some-times | Often | Very Often |
|---|---|---|---|---|---|
| O N/A (Not Applicable) | | | | | |
| Educator Portal | O | O | O | O | O |
| Online Instructional Modules | O | O | O | O | O |
| Teacher-Directed Lesson Plans | O | O | O | O | O |
| Inquiry-Based Lesson Plans | O | O | O | O | O |
| MS PowerPoints | O | O | O | O | O |
| Handouts | O | O | O | O | O |
| Quizzes | O | O | O | O | O |

22. Please rate the value of each of the following DimensionM supplemental products.

| | | | | | |
|---|---|---|---|---|---|
| | | | | Signifi | |

| | No | Little | Some | -<br>cant | Great |
|---|---|---|---|---|---|
| O N/A (Not Applicable) | | | | | |
| Teacher Portal | O | O | O | O | O |
| Online Teaching Modules | O | O | O | O | O |
| Teacher-Directed Lesson Plans | O | O | O | O | O |
| Inquiry-Based Lesson Plans | O | O | O | O | O |
| MS PowerPoints | O | O | O | O | O |
| Handouts | O | O | O | O | O |
| Quizzes | O | O | O | O | O |

23. To what degree do you believe the math games used in this study correlate to district benchmark and state FCAT exams?

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| No Correlation | Little Correlation | Some Correlation | Correlation | High Correlation |

24. What factors affect the use and integration of math games and/or other innovative programs in your class?

26. Have you witnessed any differences in game play based on gender, please explain?

27. Does one gender appear more or less comfortable with playing the math video games?

28. When you think about using DimensionM™ with students, what is your ONE greatest concern?

29. Do you believe that you could significantly improve students' math scores next year using DimensionM™ games and supplemental products? In other words, now that you've had experience using DimensionM™ games and supplemental products, do you think you can significantly improve students' math scores? Yes | No? Why or Why not?

30. What recommendations do you have for improving DimensionM™ products and services?

31. Do you have any additional questions or comments?

Thank You for Your Time and Insights. They are greatly appreciated!

# APPENDIX B: UNIVERSITY OF CENTRAL FLORIDA IRB APPROVAL LETTER

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901, 407-882-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

## Notice of Expedited Initial Review and Approval

From : **UCF Institutional Review Board**
**FWA00000351, Exp. 5/07/10, IRB00001138**

To : **Atsusi Hirumi**

Date : **August 01, 2007**

IRB Number: **SBE-07-05091**

Study Title: **The Effects of Modern Math Computer Games on Student Math Achievement, Math Anxiety and Motivation.**

Dear Researcher:

Your research protocol noted above was approved by **expedited** review by the UCF IRB Chair on 7/30/2007. **The expiration date is 7/29/2008.** Your study was determined to be minimal risk for human subjects and expeditable per federal regulations, 45 CFR 46.110. The category for which this study qualifies as expeditable research is as follows:

7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

The IRB has approved a **consent procedure which requires participants to sign consent forms.** Use of the approved, stamped consent document(s) is required. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Subjects or their representatives must receive a copy of the consent form(s).

All data, which may include signed consent form documents, must be retained in a locked file cabinet for a minimum of three years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained on a password-protected computer if electronic information is used. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

To continue this research beyond the expiration date, a Continuing Review Form must be submitted 2 – 4 weeks prior to the expiration date. Advise the IRB if you receive a subpoena for the release of this information, or if a breach of confidentiality occurs. Also report any unanticipated problems or serious adverse events (within 5 working days). Do not make changes to the protocol methodology or consent form before obtaining IRB approval. Changes can be submitted for IRB review using the Addendum/Modification Request Form. An Addendum/Modification Request Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at **http://iris.research.ucf.edu** .

**Failure to provide a continuing review report could lead to study suspension, a loss of funding and/or publication possibilities, or reporting of noncompliance to sponsors or funding agencies.** The IRB maintains the authority under 45 CFR 46.110(e) to observe or have a third party observe the consent process and the research.

On behalf of Tracy Dietz, Ph.D., UCF IRB Chair, this letter is signed by:

Signature applied by Janice Turchin on 08/01/2007 10:56:26 AM EDT

Janice m Turchin

IRB Coordinator

# APPENDIX C: SCHOOL DISTRICT IRB APPROVAL LETTER

Submit this form and a copy of your proposal to:
*Accountability, Research, and Assessment*
*P.O. Box 271*
*Orlando, FL 32802-0271*

**Orange County Public Schools**

**RESEARCH REQUEST FORM**

Your research proposal should include: Project Title; Purpose and Research Problem; Instruments; Procedures and Proposed Data Analysis

Requester's Name: Atsusi Hirumi, Ph.D. Date: June 22, 2007

Address: PO Box 161250, 4000 University Blvd., Orlando, FL 32816-1250 Phone: (407)-823-1760

Business: University of Central Florida Phone

Project Directors or Advisors: Director – Atsusi Hirumi, Ph.D., Advisors – Dr. Micheal Hynes and Dr. Haiyun Bai; Graduate Research Assistants – Masureh Kabritchi, Renee Henry-Nease, Wendi Kappers, and Matt Henry.

Degree Sought: (check one) ☐ Associate ☐ Doctorate ☐ Bachelor's × None ☐ Master's ☐ Specialist

Project Title: The Effects of Modern Math Computer Games on Student Math Achievement, Math Anxiety and Motivation.

**ESTIMATED INVOLVEMENT**

| PERSONNEL/CENTERS | NUMBER | AMOUNT OF TIME (DAYS, HOURS, ETC.) | SPECIFY/DESCRIBE GRADES, SCHOOLS, SPECIAL NEEDS, ETC. |
|---|---|---|---|
| Students | Approx. 500 | 3hrs/week x 36 weeks | Grades 6-10 |
| Teachers | Approx. 25 | 3hrs/week x 36 weeks | Middle and High School Math Teachers |
| Administrators | | | |
| Schools/Centers | 3 | | Ocoee MS, Colonial 9th Grade Center and Colonial HS. |
| Others (specify) | | | |

Specify possible benefits to students/school system: The result of the study will help school district administrators and educators make informed decisions on the purchase and use of Tabula Digita DimensionM educational video game products to enhance student math learning and motivation based on rigorous experimental research data.

**ASSURANCE**

Using the proposed procedures and instrument, I hereby agree to conduct research in accordance with the policies of the Orange County Public Schools. Deviations from the approved procedures shall be cleared through the Senior Director of Accountability, Research, and Assessment. Reports and materials shall be supplied as specified.

Requester's Signature [signature]

Approval Granted: ☒ Yes ☐ No Date: 7-9-07

Signature of the Senior Director for Accountability, Research, and Assessment [signature]

NOTE TO REQUESTER: When seeking approval at the school level, a copy of this form, signed by the Senior Director, Accountability, Research, and Assessment, should be shown to the school principal.

Reference School Board Policy GCS, p. 249

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RECEIVED JUN 25 2007

# APPENDIX D: TEACHER INFORMED CONSENT

[Month Day, 2007]

Dear Educator:

My name is Dr. Atsusi Hirumi, and I am an Associate Professor and Co-Chair of the Instructional Technology at the University of Central Florida. As part of my research, I am asking teachers at several Middle Schools and a High School in Orange County Public Schools to participate.

The purpose of the research study is to determine the effects of a set of educational video games and related instructional materials on students' mathematics achievement, mathematics anxiety, and mathematics course motivation. The researcher wants to document and write about your mathematics class and the effects the video games had on everyone in the class. The results of this study will help the school district make informed decisions about using the game, as well as help educators make better use of such instructional materials. The results will also help educational game designers create better games and supporting instructional materials for teachers and students. You should feel good about assisting with this important research and sharing your successes.

With your consent, students in your mathematics classes will be asked to volunteer for the study. Of those students who volunteer and sign (or have their parents/caregivers sign) a similar consent form, scores on district and school mathematics exams will be recorded. Participating students will also be asked to complete a questionnaire regarding their mathematics anxiety and mathematics class motivation at the beginning, mid, and end of the school year. Your class will also be observed (once per nine-week term) and you and some of your students may be asked to be interviewed by researchers, a professor and/or a doctoral candidate at the University of Central Florida. Your class will NOT be videotaped. The interviews will be held in the school office during non-instructional time and should take less than 30 minutes. The interview will be tape recorded for transcription purposes only. All data, including tapes, completed observation forms, mathematics achievement scores, and responses to mathematics anxiety and mathematics course motivation questionnaires will be stored in a locked cabinet in my research and development laboratory at UCF (Teaching Academy Room 321) and will be destroyed soon after the research process is complete.

Please Note: All data, including participating students' personal information, will also be given to the game designers who will also use the same basic procedure to secure the data and protect your right, as well as your students' right to privacy. The personal information collected will include your students' name, email address, and online contact information. Names, email addresses and online contact information will only be used for administrative purposes. The information will not be used for marketing the game designers' products or services in any manner. By signing the consent form, you are also agreeing to allow us to release the data to the game designers.

Your name, the names of your students, and the name of your school will be kept confidential and will not be used in any report, analysis, or publication by the researchers or the game designers. All identifying information will be replaced with alternate names or codes. In addition, the researcher is requesting your permission to access participating students' documents and school records such as those available in the cumulative file, and students' grades.

There are no anticipated risks, compensation or other direct benefits to you as a participant in this interview. You are free to withdraw your consent to participate and may discontinue your participation in the interview at any time without consequence.

If you have any questions about this research project, please contact me at (407) 823-1760 or by email at hirumi@mail.ucf.edu. Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (IRB). Questions or concerns about research participants' rights may be directed to the Institutional Review Board Office, IRB Coordinator, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246. The telephone number is (407) 823-2901.

Please sign and return this copy of the letter to the Research assigned to your school. A second copy is provided for your records. By signing this letter, you give me permission to report the information about your students' mathematics achievement, mathematics anxiety, mathematics course motivation, along with observation and interview data noted in the letter as part of my research.

Sincerely,

Atsusi Hirumi, Ph.D.
Associate Professor and Co-Chair
Instructional Technology
University of Central Florida

____ I have read the procedure described above for the research study.

____ I voluntarily agree to participate in the study.

____ I agree to be audio taped during the interview.

____ I give consent for the online collection and use by the game designers, and the disclosure of my child's personal information to the game designers for administrative purposes only

_______________________________________ / ______________
Participant Date

_______________________________________ / ______________
Principal Investigator Date

# APPENDIX E: STUDENT SCRPIT

A professor at the University of Central Florida, Dr. Atsusi “2c” Hirumi, would like to ask you to participate in a research study to see if a single player and multi-player mathematics video game has any effect on your mathematics skills or mathematics attitudes.

The results of the study will also help OCPS decide whether to pursue the games for the entire district, as well as help guide future research and development.

Participation will not affect your grade in this course in any manner.

If you do not want to participate, that’s fine, just please let me know.

If you would like to participate, would you please ask your parents to read and sign the Parental Informed Consent Form and return it to me the next day? It’s essential that we have your parents or caregivers approval or you can not participate in the study. So, please do not forget.

Thank you.

# APPENDIX F: PARENT/GUARDIAN INFORMED CONSENT

August 24, 2007

Dear Parent/Guardian:

Your child's mathematics class is participating in a study that is being conducted by professors at the University of Central Florida, College of Education. Your child's identifying information has not been shared in any way with the researcher at this time. Your child's class was chosen because it meets the criteria for this study and you, as parent, are being offered the opportunity to have your child participate.

The research project involves determining the effects of a set of educational video games and related instructional materials on students' mathematics achievement, mathematics anxiety, and mathematics course motivation. The researcher wants to document and write about the mathematics class and the effects the video games had on everyone in the class. The results of this study will help the school district make informed decisions about using the game, as well as help educators make better use of such instructional materials. The results will also help educational game designers create better games for students. Your child should feel good about assisting with this important research and sharing their successes.

With your consent, your child mathematics scores on district and school mathematics exams will be recorded. Your child will also be asked to complete a Game Preparation and Performance Check prepared by the game designer, and questionnaire regarding your child's mathematics anxiety and mathematics class motivation. Your child's class will also be observed (once per nine-week term) and your child may be asked to be interviewed by researchers, a professor and/or a doctoral candidate at the University of Central Florida. The class will NOT be videotaped. The interview will be held in the school office during non-instructional time and should take less than 30 minutes. The interview will be tape recorded for transcription purposes only. Tapes will be stored in a locked cabinet at the UCF and will be destroyed soon after the research process is complete.

Please Note: All data, including your child's personal information, will also be given to the game designers who will also use the same basic procedure to secure the data and protect your right, as well as your child's right to privacy. The personal information collected will include your child's name, email address, and online contact information. Names, email addresses and online contact information will only be used for administrative purposes. The information will not be used for marketing the game designers products or services in any manner. By signing the consent form, you are also agreeing to allow us to release the data to the game designers.

Your child's name, the names of his/her teachers, and the name of your child's school will be kept confidential and will not be used in any report, analysis, or publication by the researchers or by the game designers. All identifying information will be replaced with alternate names or codes. In addition, the researcher is requesting your permission to access your child's documents and school records such as those available in the cumulative file, and his/her grades.

Your child will be allowed the right to refuse to answer any questions that make him/her uncomfortable, and he/she may stop participating in this research at any time. Your child will be reminded of this immediately prior to the interview. I have attached a copy of the interview questions for your information.

You may contact me at 407-823-1760 or email at hirumi@mail.ucf.edu, for any questions you have regarding the research procedures. Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (IRB). Questions or concerns about research participants' rights may be directed to the UCF IRB office, University of Central Florida, Office of Research & Commercialization, University Towers, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246, or by campus mail 32816-0150. The hours of operation are 8:00 am until 5:00 pm, Monday through Friday except on University of Central Florida official holidays. The telephone number is (407) 823-2901.

Sincerely,

Atsusi Hirumi, Ph.D.
Associate Professor and Co-Chair
Instructional Technology
University of Central Florida

____ I have read the procedure described on the previous pages.

____ I have received a copy of this form to keep for my records.

____ I give consent for the primary researcher to interview my child's at the school with proper adult supervision.

____ I give consent for the primary researcher to have access to my child's cumulative folder, and grades.

____ I give consent for the online collection and use by the game designers, and the disclosure of my child's personal information to the game designers for administrative purposes only

I voluntarily give my consent for my child, ________________________, to participate in Dr. Hirumi's study entitled, "The Effects of Modern Mathematics Computer Games on Student Mathematics Achievement, Mathematics Anxiety and Motivation."

___________________________________ / ___________

Parent/Guardian Date

___________________________________ / ___________

2nd Parent/Guardian Date

(or Witness if no 2nd Parent/Guardian)

Please sign and return one copy of this page and ask your child to return it to class.

# APPENDIX G: COPYRIGHT PERMISSION FOR FIGURE 1

COGNITIVE SCIENCE SOCIETY
University of Texas at Austin
Department of Psychology
1 University Station A8000
Austin, TX 78712-0187
phone : 512-471-2030
fax: 512-471-3053
email : CogSci@psy.utexas.edu
http://www.cognitivesciencesociety.org/

March 5, 2008

Mansureh Kebritchi
University of Central Florida
4049 Heirloom Rose Place
Oviedo, Florida 32766

The Cognitive Science Society, with author approval, grants permission to reprint Figure 3, page 349, from this *Cognitive Science* Journal article:

Malone, T. (1981). Toward a theory of intrinsically motivating instruction. Cognitive Science, 5(4), 333-369.

This figure will be used in Mansureh Kebritchi's doctoral dissertation, prepared at the University of Central Florida, entitled "Effects of a series of mathematics computer games on learning and motivation: an experimental study."

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Deborah Gruber
Cognitive Science Society, Inc.
Department of Psychology
The University of Texas at Austin
1 University Station A8000
Austin, TX 78712-0187

# APPENDIX H: COPYRIGHT PERMISSION FOR FIGURE 2

March 6, 2008
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I would like your permission to reprint the screenshot of Super Tangrams in my dissertation.

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Thank you for your attention in this matter.
Sincerely,
Mansureh Kebritchi
Ph.D. candidate, Education, Instructional Technology
University of Central Florida
4049 Heirloom Rose Place, Oviedo, Florida, 32766
Email: Kebritchi@gmail.com
Phone: 407-366-8469

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:

By: K. SEDIG (Please type your name)

Date: March 6, 2008

March 6, 2008
Dear Phoenix Quest Copyright Holder (s):

I am completing a doctoral dissertation at the University of Central Florida entitled “Effects of a series of mathematics computer games on learning and motivation: an experimental study.”
I would like your permission to reprint the screenshot of Phoenix Quest in my dissertation.

The screenshot will be reproduced as follow:

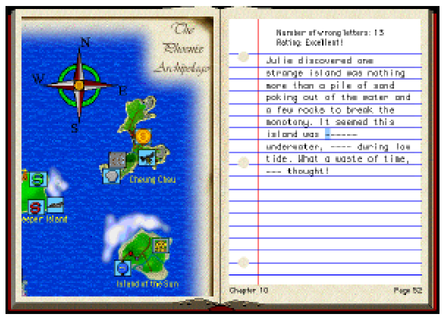


Figure 9 The Screenshot of Phoenix Quest. Adapted with permission from the author.

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Thank you for your attention in this matter.
Sincerely,
Mansureh Kebritchi
Ph.D. candidate, Education, Instructional Technology
University of Central Florida
4049 Heirloom Rose Place, Oviedo, Florida, 32766
Email: Kebritchi@gmail.com
Phone: 407-366-8469

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By: Michele Ng on behalf of Maria Klawe

Date: March 6, 2008

# APPENDIX I: COPYRIGHT PERMISSION FOR FIGURE 3

Jason Elliott and Amy Bruckman
College of Computing
Georgia Institute of Technology
Atlanta, GA 30332-0280
{jlelliot, asb}@cc.gatech.edu

March 3, 2008

Dr. Elliott and Dr. Bruckman:

I am completing a doctoral dissertation degree at the University of Central Florida entitled "Effects of a series of mathematics computer games on learning and motivation: an experimental study."
I would like your permission to reprint in my dissertation, Figure 6 from your presentation:
Elliott, J., & Bruckman, A. (2002). Design of a 3-D Interactive Mathematics Learning Environment. *Proceedings of DIS 2002 (ACM conference on Designing Interactive Systems). London, UK*. Retrieved July 7, 2007 from [http://www.cc.gatech.edu/elc/aquamoose/pubs/amdis2002.pdf](http://www.cc.gatech.edu/elc/aquamoose/pubs/amdis2002.pdf)

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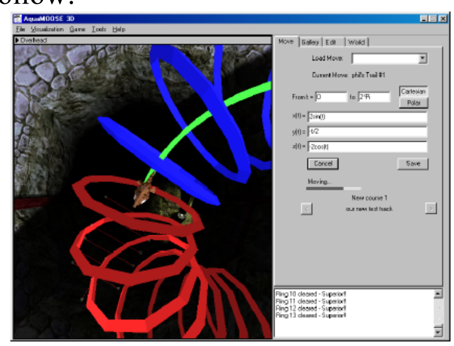

From "Design of a 3-D Interactive Mathematics Learning Environment," by J. Elliott and A. Bruckman, 2002, Proceedings of DIS 2002 (ACM conference on Designing Interactive Systems). London, UK, p.6.

Figure 3 The Screenshots of Ring game in AquaMOOSE.

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Thank you for your attention in this matter.
Sincerely,
Mansureh Kebritchi

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:

By: _____Amy Bruckman__________ Jason Elliott, Ph.D.___ (Please type your name)

Date: ___3/4/08__________________ March 13, 2008_________________________

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Date: Mar 3, 2008 5:01 PM, subject: CopyrightPermission_ForDissertation

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Figure 3 The Screen Layout of the Darts Game

Further detailed information are:
Name: Mansureh Kebritchi Job Title: PhD. Candidate
Name of Company/University: University of Central Florida Department: Educational Research, Technology, and Leadership in the College of Education
Street Address: 4049 Heirloom Rose Place, City: Oviedo State: Florida,Country: U.S.A., Zip/Postal Code:32766
Office phone: 407-366-8469 E-mail address: Kebritchi@gmail.com
Name of SAGE publication Journal: Simulation & Gaming DOI: 10.1177/1046878105282276
Publication date: Dec 1, 2005, Author(s): M. P. J. Habgood, S. E. Ainsworth, S. Benford,Pagenumber(s):483-498
Mansureh Kebritchi, Ph.D. candidate, Education, Instructional Technology, University of Central Florida

# APPENDIX J: COPYRIGHT PERMISSION FOR FIGURE 5

March 3, 2008

Dear Dr. Kolb:

This letter will confirm our recent Email conversation. I am completing a doctoral dissertation degree at the University of Central Florida entitled "Effects of a series of mathematics computer games on learning and motivation: an experimental study."
I would like your permission to reprint in my dissertation the circular experiential learning figure provided in your book:
Kolb, D. A. (1984). *Experiential learning: experience as the source of learning and development.* Englewood Cliffs, N.J: Prentice-Hall.

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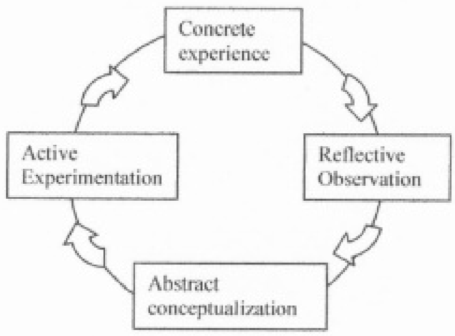


From "Experiential Learning: Experience as the Source of Learning and Development," by D.A. Kolb, 1984, Englewood Cliffs, N.J: Prentice-Hall. Adapted with permission from the author.

Figure 1 Kolb's (1984) circular learning model based on experiential learning theory.

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Thank you for your attention in this matter.

Sincerely,
Mansureh Kebritchi

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By: ALICE KOLB (Please type your name)

Date: 3-07-2008

# APPENDIX K: COPYRIGHT PERMISSION FOR TABLE 5

March 3, 2008

Dear Dr. Blixer:

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I would like your permission to reprint in my dissertation Table 1 at page 13 from your presentation at:
Bixler, B. (2006). *Motivation and its relationship to the design of educational games.* Paper presented at the NMC. Cleveland, Ohio. Retrieved September 10, 2007 from http://archive.nmc.org/events/2006summerconf/materials/Bixler/m&g.pdf

The Table is modified, cited, and to be reproduced as follow:

The comparison of two motivation theories of ARCS model and Intrinsic Motivation

| ARCS model, Keller (1987a) | Intrinsic Motivations, Malone and Lepper (1988) |
|---|---|
| • Attention: obtaining and sustaining | • Provide optimally challenging activities<br>• Change sensory conditions to arouse curiosity |
| • Relevance: Meet the needs of the learners.<br>• State goals. | • State goals or allow goals to emerge |
| • Confidence: Develop an expectancy for success. | • Provide an optimal level of challenge<br>• Provide performance feedback. |
| • Satisfaction: How good do people feel about their accomplishments?<br>• Give learners control over reaching goals that are intrinsically motivating | • Provide control over the learning environment |
| | • Use fantasy to help the student experience power, success, fame, and fortune. Also helps learners relate new learning to a past experience |

From "Motivation and Its Relationship to the Design of Educational Games," by B. Blixer, 2006, Paper presented at the NMC, Cleveland, Ohio, p.13. Adapted with permission from the author.

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Thank you for your kind attention in this matter.

Sincerely,
Mansureh Kebritchi

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By: __Brett Bixler________________________ (Please type your name)

Date: __3-3-08__________________

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Bixler, B. (2006). Motivation and its relationship to the design of educational games. Paper presented at the NMC. Cleveland, Ohio. Retrieved September 10, 2007from http://archive.nmc.org/events/2006summerconf/materials/Bixler/m&g.pdf

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