

# MOTIVATIONAL EFFECTS OF INSTRUCTIONAL SUPPORT PROVIDED BY GAME-BASED LEARNING OF HIGH SCHOOL MATHEMATICS

by

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(Under the Direction of Jay W. Rojewski)

## ABSTRACT

The purpose of this experimental study was to examine the interactive effects of instructional support and game-based learning of high school mathematics. This study focused on the use of a computer game as the vehicle of instructional support, and self-determination theory was applied to evaluate students' motivation by analyzing motivational factors of autonomy, relatedness, and competence.

Pretest-posttest control group design with random assignment was used to evaluate students' academic achievement, while posttest-only control-group design with random assignment was used to evaluate students' game enjoyment and the motivational effects of instructional support in game-based learning of high school mathematics. All participants were randomly assigned to either a control group or one of three treatment groups. Participants in the control group engaged in learning without treatment of computer game or instructional support, and those in one of the three experimental conditions engaged in (a) learning mathematics with instructional support in non-gaming environment, (b) game-based learning of mathematics with instructional support of guided practice and feedback, or (c) game-based learning of mathematics without instructional support.

The data were analyzed for 145 participants who completed all three sessions of treatments. A series of *t*-tests were conducted to evaluate the differences of game enjoyment between game treatment with and without instructional support. A series of  $2 \times 2$  analysis of variance (ANOVA) were conducted to evaluate the interaction of game and instructional support on academic achievement and motivation factors of autonomy, competence, and relatedness. Instructional support embedded in the game did not impact participants' game enjoyment level, academic achievement or motivation. Those participants who experienced game treatment demonstrated lower levels of relatedness, competence, and autonomy than those without game treatment in the second session.

Instructional support and game-based learning of high school mathematics impacted game enjoyment, achievement, and motivation differently in the current study compared to previous studies in elementary and middle schools. Recommendations for future research involve two major components of game-based learning, including internal contexts (game idea and functionality) and external contexts (applications).

**INDEX WORDS:** Game-based learning, Instructional support, Motivation, Self-determination theory

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## DEDICATION

This dissertation is dedicated to my grandmother who, in her nine and a half decades of life, took care of our family of four generations, raised me, and was always unconditionally proud of me. I pursued this degree to make you proud.

To my grandfather who, in his nine and a half decades of life, fought for freedom in World War II, survived poison and torture, and taught me to face challenges in life. It is my honor to present my work to you.

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## CHAPTER 1

### INTRODUCTION

Over the past two decades, technological advancements have had an impact on the fundamental means of teaching and learning by providing computer and Internet-based environments that are both interactive and entertaining. Game-based learning, which engages students in the interactive and entertaining environment of computer games, has been brought to the attention of researchers, educators, and game developers. Game-based learning refers to the integration of learning and interactive entertainment of digital games (Prensky, 2001). Squire (2008) described game-based learning as players' experience of digital worlds that support reaction, feelings, emotions, and identities. Prensky (2001) listed eight genres of games including action, adventure, fighting, puzzle, role-playing, simulation, sport, and strategy games. Games and Squire (2011) introduced the history of educational games as a progression from drill and practice to fantasy and adventure, constructionism, educational prototypes, and finally, serious game, the games of educational potentials for learning. Gee (2011) argued that all games belong to one of two categories: *problem games* designed to solve a problem or *world games* that simulate real-world scenarios.

#### **Rationale**

Multiple empirical studies have shown positive results when studying game-based learning in specific subjects such as computer science (Papastergiou, 2009), social studies (Abrams, 2009; Huizenga, Admiraal, Akkerman, & Ten Dam, 2009), and mathematics (Ke, 2008). Effects of game-based learning can be studied across different subjects such as that

represented by the current science-technology-engineering-mathematics (STEM) programs found at the elementary and secondary through postgraduate levels (U.S. Department of Education, 2007). According to Sanders (2009), “There is sufficient evidence with regard to achievement, interest, and motivation benefits associated with new integrative STEM instructional approaches to warrant further implementation and investigation of those new approaches” (p. 22). Clark and Ernst (2009) found that gaming brings technology to other STEM subjects, as well as career awareness to classrooms. Evidences indicated that game-based learning can be studied across technology and mathematics, as well as career-related courses.

The subjects of technology, mathematics, and career are important areas in high school career and technical education (CTE) curriculum. Career and technical education includes educational activities that teach academic and technical knowledge and skills for employment in the Carl D. Perkins Career and Technical Education Act (2006). Mathematics is a major employable skill that career and technical education attempts to improve in its curriculum. Stone, Alfeld, and Pearson (2008) demonstrated a math-enhanced model to integrate mathematics in career and technical education curriculum in order to introduce mathematics concepts in career-related contexts. The ultimate goal of the model was to help students understand traditional mathematics examples and succeed in formal assessments. Wu and Greenan (2003) indicated that career and technical educational curriculum should integrate generalizable mathematics skills in order to facilitate the transition of learners from CTE to educational and practical skills. It is necessary for researchers to engage in further investigation on the effects of game-based learning of mathematics beyond career and technical education contexts by integrating generalizable mathematics problems in CTE curriculum.

## **Games and Learning**

Prensky (2001) discussed many elements of games that are attractive to both educators and students and that can be aligned with interactive learning. Prensky argued that game-based learning becomes a natural way that children learn and that game-based learning makes learning more effective because it compliments with good practices in learning. Gee (2003) discussed 36 principles of learning that are built into good video games and argued that good learning principles designed in a game facilitates learning, fitting well with school-based instruction. Gee (2007) further organized these principles in three major categories, including empowered learners, problem-solving, and understanding. Principles such as student engagement and student-centered approach in daily instruction can be linked with good design in computer games that make learning fun (Gee, 2007; Prensky, 2001).

Although Gee (2011) saw great potential in learning through games, he argued that testing the hypothesis that games are good for learning is not possible. Gee argued that a game is only software and that learning occurs in the social contexts of the game. A game should be tested based on learning theories, but learning theories may result in a complex interaction of outcomes and require different types of evaluation. Gee suggested that empirical research on games and learning may not produce any meaningful result due to the difference of genres of games and types of learners. Thus, he concluded that studies on games and learning will only show the positive or negative effects of a given genre of games toward specific type of learners in a given testing context.

## **Game-Based Learning and Instructional Support**

Van Eck (2006) listed three approaches for game-based learning, including student-developed, teacher-developed, and commercial games. Both commercial and teacher-developed



games can be defined as *instructionist* approaches (Papert, 1993). Kafai (2006) stated that instructionists turn instructional materials into instructional games and “a common feature in nearly all those games is that they integrate the game idea with the content to be learned” (p. 37). O’Neil, Wainess, and Baker (2005) suggested that contents within the instructional context of game activate learning, while Gee (2011) supported the idea that a learning system accompanied with a game makes learning happen. Tobias, Fletcher, Dai, and Wind (2011) suggested using the term *instructional support* to define any type of assistance or instruction embedded within a game.

Games and Squire (2011) stated that educational games “relied heavily on a fantasy theme wrapped around drill and practice activities to promote skills in math, language arts, and problem solving” (p. 30). According to Tobias (1982), drill and practice are the instructional content in a form that students can respond by choosing from various answers. Leemkuil and de Jong (2011) defined exercises in simulations as assignment, similar to activities in drill and practice. Van Joolingen and de Jong (2003) distinguished several types of assignments including investigation, specification, explication, optimization, and operation. Studies have shown that assignments of content knowledge have been implemented in educational games. Cameron and Dwyer (2005) applied questions and answers in a game to test the learning on content knowledge. Moreno and Mayer (2005) asked players to select the right answers to questions on specific content knowledge within a game.

Tobias et al. (2011) suggested further investigation to identify which forms of instructional support are mostly likely to promote deeper or more frequent cognitive processing. For studies of instructional support within a game, the effectiveness of the specific forms of support should be specified. Tobias et al. stated that instructional support covers guidance,

explanations, directions, and other types of assistance. Leemkuil and de Jong (2011) identified a number of forms of instructional support including assignments, explanations and background information, monitoring tool, hypothesis scratchpads, predefined hypotheses, experimentation hints, process coordinators, and planning tools.

Guidance and feedback as important forms of instructional support have been analyzed in many studies. Lee (1999) reported that guidance produces more learning in simulation games. Cameron and Dwyer (2005) found statistically significant gain in achievement when feedback was provided for quiz questions in a game. Moreno and Mayer (2005) analyzed feedback (right or wrong answer) and guidance (explanation of the answer) in a study on instructional support. These researchers defined guidance as explanatory feedback, distinguishing it from responsive feedback, and indicated that explanatory feedback and reflection promoted learning. Based on what Lee (1999), Cameron and Dwyer (2005), and Moreno and Mayer (2005) described, explanatory feedback, as one specific form of instructional support, can be further studies in game-based learning.

Kerr (1995) stated that computer programs can diagnose students' current learning and determine students' next learning activities. Kintsch (2009) described guided practice as a way to facilitate students' learning with proper level of challenge. Kintsch argued that guided practice should assess students' current performance and decide what instructional support should be provided next based on assessment results. Students can continue to the next level of learning if satisfactory results are obtained or can practice similar questions if they do not pass the assessment. Repeated practice can be in demonstration format (Clark, 2009) or worked-examples (Wise & O'Neil, 2009). Practice is similar to an intelligent tutorial system that provides drill and

practices (Fletcher, 2009). Based on discussions of Kerr (1995), Kintsch (2009), Clark (2009), and Wise and O'Neil (2009), guided practice can be further investigated in game-based learning.

### **Game-Based Learning and Motivation**

Prensky (2001) suggested that game-based learning makes non-intrinsically motivated activities more enjoyable. Many researchers have revealed a positive relationship between game-based learning and student motivation (Ke, 2008; Papastergiou, 2009; Van Eck & Dempsey, 2002). Motivation covers extrinsic motivation which “refers to the performance of an activity in order to attain some separable outcome,” and intrinsic motivation which “refers to doing an activity for the inherent satisfaction of the activity itself” (Ryan & Deci, 2000b, p. 72). According to Ryan and Deci's (2000b) self-determination theory, three basic needs—relatedness, competence, and autonomy—are of central importance if students are to internalize extrinsic motivation so that external values can be “evaluated and brought into congruence with one's other values and needs” (p. 73). Relatedness refers to the need to feel belongingness and connectedness with others. Competence relates to the feeling of competency toward the activities. Autonomy facilitates a sense of choice and freedom from external pressure.

Many elements in game-based learning can be associated with these three universal needs that eventually impact intrinsic and extrinsic motivation. Papert (1980) developed the notion of learning in a micro-world, a world within a computer program where students are motivated to explore, or a virtual environment which is difficult to reach in the real world. Rieber (1996) described a sense of micro-worlds that bring learning into meaningful and playful interaction through fantasy and challenge in digital games. Rieber and Noah (2008) stated that game players are challenged in the gaming context and that they experience enjoyment as they gain mastery of the game. Dickey (2007) argued that current games are more sophisticated than previous games

as a result of their various forms. Dickey listed choice, control, collaboration, challenge, and achievement in an environment known as Massively Multiplayer Online Role-Playing Games (MMORPG) where character design, narrative, chat, and communication tools are employed. Robertson and Howells (2008) found that students are also motivated and determined to achieve when they develop their own computer games. Yee (2006) identified achievement, social, and immersion components as motivational factors in online games. These discussed motivational factors in computer games highly correlate to the three psychological needs of relatedness, competence, and autonomy in Ryan and Deci's (2000b) self-determination theory.

### **Game-Based Learning of High School Mathematics**

Game-based learning has been studied with both the teaching and learning of mathematics extensively. Ke (2008) found that game-based learning promoted positive attitudes about mathematics among fifth graders. Moreover, the competition and context elements in game-based learning improved students' positive attitude on mathematics at the middle school level (Van Eck, 2006; Van Eck & Dempsey, 2002). Sedig (2008) found that game-based learning motivated sixth graders to engage in mathematics concepts in an enjoyable manner. Kafai, Franke, Ching, and Shin (1998) found that game design provided discussion, reflection, and collaboration within a meaningful context for fifth graders in mathematics classes. Scanlon, Buckingham, and Burn (2005) argued that, beyond context, student engagement with characters and narratives, rule-based challenges, and engagement with other players are three important motivational factors in game-based learning in mathematics.

In studies of game-based learning of mathematics in elementary and middle schools, evidences were uniformly consistent in indicating that context, engagement, and challenges are motivational factors. These factors can be related to the three basic psychological needs of

relatedness, competence, and autonomy in self-determination theory. However, few studies have been conducted to examine the effects of game-based learning on high school students. Rice (2001) reported that the dramatic transition from middle school to high school can negatively impact students' attitude toward mathematics. Alspaugh (1998) found a dramatic achievement loss in all academic areas during the first year of high school. Therefore, it is necessary to investigate the effects of game-based learning of mathematics to develop an understanding of how game-based learning can help career and technical education students in high schools.

### **An Interpretation of Game-Based Learning**

Prensky (2001) suggested that game enjoyment is the primary goal of game-based learning and many fun elements have been implemented in commercial games. Games are dynamic systems of formal and dramatic elements that challenge players to accomplish objectives by following rules and procedures (Fullerton, Swain, & Hoffman, 2008). For educational games, instructional content is embedded (Kafai, 2006) while instructional support (Tobias et al., 2011) such as guidance and directions are integrated in game environment. Elements in dynamic system of games have been discussed in game design. Fullerton, Swain, and Hoffman (2008) explained that games include formal elements such as players, objectives, procedures, rules, resources, conflict, boundary, and outcome and dramatic elements such as challenge, play, premise, character, story, and world building. Educational games integrate learning objectives and instructional supports in formal and dramatic elements.

Previous studies have discussed interactive learning and situated learning (Gee, 2003, 2007; Prensky, 2001) as well as feedback and guidance (Cameron & Dwyer, 2005; Moreno & Mayer, 2005) in educational games. These studies suggested great potential of game-based learning when learning strategies are integrated in game elements. However, educational games

are not, by themselves, game-based learning. Gee (2011) suggested that contexts of educational games make learning happen. Figure 1.1 shows the structure of game-based learning in this study.

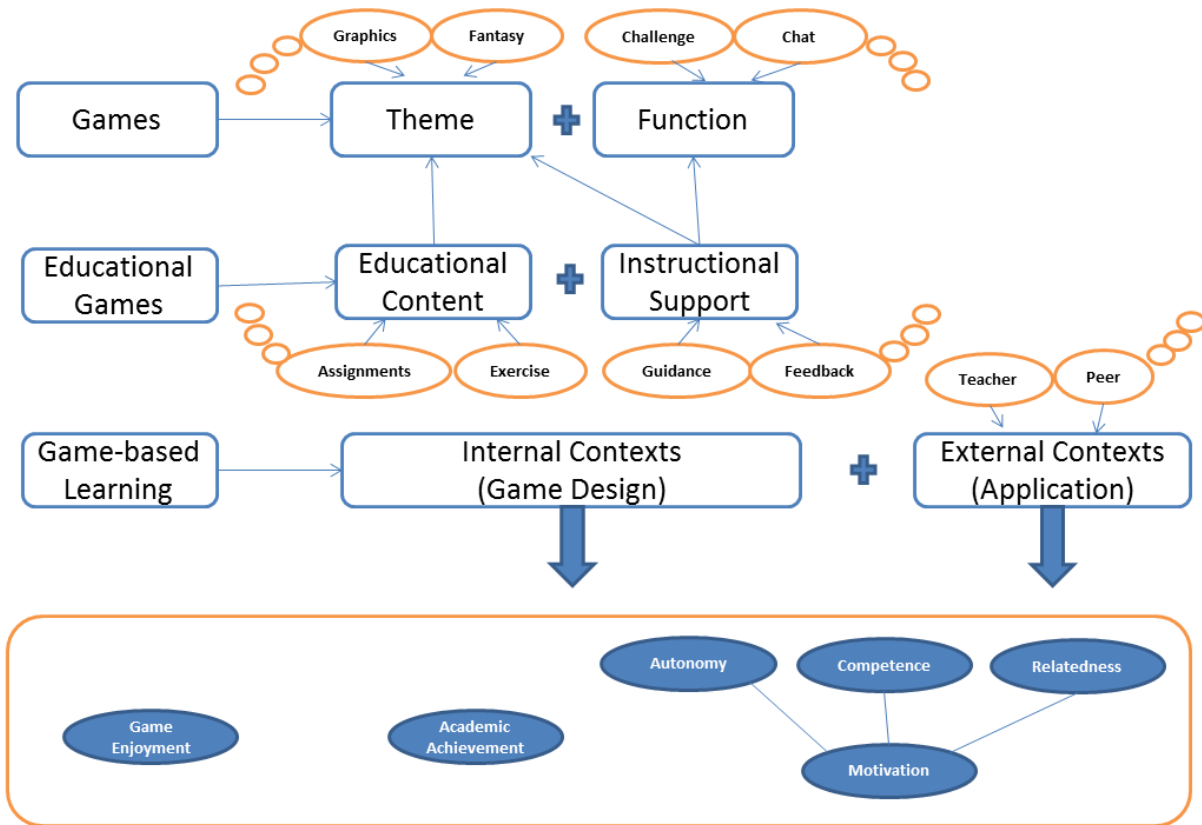


Figure 1.1. The structure of internal and external contexts of game-based learning

Game-based learning includes educational games that integrate game and educational elements and applications of those games. The integration of regular game and educational elements is considered internal context of game-based learning. Applications of educational games are considered external contexts of game-based learning. Studies on game-based learning should cover not only internal factors of good educational games but also application of those games. Previous studies have shown great potential of internal contexts of game-based learning (Gee, 2003, 2007; Prensky, 2001), but little studies have been developed to investigate impacts of external contexts. This study evaluates factors in both contexts of game-based learning

because all factors may impact students' game enjoyment, academic achievement, and motivation.

### **Purpose and Questions**

The purpose of this experimental study was to examine the interactive effects of instructional support and game-based learning of high school mathematics. Instructional support referred to any type of assistance that helps students learn and included guidance, explanations, directions, and other types of assistance (Tobias, Fletcher, Dai, & Wind, 2011). This study focused on the use of a computer game as the vehicle of instructional support. The computer game, *MathFighter*, was a researcher-developed game that integrated mathematics concepts. The control condition was learning without participation of computer game or receipt of instructional support. Three experimental conditions were (a) learning mathematics with instructional support in a non-gaming environment, (b) game-based learning of mathematics with instructional support consisting of guided practice and feedback, and (c) game-based learning of mathematics without instructional support.

The dependent variable, motivation, included both extrinsic and intrinsic motivation, where extrinsic motivation referred "to the performance of an activity in order to attain some separable outcome" and intrinsic motivation referred "to doing an activity for the inherent satisfaction of the activity itself" (Ryan & Deci, 2000b, p. 72). According to Ryan and Deci (2000b), three basic psychological needs—relatedness, competence, and autonomy—are of central importance in transforming extrinsic motivation into intrinsic motivation so that external values can be "evaluated and brought into congruence with one's other values and needs" (p. 73). Relatedness refers to the feeling of belongingness and connectedness with others. Competence refers to the feeling of competency with respect to an activity. Autonomy refers to a sense of

choice and freedom from external pressure. Relatedness, competence, and autonomy were examined as indicators of intrinsic and extrinsic motivation.

In this study, the following research questions were addressed:

1. What was students' level of enjoyment toward computer games with or without instructional support?
2. What was students' academic achievement on mathematics based on whether game-based learning or instructional support was provided?
3. What were the characteristics of students' motivation toward mathematics based on whether game-based learning or instructional support was provided when measured on the motivational factors of autonomy, competence, and relatedness?
4. What were the differences of students' level of game enjoyment toward computer games with or without instructional support?
5. What were the interactive effects of game-based learning and instructional support on students' academic achievement?
6. What were the interactive effects of game-based learning and instructional support on students' motivation toward mathematics when measured on the motivational factors of autonomy, competence, and relatedness?

### **Theoretical Framework**

Self-determination theory was applied to evaluate students' motivation. In self-determination theory (SDT), Ryan and Deci (2000a) defined motivation as “to be moved to do something” (p. 54). “Someone who is energized or activated toward an end is considered motivated” (p. 54). Level of motivation can be the same, but orientation can vary because people are motivated by different attitudes and goals. Self-determination theory (SDT) distinguished



different types of motivation based on different reasons that people are motivated. These different types include intrinsic motivation, defined as “doing something because it is inherently interesting or enjoyable” (p. 55), and extrinsic motivation, defined as “doing something because it leads to a separable outcome” (p. 55). Operant theory (Skinner, 1953) stated that changes in behaviors are the result of responses to external stimuli and that external drives such as rewards are the condition needed to initiate an individual’s response. Cognitive theories explain learning as the result of observation on environment and environmental influence on individual behavior (Bandura, 1986). Effectance theory (White, 1959), flow theory (Csikszentmihalyi, 1975), and self-determination theory (Ryan & Deci, 2000b) have studied motivation from psychological perspective.

### **Basic Psychological Needs**

Self-determination theory (SDT) focuses on the psychological needs of competence, autonomy, and relatedness (Ryan & Deci, 2000b). In earlier works, Hull (1943) proposed that motivational needs are biological, while McClelland (1965) proposed that the motivational needs of achievement, affiliation, and power are acquired over time and are shaped by experience. In contrast, self-determination theory (SDT) defines motivational needs as innate and psychological. The SDT investigates “people’s growth tendencies and innate psychological needs that are the basis of self-motivation and personality integration, as well as for the conditions that foster those positive processes” (p. 68). Relatedness refers to feelings of belongingness and connectedness with others. Ryan and Deci (2000b) explained that external tasks are normally not interesting and people initially perform such tasks primarily because those tasks are prompted or valued by others in one’s social circle. Competence refers to feelings of efficaciousness with respect to an activity. People are motivated through social-contextual events such as optimal challenges,

positive feedback, and rewards that lead to a feeling of competence. Autonomy refers to a sense of choice and freedom from external pressure. A sense of self-determination and supportive context is the most important factor to cultivate motivation. In self-determination theory, these three basic psychological needs are critical factors for understanding and predicting intrinsic and extrinsic motivation.

### **Cognitive Evaluation Theory and Organismic Integration Theory**

Cognitive evaluation theory, a sub-theory of self-determination theory, examines the social and environmental factors that facilitate intrinsic motivation (Deci & Ryan, 1985). Ryan and Deci (2000b) examined intrinsic motivation through the conditions that sustain intrinsic motivation rather than the causes. Cognitive evaluation theory focuses on the fundamental needs for competence and autonomy, formulated from studies on feedback and rewards. Ryan and Deci argued that perceived competence such as optimal challenges and positive performance feedback facilitates intrinsic motivation. They argued that “the feeling of competence will not enhance intrinsic motivation unless accompanied by a sense of autonomy” (p. 70). Thus, people must experience a sense of both competence and autonomy to sustain intrinsic motivation, and the contextual supports for competence and autonomy come from prior perceptions on these two factors. Perceived autonomy such as choices and self-direction enhances intrinsic motivation, and perceived control such as external reward and pressure undermines intrinsic motivation.

Relatedness is the third factor in cognitive evaluation theory because intrinsic motivation is more likely to flourish in a context of security and affiliation. Cognitive evaluation theory posits that the three basic needs of competence, autonomy, and relatedness motivate only for activities that have been intrinsically motivated, but the principle does not apply to activities without intrinsic motivation. Therefore, cognitive evaluation theory facilitates and enhances

existing intrinsic motivation, and the basic needs of competence and autonomy must be satisfied for the enhancement, while relatedness is an optional factor to support intrinsic motivation.

Organismic integration theory, another sub-theory of self-determination theory, details and differentiates various forms of extrinsic motivation that internalize and integrate external values (Ryan & Deci, 2000b). Internalization refers to people's acceptance of a value and integration refers to people's transformation of the value into their own. According to Ryan and Deci (2000b), extrinsic motivation varies based on degree of autonomy. The least autonomous form is *external regulation* where behaviors are performed as a result of external demand or reward. The second type is *introjected regulation* where people perform behaviors due to self-esteem or pride. A more autonomous form of extrinsic motivation is *identified regulation* where people perform behaviors because they accept the value as personally important. The most autonomous form of extrinsic motivation is *integrated regulation* where people perform behaviors because they incorporate external activities into their own value system.

According to Ryan (1995), the internalization process can be developed at any point depending on prior experiences and current situational factors. The organismic integration theory perceives relatedness as an important factor in prompting behavior changes. Ryan and Deci (2000b) argued that extrinsically motivated behaviors are normally not interesting and the internalization of those behaviors is more likely to occur when they are also valued by members of the individual's social circle or community. In addition, people are more likely to adopt activities that they feel efficacious and competent about. Finally, a feeling of autonomy allows people to transform values into their own. Thus, relatedness and competence yield introjected regulation but the combination of relatedness, competence and autonomy is more likely to yield the integration of an extrinsic motivation into intrinsic motivation.

## **Practices of Self-Determination Theory**

Self-determination theory (Ryan & Deci, 2000b) hypothesizes that intrinsic motivation can be inferred if competence and autonomy are observed. Further, if the basic needs of competence, autonomy, and relatedness are all observed, extrinsic motivation can be internalized and integrated to form intrinsic motivation. The theory posits that the three basic psychological needs can be used to indicate a student's potential intrinsic and extrinsic motivation. In Ryan and Deci's (2000b) approach, researchers can determine students' motivation by describing their level on the three psychological needs.

Niemiec and Ryan (2009) analyzed various educational studies and suggested that teacher's support of three psychological needs improves students' self-regulated learning and academic performance. Many other studies have demonstrated similar results, correlating basic psychological needs to intrinsic and extrinsic motivation (Black & Deci, 2000; Grolnick, Ryan, & Deci, 1991; Niemiec, Lynch, Vansteenkiste, Berstein, Deci, & Ryan, 2006; Standage, Duda, & Ntoumanis, 2006). In these studies, the satisfaction of psychological needs of competence, relatedness, and autonomy have been positively related to student motivation.

Self-determination theory has been applied in many different fields to study motivation. The three basic psychological needs of relatedness, competence, and autonomy have been used to evaluate employee motivation in the workplace (Ilardi, Leone, Kasser, & Ryan, 1993), as well as interpersonal relationships (La Guardia, Ryan, Couchman, & Deci, 2000). Various studies have applied the theory to evaluate school environments and student motivation in different school settings such as high stakes testing (Ryan & Brown, 2005), parental influence (Roth, Assor, Niemiec, Ryan, & Deci, 2009), teacher evaluation (Filak & Sheldon, 2003), and educational subjects such as physical education (Taylor, Ntoumanis, & Smith, 2009) and

accounting (Miller & Stone, 2009). These studies found that the satisfaction of three psychological needs is positively related to people's intrinsic and extrinsic motivation in different social settings.

The most relevant study of self-determination theory to the present study is the investigation of video game play and player motivation. Ryan, Rigby, and Przybylski (2006) applied the tenets of self-determination theory to their study and found a positive relationship between satisfaction of the three psychological needs of self-determination theory and video game players' enjoyment. Ryan et al. developed four studies on treatments with game experiences and collected data using the *Game Play Questionnaire* after treatments. They found that the results of autonomy, competence, and relatedness subscales were positively correlated to game enjoyment and preferences for future play subscales. They also demonstrated that self-determination theory can be applied to analyze and understand the relationships of video game play and players' motivation.

### **Importance of Study**

Gee (2011) stated that many commercial games set the example of how to implement learning theories in game play. Games and Squire (2011) suggested collaboration among game designers, educators, and learning theorists because "designing, developing, and distributing quality educational games require interdisciplinary skills across educational technology, educational research, the learning sciences, and disciplinary knowledge" (p. 37). Tobias et al. (2011) indicated that commercial game developers are unlikely to provide source code of games for modification, which makes facilitation of specific learning content difficult. With the advancement of technology, many tools are available for teachers to design games. Cooper, Dann, and Pausch (2000) discussed the application of Alice software in 3D animation design.

Maloney, Resnick, Rust, Silverman, and Eastmond (2010) described Scratch software that can be used to create games with drag and drop blocks. These tools enable teachers to design educational games and modify existing games with specific instructional support. Findings from this study may support better practices for teachers to effectively integrate instructional support into educational games they develop.

Van Eck (2006) listed three types of game-based learning, and both commercial games and teacher-made games can be categorized as reflecting an instructionist approach (Papert, 1993). Many studies on game-based learning have examined individual forms of instructional support in game-based learning such as advice (Leutner, 1993), feedback, and reflection (Cameron & Dwyer, 2005; Moreno & Mayer, 2005). Tobias et al. (2011) suggested further investigation on different forms of instructional support. This study examined two elements of instructional support including feedback and guided practice while specific subject materials of high school mathematics were integrated into the instructional support. Result of this study increase an understanding of how instructional support elements impact the learning system of an educational game, and demonstrate the effects of instructional support toward game-based learning of high school mathematics.

Many studies on instructional support have examined the effects of specific forms of support at postsecondary level (Cameron & Dwyer, 2005; Moreno & Mayer, 2005). Van Eck and Dempsey (2002) studied the effect of instructional support in the form of advice to middle school students. However, few studies have been developed to examine the effect of instructional support for high school students. Specifically, studies need to be developed to evaluate whether instructional support has an impact on students' motivation toward game-based learning of mathematics at high school level. While the same instructional support elements and

motivational factors are implemented in an educational game, the effects may vary for elementary, middle, and high school students due to different type of learners and learning contexts. This study specifically evaluates the effects of instructional supports toward game-based learning of high school mathematics.

Although academic performance is an important factor in evaluating game-based learning, this study considered motivation as equally important as academic achievement during high school because research on motivation can contribute “to the design of social environments that optimizes people’s development, performance, and well-being” (Ryan & Deci, 2000b, p. 68). This study focused on the psychological perspectives of high school students to examine the causes of the academic discrepancies during high school years (Alsbaugh, 1998). Self-determination theory focuses on innate and psychological needs that support positive progress of personal growth (Ryan & Deci, 2000b). This study applies self-determination theory to relate game-based learning to psychological needs and motivation. The three basic psychological needs—relatedness, competence, and autonomy— are indicators of motivation in this study, and the psychological satisfaction approach further supports the innate and psychological perspective on motivation from self-determination theory. This study contributes to the literature on self-determination theory by providing evidence between three psychological needs and high school students’ motivation on studying mathematics through game-based learning.

Researchers who study motivation theory, game-based learning, and instructional support may benefit from this research because findings demonstrate results of (a) how the psychological (motivation) needs of autonomy, competence, and relatedness are influenced through the learning of high school mathematics in a game playing environment, and (b) the impact of game-based learning and instructional support in a mathematics learning situation. Educational game

designers may benefit from this research because an analysis of internal contexts of game-based learning improves effective design of educational games. High school career and technical education (CTE) teachers may benefit from this research because results show how different forms of instructional support influence student achievement and motivation when game-based learning is applied.



## **CHAPTER 2**

### **REVIEW OF THE LITERATURE**

Over the past two decades, technological advancements have had an impact the fundamental means of teaching and learning by providing computer and Internet-based environments that are both interactive and entertaining. Game-based learning, which engages students in the interactive and entertaining environment of computer games, has been brought to the attention of researchers, educators, and game developers. Game-based learning refers to the integration of learning and interactive entertainment of digital games (Prensky, 2001). Squire (2008) described game-based learning as players' experience of digital worlds that support reaction, feelings, emotions, and identities. Prensky (2001) listed eight genres of games including action games, adventure games, fighting games, puzzle games, role-playing games, simulation games, sport games, and strategy games. Games and Squire (2011) introduced the history of educational games as a progression from drill-and-practice to fantasy and adventure, constructionism, and finally serious game. Gee (2011) suggested two categories of games: problem games where the goal is to solve a given problem, and world games which simulate the world.

#### **Game-Based Learning**

Games and Squire (2011) explained that the early educational games are primarily drill-and-practice games to motivate students to use the game repeatedly. The motivation theory behind this type of game focused on the state of flow (Csikszentmihalyi, 1975) to create engaging experiences. According to Games and Squire, simulation games were brought in as an

educational tool to simulate real world experiences in fields such as economics, finance, and strategic management where players play the role of commander, business leader, colonial explorer, or city manager. Later, Papert's (1980) constructionism approach of building artifacts within games was studied and developed by researchers. Then, educational games were developed into interactive adventure games where players can play a role in a story or fantasy (Games & Squire, 2011).

Games and Squire (2011) introduced the development of serious games, an approach of game development that is closely aligned with learning theories. In some practices, educational games “relied heavily on a fantasy theme wrapped around drill and practice activities to promote skills in math, language arts, and problem solving” (p. 30). In other studies, researchers built a suite of prototypes to “illustrate the range of educational capacities that games could achieve, from construction to simulation to interactive narrative” (p. 33). Games and Squire recommended further collaboration between educational game researchers and game designers. “Designing, developing, and distributing quality educational games requires interdisciplinary skills across educational technology, educational research, the learning sciences, and disciplinary knowledge—as well as any number of fields represented in game design” (p. 37).

### **Prensky's (2001) Discussion on Game-based Learning**

Prensky (2001) argued that the younger generations grow up in a digital environment and they have new needs and preferences in learning. Digital media has become the new language that children use to learn, and children develop thinking skills by playing digital games. Prensky argued that the new generation is experienced in processing information quickly, applying multiple tasks simultaneously, and accessing information randomly. Children are more used to expecting graphics, playing, fantasy, and social connectivity in their learning. Game-based

learning becomes a natural way that children learn. The elements in game-based learning meet the needs of students in their learning. Therefore, it can be expected that game-based learning will be easily adopted by students.

Prensky (2001) argued that technology makes learner-centered education possible. He stated that education reformers have advocated for new education approaches with great emphasis on learners' experience. There are several practices that students can acquire at their own pace, with their own learning style, and from their selected subjects. Technology provides enormous potential that student-centered approaches can be applied, and game-based learning provides a great opportunity to apply technology into learning by engaging with video games.

I believe that it is easier to make a good, educational game than it is to make a good, education movie or TV show. It is easier because a great game can start with just a small captivating idea, or because tools exist and it is possible to reuse code and assets, or because successful entertainment models can be repurposed relatively easily, or because small teams have produced excellent learning games. (p. 95)

Prensky (2001) discussed many elements that make computer games attractive: A good game design is challenging, creative, and focused, and a good game has character, tension, and energy. Meanwhile, the characteristics of interactive learning lead game-based learning to the ultimate goal of student learning. Prensky suggested that game-based learning can be fun and closely tied to teaching. Game-based learning is learner-centered, and having fun is the primary factor of game-based learning. People are attracted to play and they consider themselves players rather than students in game-based learning. Thus, the principle of game-based learning should be phrased as "fun first, learning second" (p. 179). Table 2.1 displayed the elements of games and interactive learning provided by Prensky (2001).

Table 2.1

*Elements of Games and Interactive Learning*

Game elements	Interactive learning elements
Fun gives enjoyment	Practice and feedback
Play gives involvement	Learning by doing
Rules give structure	Learning from mistakes
Goals give motivation	Goal-oriented learning
Interactive gives doing	Discovery learning and guided discovery
Outcomes and feedback give learning	Task-based learning
Adaptive gives flow	Question-led learning
Win gives ego gratification	Role playing
Conflict, competition, challenge, and opposition give adrenaline	Coaching
Problem solving gives social creativity	Constructivist learning
Interaction gives social group	Accelerated learning
Story gives emotion	Selecting from learning objectives
	Intelligence tutoring

Prensky (2001) stated that learning is a complex process and there is no one perfect model for learning. He listed many good practices such as challenging activities, positive feedback, reflection, coaching, playing, having fun, and relevant experience. Fortunately, most of the practices can be integrated within educational games. Prensky stated that digital games offer infinite amounts of knowledge at different levels of challenge so that games can be accustomed to the desire of each player. Many good practices of learning can be incorporated into games to meet the learning needs of individual students.

**Gee's (2003, 2007, 2011) Discussion on Games and Learning**

Gee (2003) argued that literacy in forms of reading and writing is limited because people only understand the dictionary-like meaning without being able to put meaning into different

contexts. Gee suggested that video games should be recognized as a family of different semiotic domains, signs in a format of images, sounds, movements, and equations that “stand for different meanings in different situation, contexts, practices, culture, and historical period” (p. 18).

Semiotics domain involves situated learning, learning in both content and social practices, learning the principles related to the content and social practices, and life-world learning. People can be literate in such domains that are contradictory to traditional forms of literacy in reading and writing because of their expertise in social contexts. Gee indicated that learning in a semiotic domain such as gaming involves active participation, instead of passive content, to experience the world, gain resources for further learning, and help create certain relationships among people.

Gee (2003) suggested 36 equally important learning principles that can be embedded into good educational games. Table 2.2 illustrates these principles and the explanation of the principles (Gee, 2003). The principles suggested that characteristics of game-based learning in a rich and virtual context cannot be achieved in the real world. These games employ a combination of multiple formats of signs (text, image, sound, and activity) in a situated learning context. Learning occurs in the gaming context with dispersed but organized knowledge so that learners access various forms of knowledge and the social context of the knowledge in various formats. Knowledge in a game is facilitated incrementally and methodically so that learners have access to ample samples and repeated practice. The virtual identity, achievement, challenge, rich context, and affiliation group within a game offer great motivation to learners to engage in learning. Gee suggested that critical learning occurs in the interactive and contextual environment of a game.

Table 2.2

*Gee's 36 Principles of Learning in Educational Video Games*

Principle	Content of principle
Active, critical learning principle	Learning environment encourages active learning
Design principle	Learning about design is core to learning experience
Semiotic principle	Learning multiple sign system (images, word, etc.)
Semiotic domain principle	Learning involves mastering domain in groups
Meta-level thinking semiotic domains	Learning involves critical thinking with other domains
Psychosocial moratorium principle	Learners take risks in virtual space
Committed learning principle	Learners are committed to virtual identity
Identity principle	Learners take an different identity in virtual world
Self-knowledge principle	Learners learn about their potential in virtual world
Amplification of input principle	Learners get ample output with little input
Achievement principle	Learners grow mastery and ongoing achievement
Practice principle	Learners get contextual practices
Ongoing learning principle	Learners adapt to new or changed condition
Regime of competence principle	Learners engage in challenging activities
Probing principle	Learning in a cycle of probing the world
Multiple routes principle	Learners learn in multiple styles
Situated meaning principle	Learning is situated in embodied experiences
Text principle	Texts are understood in context and experiences
Inter-textual principle	Learners learn text as a family of related texts
Multimodal principle	Knowledge is built through various modalities
Material intelligence principle	Thinking and knowledge are stored in material objects
Intuitive knowledge principle	Intuitive knowledge is repeatedly practiced
Subset principle	Learning takes place in subset domains
Incremental principle	Learning is incremented
Concentrated sample principle	Learners get to practice concentrated samples often
Bottom-up basic skills principle	Basic skills are learned in context
Explicit information on-demand	Learners get explicit information on-demand
Discovery principle	Allow learners to explore and experiment
Transfer principle	Learners transfer what they learned earlier
Cultural models about the world	Learners reflect their cultural models in the real world
Cultural models about the learning	Learners reflect their cultural models of learning
Cultural models about semiotic domain	Learners reflect their cultural model within a domain
Distributed principle	Knowledge is distributed across learners and context
Dispersed principle	Knowledge is dispersed with other learners
Affinity group principle	Learners constitute affinity group
Insider principle	Learners are insider of learning experience

Gee (2007) further argued that “games act like the human mind and are a good place to study and produce human thinking and learning” (p. 23) because humans understand best when

they simulate experiences, and because video games provide the visual and auditory experiences in the virtual environment. Gee indicated that game designers get new players to learn long and complex games by using methods of getting people to learn and to enjoy learning. Gee discussed learning principles in games and categorized these principles in three sections: empowered learners, problem solving, and understanding. Table 2.3 summarizes the three categories of learning principles applied in games (Gee, 2007).

Table 2.3

*Gee's (2007) Learning Principles in Games*

Principles	Game elements
Empowered learners	
Learners feel like active agent (co-design)	Players dictate the game world
Learners choose learning styles (customization)	Players customize game play
Valued identity leads to commitment (identity)	Players create identity in games
Manipulation and Distributed Knowledge	Players manipulate characters
Problem solving	
A garden path approach (well-ordered problems)	Ordered problems in games
Challenges are pleasantly frustrating for competence	Adjustable challenges in games
Repeated cycles of practicing skills	Cycle of expertise in games
Information on-demand and just-in-time	Prompt information in games
A simplified system with key variables (fish tanks)	Tutorials in a game
Safe havens from real world risk (sandbox)	Sandbox effect in games
Practice skills in a context (skills as strategy)	Practice to succeed in games
Understanding	
Learning skills in a big picture (system thinking)	Fit each act into the entire game
Understanding from reconstructions of experiences	Game actions as experience

In game play, players control their playing experiences, and the virtual world changes based on players' decision. Knowledge in a game is organized in a social context, and players can practice skills repeatedly. Problems in a game are always under the big picture of the game so that players can simulate real life experiences without physical risks. Gee (2007) suggested that the principles of learning in games fit school environment and games can be applied in education.

Gee (2011) argued that video games are good for learning is untestable because (1) different categories of games have different learning effects but there is no agreeable theory on categories of games, (2) there are few theories to define goodness of games, (3) the definition of good serious games may differ from that of commercial games, (4) learners are different and a category of games may not work for all types of learners and (5) a game is only a software while learning happens in the social interactive system among learners who play the game. Gee suggested that a researcher needs to specify the content of the game and the learning system built around the game when testing games for learning. Gee stated that there are few theories to support a test of the goodness of a game, the learning system around the game, and the integration of the game and learning system.

Gee (2011) suggested that a learning theory should be applied to games for learning and “that researchers testing games for learning need to specify clearly what theory of learning their game implemented and they need to show the game implemented that theory well” (p.229). However, Gee stated that learning theories normally predict a complex set of interacting outcomes and any outcome in isolation does not relate to the theory tested. Therefore, different outcomes may occur in the test of a game because the test may be based on different learning theories. Gee stated that simplistic empirical research on games and learning may not give any meaningful conclusion.

Since we do not yet have entirely good theories of game genres, what makes a game good, the nature of good (big ‘G’) Games, the categories of learners and gamers and their interactions, and the predicted interacting, integrated outcomes of combinations of theories of learning and game design, there is a lot of work that remains to be done. (p. 231)



### **Instructional Support in Game-based Learning**

Gee (2011) argued that a game is only software and the learning occurs in the social system around the game. Games and Squire (2011) suggested the involvement of educators in the design process of educational games. Kerr (1995) stated that computer software alone cannot develop or implement a curriculum and that effective instruction needs to consider the nature of learners so as to apply technology to the ability level of students. Therefore, it is arguable that an educational game needs instructional activities to (a) integrate appropriate assistance and instructions, (b) facilitate learning based on students' ability, and (c) provide a social system for learning. Tobias, Fletcher, Dai, and Wind (2011) suggested using the term of instructional support to define any type of assistance or instruction embedded within a game. In studying instructional support in games, different forms of instructional support need to be addressed.

### **Instructional Support in Conventional Contexts**

Instructional support has been studied in non-gaming environments with different terms such as guidance. Wise and O'Neil (2009) stated that "anything an instructor provides to students to aid their learning and performance" (p. 83) can be described as guidance. Wise and O'Neil included explanation, feedback, help, modeling, scaffolding, and procedure direction under the term of guidance. Wise and O'Neil suggested that the amount, context, and timing of guidance are all important dimensions of instruction—a sufficient amount of guidance is important to the effectiveness of instruction; the context of guidance, such as a worked-example, provides to students a model to understand instructional content; immediate feedback promotes short-term learning, and delaying feedback results in long-term retention. Wise and O'Neil's study suggests that guidance can be divided into reasonable pieces, provided with worked-examples in similar contexts, and coupled with immediate and delayed feedbacks. Wise and

O'Neil advocated for situated, flexible and responsive guidance that meet the needs of student learning.

Clark (2009) defined guidance as “providing students with accurate and complete procedure information” (p. 161). Clark suggested that guidance can be provided in demonstration of new knowledge with a sequence of actions and decisions to accomplish a task. Guidance forces students to practice the provided procedure and problem-solving skills and offers supportive and corrective feedback during practices. Clark provided three criteria of guidance: (a) guidance provides accurate and complete demonstration, (b) guidance provides practice to support adaptive transfer, and (c) guidance provides immediate feedback on the practice of procedures. Clark's criteria of procedure and feedback within guidance are similar to Wise and O'Neil's (2009) concept of the worked-example and immediate feedbacks.

Kintsch (2009) defined guided practice as when instructors provide feedback to reflect students' current performance and select new tasks within students' capability of learning. Thus, instructors need to provide guided practice that facilitate student learning with proper level of challenge. Kintsch suggested that instructors provide (a) feedback to allow students to assess their current level of understanding, (b) hints about what to do when students are faced with difficulties and challenges, (c) new task to advance learning. Kintsch suggested that there are two approaches of guided practice: teaching general problem solving skills and teaching a domain specific strategy. Kintsch argued that domain specific skills cannot be transferred across situations and decontextualized knowledge may not be usable in any situation. Therefore, Kintsch argued that guided practice needs to be at the right level of abstraction, neither limited to concrete situation nor completely decontextualized, but rather to be offered with generalizable

situations. Kintsch supplemented deeper understanding on how different guidance can be implemented strategically.

Fletcher (2009) described the advantages of drill and practice as focusing on an explicit instructional objective, promoting motivation and engagement through interaction, and meeting individual needs in real time. Fletcher argued that drill and practice matches practices of intelligent tutorial system with adjusted content, sequence, difficulty, and pace for individual learners. Fletcher suggested that drill and practice is effective when objectives require steps to construct correct responses. Fletcher argued that computer-based drill and practice can be easily adopted by educational administration because of the cost effectiveness of this approach.

Kerr (1995) discussed three types of computerized instruction: drill, tutorial, and simulation. Kerr suggested that drill enhances lower-order skills with repetition and memorization, tutorials provide logical information in a sequential manner to support comprehension, and simulation provided computer experiences that closely match real-life experiences. Kerr stated that computer program can diagnose student learning by determining current situation, making an assessment, choosing a treatment, implementing the treatment, evaluating the result, and continuing the cycle again. Kerr suggested that computer program can establish formative assessment in student progress and guide students to next level. In other case, computer programs can provide remedial exercises and reinforce current work with enriched exercises or tests. The strategies of sequential instruction and assessment-driven decisions of advancement or remedial work can be implemented as instructional support in gaming context.

Tobias (2009) suggested that guidance and other forms of instructional support need to be investigated. Tobias suggested a hierarchy of different types of instructional support to reduce ambiguity in studies. Duffy (2009) suggested that studies on amount and types of guidance miss

the foundation of instruction support—learners as the driver of learning. Duffy argued that both simulation and drill and practice are acceptable approaches of instruction, and the driving force of learning is essential to make instructional effective. Students need to be motivated to learn from instructional activities, and the role of instruction is to support learning.

### **Instructional Support in Games**

Different forms of instructional support have been studied in games and simulations. Moreno and Mayer (2005) studied instructional support in forms of feedback and reflection in computer games. Undergraduate freshmen ( $n=105$ ) were randomly assigned to four treatment groups: guidance with reflection, guidance without reflection, no guidance with reflection, no guidance without reflection. Participants were exposed to various versions of games that teach knowledge on how to design plants on a new planet. After treatments, students took problem-solving tests, and results were collected. Significant differences were found among guidance and non-guidance groups,  $F(4, 98)=14.01, p<.01$ . Explanatory feedback refers to giving explanation of why the answers are correct or wrong, and responsive feedback refers to giving only the right or wrong of the answer without explanation. Moreno and Mayer found that “groups presented with the agent’s explanatory feedback gave significantly more correct answers on their transfer tests than those presented solely with information on the correctness of their answers” (p. 122). Students in the guidance with reflection group gave significantly fewer wrong answers than those in non-guidance with reflection,  $F(1, 51)=16.57, p<.01$ . Moreno and Mayer’s results showed that guidance enhanced student learning in games and explanatory feedback tends to have better result than corrective feedback.

Cameron and Dwyer (2005) studied feedback by asking students to play an instructional game. Participants ( $n=300$ ) were assigned to four treatment groups: (a) instruction only—

students study instructional units without instructional game, (b) instruction with instructional game—students play instructional games and work on questions without feedback, (c) instruction with instructional game—students play instructional game and work on questions with responsive feedback, and (d) instruction with instructional game—students play instructional games and work on questions with elaborative feedback. Results showed significant differences in student achievement when elaborative feedback was provided. The positive influence of feedback in games is related to studies of feedback in non-game environment (Clark, 2009; Kintsch, 2009; Wise & O’Neil, 2009). It can be concluded that elaborative (explanatory) feedback, which provides explanations of right or wrong answer, is an effective form of instructional support in games.

Advisement, a form of instructional support to provide background knowledge, prior knowledge and hints, has been studied in game context. Van Eck and Dempsey (2002) studied the interaction of competition and contextual advisement in a game that students are required to paint rooms. Students ( $n=123$ ) were randomly assigned to a control group and four treatment groups (with or without competition, with or without contextual advisement). Student took a pre-test, played the simulation game and took a post-test in three-day sessions. The result showed that students in contextual advisement without competition group had a higher transfer score than those in non-contextual advisement without competition. Students in non-contextual advisement with competition had higher transfer of mathematics scores than those in contextualized advisement with competition. The result showed that competition negatively impacted contextual advisement. Therefore, competition elements need to be carefully evaluated when advisement is provided in a game.

Leemkuil and de Jong (2011) studied feedback and advisement in simulation games where players played the role of knowledge manager to improve a company's knowledge household. Three experimental groups ( $n=28$ ,  $n=29$ ,  $n=286$ ) played three versions of the simulation games. The result showed significant differences between pre-test and post-test scores (effect size: 0.9, 0.8, and 0.7), and tools offering background information, feedback, and advices were frequently used by players. Leemkuil and de Jong stated that the use of advisement, including hints and recommended intervention of problems, has a significant relationship with the game performance. Leemkuil and de Jong found a significant correlation between the frequency of access of feedback and a student's post-test score. Leemkuil and de Jong indicated that players who access more background information in the game had higher post-test scores. The positive effect of advisement in games is related to hint and background information (Kintsch, 2009) and procedures (Clark, 2009; Wise & O'Neil, 2009) in conventional instructional support.

Beyond the forms of instructional support, features of support have been studied in game contexts. Mayer (2011) stated that guidance in a form of voice is more effective than that in text format. Moreno and Flowerday (2006) found that students are more willing to study with an animated agent. Dehn and van Mulken (2000) stated that students found animated agents more interesting and students' attention increased with an animated agent. Mayer, Mautone, and Prothero (2002) found that using pictorial format in instructional support improved students' performance on tasks. Although features of instructional support are not a focus of the proposed study, it can be suggested that animated features are another dimension to study instructional support.

Mayer (2011) listed three genres of game research: (a) value-added research examines the features to support learning, (b) cognitive consequence research examines what can be learned in games, and (c) media comparison research examines the difference between game and conventional media. The audio and pictorial features have been studied as value-added approach (Mayer, Mautone, & Prothero, 2002; Moreno & Flowerday, 2006). Cognitive consequence and media comparison approaches have been studied in instructional support (Moreno & Mayer, 2005). Leemkuil and de Jong (2011) suggested studying four types of supports: (a) focus on important elements, (b) choosing action and intervention, (c) evaluation, and (d) reflection. Advice, background information, and hints are related to the first and second types of support, and feedback and reflection are related to evaluation.

When studying instructional support in gaming contexts, it can be summarized that instructional support needs to be provided as intelligent guidance so that students are motivated to learn by the supporting system. The individual forms and amount of instructional support should be designed strategically to meet the exact needs of student learning in real time. For example, the directional supports (procedures and worked-examples) need to be offered to provide required knowledge for assignments in a game. Hints and feedback needs to be provided when students work on an assignment so that students receive assistance on difficult problem and know their current level of performance. Intelligent systems can guide students to practice or advance based on the assessment. An integrated system with various forms of instructional support needs to be provided to motivate student learning.

Good applications of instructional support have yet to be studied in gaming contexts. Table 2.4 shows the elements of instructional support in regular studies and in gaming studies. The practices of an intelligent tutorial system (Fletcher, 2009), guided practice (Kintsch, 2009)

and tutorial (Kerr, 1995) have not been intensively explored as instructional support in games. Individual studies on feedback, advice, and hint cannot examine the full potential of instructional support within a game. It can be suggested that studies on instructional support should focus on a system of support that covers various forms of support in a game. Beyond advice, worked example, hint and feedback, the effectiveness of guided practice, and the evaluation system to either assign players to next level or to remedial work should be further studied. Instructional support should be designed and studied as an intelligent system to facilitate learning within a game.

Table 2.4

*Criteria of Instructional Support*

Criteria	Conventional	Game
Procedures	Wise and O'Neil (2009) Clark (2009)	
Worked-example	Wise and O'Neil (2009)	
Feedback	Wise and O'Neil (2009) Clark (2009) Kintsch (2009)	Moreno and Mayer (2005) Cameron and Dwyer (2005)
Practice	Clark (2009)	
Evaluation	Kerr (1995) Kintsch (2009)	
Tutorial	Kerr (1995)	
Guided practice	Kintsch (2009)	
Advice (hint, background)	Kintsch (2009)	Leemkuil and de Jong (2009) Van Eck and Dempsey (2002)
Drill and Practice	Fletcher (2009)	
Reflection		Moreno and Mayer (2005)

**Related Motivation Theories**

Many motivation theories can be observed in game-based learning—the operant theory of stimuli and response pattern (Skinner, 1953) emphasizes on practice and drill; social cognitive theory (Bandura, 1986) explains that people learn from observing the environment; Maslow's



(1970) the hierarchy of needs describes on belonging, esteem, and self-actualization; three needs theory (McClelland, 1976) studies on achievement, affiliation, and power; and personal causation theory (deCharms, 1968) advances the idea that that people want to control their own behaviors. The effectance theory (White, 1959), flow theory (Csikszentmihalyi, 1975), and self-determination theory (Ryan & Deci, 2000b) explained motivation from innate and psychological perspective but have different focuses on intrinsic motivation.

### **Effectance Motivation**

White (1959) argued that motivation theories built upon primary drives “have proved to be inadequate in explaining exploratory behavior, manipulation, and general activity” (p. 328) and that the theory of basic instincts cannot explain the development of the effective ego. White stated that “there is no longer any compelling reason to identify either pleasure or reinforcement with drive reduction, or to think of motivation as requiring a source of energy external to the nervous system” (p. 328). White used the word competence to indicate the common behaviors to learn how to interact effectively with the environment. White proposed that the competence capacity is considered an innate attribute and is “attainted through prolonged feats of learning” (p. 297). White used the term *effectance* to describe one’s motivation of competence. The experience produced by the motivation of competence is described as a feeling of effectance. White argued that effectance motivation is moderate and persistent, leading to a competent interaction without an immediate pressing need.

Harter (1981) expanded White’s (1959) effectance motivation by arguing that the general need for effectance is too broad, making it difficult to operationalize in empirical tests. Harter refined the need of effectance into three components: preference for challenge, curiosity, and independent mastery. The components were used to develop three subscales to study children’s

intrinsic versus extrinsic motivation toward learning. Harter designed the framework to test the relationship between competence and intrinsic motivation, and the subscales were the instruments to test the relationship in children.

While White (1959) studied intrinsic motivation and competence as a general concept, Harter studied effectance in a practical approach. White related the development of competence to the learning process, stating that the need of competence provides the energy for learning. The effectance motivation can be generally applied to learning activities such as walking, manipulating, and acting effectively. Thus, effective actions will lead to the feeling of competence, and the motivational counterpart of competence is called effectance motivation. Harter (1981) conceptualized the components of effectance motivation for the purpose of measuring intrinsic motivation of students. In her study, the measurement of preference of challenge, curiosity, and independent mastery are applied to measure the intrinsic motivation of students. Harter's approach of effectance motivation is highly applicable to studies on student learning.

### **Flow Theory**

Csikszentmihalyi (1975) emphasized enjoyment and intrinsic motivation in his study. He defined the term *autotelic* activity as activities that “require formal and extensive energy output on the part of the actor, yet provided few if any conventional rewards” (p. 10). Intrinsically motivated activities lead to enjoyment, and the experience of enjoyment is the reward. Csikszentmihalyi provided information on the kind of rewards derived from autotelic activities and showed the characteristics that make an activity enjoyable. He demonstrated a model of intrinsic rewards and proposed that true components of enjoyment include flow experience. Csikszentmihalyi argued that people lose the sense ego and experience the unity between the

person and activity in the *state of flow*. Csikszentmihalyi developed a model of flow processes to “describe the common structure of activities that are experienced as enjoyable” (p. 11).

Csikszentmihalyi (1975) described the elements of a flow experience. First, the state of flow shows the merging of action and awareness that “is aware of his actions but not of the awareness itself” (p. 38). Flow occurs when the activities are feasible with clearly established rules. Second, flow requires a centering of attention on the activity without external interruption. Third, the structure of the activity must provide motivational elements such as competition, gain, and danger. Extrinsic reward can be distractive elements, and intrinsic motivation can be a powerful incentive added to the effect of extrinsic rewards. Fourth, flow experiences show the loss of ego and the self-forgetfulness. Fifth, flow occurs when a person is in control of the activity and the environment. Sixth, flow occurs when there is clear and unambiguous feedback from the activity. Finally, flow shows an autotelic nature in that no external rewards are required.

### **Self-Determination Theory**

Self-determination theory focuses on innately psychological needs for competence, autonomy and relatedness (Ryan & Deci, 2000b). Self-determination theory defines needs as innate and psychological, and Ryan and Deci (2000b) investigated “people’s growth tendencies and innate psychological needs as the basis of self-motivation and personality integration, as well as for the conditions that foster those positive processes” (p. 68). *Relatedness* refers to the feeling of belongingness and connectedness with others. *Competence* refers to the feeling of efficacy with respect to an activity. *Autonomy* refers to a sense of choice and freedom from external pressure. In self-determination theory, the three basic psychological needs of relatedness, competence and autonomy are critical factors of intrinsic and extrinsic motivation. These needs are fundamental indicators of motivation.

Cognitive evaluation theory (CET), a sub-theory of self-determination theory, focuses on the social and environmental factors that facilitate intrinsic motivation (Deci & Ryan, 1985). Ryan and Deci (2000b) further analyze intrinsic motivation by examining the conditions that sustain intrinsic motivation instead of the causes of intrinsic motivation. Based on feedback and rewards, cognitive evaluation theory focuses on the fundamental needs of competence and autonomy. The authors argue that perceived competence, such as optimal challenges and positive performance feedbacks, facilitates intrinsic motivation. Further, Ryan and Deci argue that “the feeling of competence will not enhance intrinsic motivation unless accompanied by a sense of autonomy” (p. 70). Thus, people must experience a sense of both competence and autonomy to sustain intrinsic motivation, and the contextual supports for competence and autonomy come from prior perception of the two factors.

Organismic integration theory (OIT), another sub-theory of self-determination theory, details and differentiates various forms of extrinsic motivation that internalize and integrate external values (Ryan & Deci, 2000b). Internalization refers to people’s acceptance of a value, and integration refers to people’s transformation of the value into their own. The least autonomous form is external regulation since behaviors are performed as a result of external demand or reward. The second type is introjected regulation, where people perform behaviors due to self-esteem, such as a feeling of pride. Identified regulation is a more autonomous form of extrinsic motivation, where people perform behaviors because they accept the value of the behavior as personally important. The most autonomous form of extrinsic motivation is integrated regulation. This is where people perform behaviors because they incorporate the external activities into their own value system. According to Ryan and Deci (2000b), the

internalization process can be developed at any point of the learning process, depending on prior experiences and current situational factors.

### **Comparison of Three Theories**

Effectance theory, flow theory and self-determination theory all describe motivation as innate and psychological. Operant theory (Skinner, 1953) states that the changes of behaviors are the result of the response to external stimuli, and that external drives such as rewards are conditions that initiate an individual's response. Cognitive theories perceive learning as a result of observation of one's environment and the environmental influence on an individual's behavior (Bandura, 1986). Effectance theory, flow theory and self-determination theory conjecture that motivation stems from an intrinsic perspective and emphasize that the source of motivation is innate. All three theories challenge previous operant theory and cognitive theories, where those theories fail to explain human needs.

All three theories describe motivational elements for intrinsic motivation. Effectance theory proposes a need for effectance as the basic motivational property. Competence is considered the result of interaction with the environment and learning. Flow theory focuses on the feeling of enjoyment and argues that people are unaware of external impacts in a state of flow. In all three theories, competition, gain, and danger are related to intrinsic motivation, and extrinsic rewards are regarded as interruption. Self-determination theories list three psychological needs as the basic elements for intrinsic motivation. The three theories uniformly show the intrinsic nature of motivation beyond external drives and demonstrated different needs in motivation. Table 2.5 demonstrates the different motivation approaches of these theories.

Table 2.5

*Motivation Theories and Motivational Focuses*

Theory	Motivational focus
Operant theory (Skinner, 1953)	Stimuli and response
Social cognitive theory (Bandura, 1986)	Observing the environment
Hierarchy of needs (Maslow, 1970)	Belonging, self-esteem, and self-actualization
Three needs theory (McClelland, 1975)	Achievement, affiliation, and power
Personal causation theory (deCharms, 1968)	Control own behavior
Effectance theory (Harter, 1981; White, 1959)	Competence
Flow theory (Csikszentmihalyi, 1975)	Enjoyment
Self-determination theory (Ryan & Deci, 2000b)	Competence, autonomy, and relatedness

However, effectance theory, flow theory and self-determination theory evaluate intrinsic motivation using different approaches. Effectance theory emphasizes the importance of competence as the major source of intrinsic motivation (White, 1959). The need of competence provides the energy for learning, and competence covers three components: preference for challenge, curiosity, and independent mastery (Harter, 1981). Flow theory approaches intrinsic motivation from enjoyment perspective, listing competition and control as elements that can initiate the state of flow (Csikszentmihalyi, 1975). Thus, competence is only one of the elements by which one can achieve enjoyment and intrinsic motivation. Self-determination theory divided motivational factors into three psychological needs of relatedness, autonomy, and competence. In contrast to effectance theory, Deci and Ryan (1985) argued that competence will not cause intrinsic motivation unless there is a sense of autonomy. Further, extrinsic motivation can be

transformed into intrinsic motivation if people perform behaviors because they assimilate the external activities into their own value system. Thus, the three theories perceive and categorize the elements of intrinsic motivation from different perspectives and offer different emphases in their studies.

### **Motivational Factors in Game-Based Learning**

Prensky (2001) stated that game-based learning is learner-centered, representing an effective learning process that can appeal to and excite people from gaming generations. The major goal of game-based learning is to motivate students. Traditional motivators include sticks, such as fear, and carrots, such as love and greed. Power, lust, self-actualization, ego-gratification, winning, pleasure, and fun are all motivators. Prensky argued that pleasure and fun will combine with other powerful elements in games to create learner-centered environment through game-based learning. Fun and play are positively related to learning because fun creates relaxation and motivation and play enhances learning by providing pleasure and involvement.

Prensky (2001) listed six key structural elements of games: (a) rules, (b) goals and objectives, (c) outcomes and feedback, (d) conflict, competition, challenge, and opposition, (e) interaction, and (f) representation and story. Rules are the most basic definition of a game, meaning that the game is organized and there is a set of limits within the game. Goals and objectives are the small pieces of what motivates learners. Outcomes and feedback measure progress, while learning takes places as a result of feedback. Conflict, competition, challenge, and opposition are the problems in a game to be solved. Interaction is the social aspect of a game. Representation and story are about themes and fantasy.

Bartle (1996) described four types of players as killers, achievers, socializers, and explorers. The author argued that players fall into each of four quadrants defined by two

dimensions of behaviors in (a) acting versus interacting, and (b) focusing on other players versus focusing on elements in virtual world. In the two dimensions of behavior, killer, achiever, and explorer can be related to the construct in the virtual world while competence, challenge, curiosity, and other motivational elements in the three motivation theories can be applied to these game constructs. Further, the behaviors of socializers can be related to the concept of relatedness described by self-determination theory. According to Bartle, the quality of a designed game can be highly related to the effects of learning, and a good game should satisfy all types of players to initiate learning through the game.

Yee (2006) identified achievement, social, and immersion components as motivation factors in online games. The achievement components include: (a) advancement, the desire to gain power and win; (b) mechanics, an interest in analyzing the underlying rules and system; and (c) competition, the desire to challenge and compete. The social components include (a) socializing, an interest in helping and chatting; (b) relationships, desire for long-term relationship with others; and (c) teamwork, being part of a group. The immersion components include (a) discovery, finding and knowing things; (b) role-playing, creating a virtual person; (c) customization, an interest in customizing the appearance of a virtual character; and (d) escapism, getting away from real life. Yee suggested that elements are independent from each other so that people are motivated through challenge may not be motivated by the social components. Yee proposed that the ten elements can be used as a framework to "understand the preference for and effects of game-play for different kinds of players" (p. 775).

Dickey (2007) argued that current games are more sophisticated in various forms, where character design, narratives, chat, and communication tools are employed. Dickey listed choice, control, collaboration, challenge and achievement in the environment of Massively Multiplayer



Online Role-Playing Game (MMPRPG). The various theories mentioned in the proposed study can be matched with the specific elements in Bartle (1996) and Yee's (2006) works. When relating the motivation factors of gaming to motivation theories, competence, mastery and fantasy can be related to the elements discussed in Effectance theory. The same elements can be found in the state of flow, and enjoyment is the key to relate gaming to flow experiences. In self-determination theory, the needs of autonomy and competence are highly related to the achievement and immersion components described in Yee's (2006) work.

Bartle (1996) and Yee (2006) demonstrated that the motivational factors not only cover the relationship between players and the construct of games but also covers the relationship among players. Thus, players can be motivated through the constructs of gaming contexts to establish competence and mastery, and the relationships between players perform an important role in initiating motivation. The effectance theory focuses primarily on competence, and flow theory focuses primarily on the elements for enjoyment. The two theories are concerned with the interaction of players and gaming constructs. Self-determination theory covers the need of relatedness beyond the need of competence and autonomy. The characteristics of game-play are not limited to the content of games. Therefore, the experiences of social interaction with the other players become an important feature in gaming experiences. The need for relatedness in self-determination theory is highly related to Yee's social component. As Gee (2011) indicated, the learning system around a game is the source of learning. Social interaction in a game will be a major source to engage in learning, and the need for relatedness is an important factor for game-based learning.

### Self-Determination Theory and Game-Based Learning

Ryan, Rigby, and Przybylski (2006) applied self-determination theory in their study on video games and showed positive relationship between the satisfaction of the three psychological needs and enjoyment. Ryan et al. developed four studies to evaluate the relationships between needs of autonomy, competence and relatedness and game enjoyment, self-esteem, preference for future play and continued play behavior. A 7-point Likert-type *Game Play Questionnaire* was used in the study, including items for in-game competence ( $\alpha=.79$ ) and in-game autonomy ( $\alpha=.66$ ). In Study 1, undergraduate students (23 male; 66 female) were required to play the game *Super Mario 64* for 20 minutes, and the questionnaires were administered as pre and post-tests. The results showed that game enjoyment and preference for future play were significantly associated with autonomy,  $F(1, 83)=4.77, p<.05$ , and competence,  $F(1, 83)=10.58, p<.001$ . In Study 2, undergraduate students (36 female; 14 male) participated in sessions during different days and played two different games with random assignment. Ryan et al. compared the effects of autonomy and competence in two games with different favorability ratings. The two games were *Zelda: The Ocarina of Time* with high rating of 97.8% favorability and *A Bug's Life* with a low rating of 56.6%. Same questionnaire as Study 1 was administered before and after a 40 minutes play. The results showed that players have higher level of enjoyment and preference for future play in *Zelda* than in *A Bug's Life*, and that autonomy,  $F(1, 48)=8.52, p<.01$ , and competence  $F(1, 48)=8.89, p<.01$ , are highly associated with players' enjoyment,  $F(1, 48)=25.11, p<.001$ , and preference for future play,  $F(1, 48)=24.75, p<.001$ .

In Study 3, Ryan et al. (2006) recruited undergraduate students (46 female, 12 male) to play four different genres of games in different sessions. Ryan et al. attempted to study the effects of autonomy and competence in different genres of games. The games were *Super Mario*

64, *Super Smash Brothers*, *Star Fox 64*, and *San Francisco Rush*. The same questionnaire as Study 1 and 2 was administered before and after 40 minutes of play sessions. The result showed that, although players' enjoyment levels vary in different games, satisfaction of autonomy,  $\beta=.55$ ,  $p<.01$ , and competence,  $\beta=.35$ ,  $p<.01$ , is positively correlated to greater enjoyment and preference for future play. Ryan et al.'s last study consisted of 730 members (51 male, 679 female) in massively multiplayer online games (MMO). Participants completed a survey related to MMO environment and the survey was similar to the questionnaire in Study 1, 2 and 3, but with fewer items on competence ( $\alpha=.63$ ) and autonomy ( $\alpha=.71$ ) and extra items on relatedness ( $\alpha=.72$ ). The study showed that autonomy and competence are predictors of players' enjoyment,  $F(1, 729)=97.37$ ,  $p<.01$ . The satisfaction of relatedness is significantly related to players' motivation and enjoyment in the MMO environment. The study showed that the nature of game control, game mastery, and in-game relationship are well related to the psychological needs of autonomy, competence, and relatedness.

Ryan et al.'s (2006) study demonstrated that self-determination theory can be applied to analyze the relationship of video game and motivation. In four experiments, the players' enjoyment and motivation are highly correlated to autonomy, competence, and relatedness. Ryan et al. suggested the satisfaction of three psychological needs—autonomy, competence, and relatedness—as indicators to predict motivation. The study indicated that players' motivation level may vary in different genres of games and in games of different favorability ratings, but the satisfaction of the three psychological needs and motivation level were positively correlated.

### **Practices of this Study**

Some commercial game developers have done a great job applying learning principles in game design so that players enjoy gaming experiences while learning academic and gaming

skills (Gee, 2007; Prensky, 2001). Prensky (2001) argued that game-based learning needs to be fun first, and then learning will follow. Games and Squire (2011) discussed the focus of flow (Csikszentmihalyi, 1975) in educational games. From the game developers' perspective, enjoyment of the gaming experience is the primary goal. From educators' perspective, learning outcomes are the primary focus of game-based learning. On one hand, game developers' perspectives can be challenged by the questions of whether enjoyment is adequate to initiate learning. On the other hand, one can challenge how much learning can be achieved in a gaming environment without game enjoyment. As Gee (2011) addressed, the definitions of a good educational game and a commercial game are different. Therefore, game-based learning needs to be studied from game developers' perspective to design motivational games and from educators' perspective to establish learning. This study may add more understanding of how to integrate two perspectives of game-based learning.

### **Application on Motivation**

Some motivational factors are universal to many motivational theories and gaming experiences, and these factors can be applied in game design. Integrating the subject content into the enjoyable context is important when developing educational games. Enjoyable contexts in games are the first factor that should be considered. Prensky (2001) mentioned fantasy and curiosity as concepts that make games enjoyable. Rieber (1996) described a sense of fantasy that brings learning into meaningful and playful interaction. The enjoyable context factor can be found in the immersion component of motivational factor in Yee's (2006) study.

Another type of enjoyable context is the simulation of life experiences in a virtual world. An advantage of a virtual world is the sandbox effect, where real life experiences can be simulated without physical risk in real life (Gee, 2007). Dai and Wind (2011) mentioned that

students of low social economic status have less access to materials in real life. A virtual world can provide disadvantaged students opportunities to simulate real life experiences by interacting with virtual characters. These students can simulate real world examples in a fantasy world without physical constraints. Therefore, the enjoyable context is a critical consideration in educational game design to facilitate motivation.

Competence is the second motivational factor that can be applied in game design. Yee (2006) stated that the achievement component of games includes the desire to gain power and win, an interest in analyzing the rules, and the desire to be challenged and to compete. Prensky (2001) listed conflict, competition, challenge, and opposition as major factors of games. Competition can be applied between players and within virtual worlds in formats such as time limits and different levels of a game. Competition can be applied between players when students try to win the game and triumph over other players. Competition within a game can be designed not only through the mastery of content but also through the comparison of performance of other players. Students can compete on the shortest time or minimum error to complete a task and achieve a goal. However, too much difficulty at the beginning may discourage gaming experiences. Van Eck and Dempsey (2002) found that competition negatively impacted players' learning when advices were implemented in a game. Prensky (2001) suggested that a good game design is balanced so that "the game is challenging but fair, and neither too hard nor too easy at any point" (p. 133).

The third motivational factor is interaction within a game. Gee (2011) argued that a game is only software and the social system around a game is the key to learn. Yee (2006) stated that the social components of games include an interest in helping and chatting, desire for long-term relationship with others, and being part of a group. Prensky (2001) listed interaction as the major

factor of game. When students play games, they want to socialize with other players or interact with the virtual characters. Interaction with other players can be achieved in multiplayer games where players can collaboratively complete a task and contribute to the game playing. Another approach of interaction can be built between the player and virtual characters. Virtual agent can provide help, guidance, and other forms of instructional support within a game.

The motivational factors of enjoyable context, competence, and social interaction can be related to many motivational theories such as flow (Csikszentmihalyi, 1975), effectance (White, 1959), and self-determination (Ryan & Deci, 2000b). While enjoyment of flow theory is heavily applied by game designers, other motivational factors such as competence and social interaction need to be addressed in designing educational games as well. This study attempts to apply self-determination theory and study motivational factors of autonomy, competence, and relatedness. Results will provide game developers practical suggestions on how to integrate motivational factors into an educational game.

### **Application on Instructional Support**

Jin and Low (2011) stated that “a game designer can either allow players to choose their own level of expertise or set up an incremental testing procedure to upgrade a learner’s status” (p. 405). When designing an educational game, students’ prior knowledge, the related curriculum, the learning objective, and the evaluation mechanism should be considered. Many studies on game-based learning examined individual forms of instructional support on game-based learning, such as advice (Van Eck & Dempsey, 2002), and feedback and reflection (Cameron & Dwyer, 2005; Moreno & Mayer, 2005). Tobias et al. (2011) suggested further investigation of different forms of instructional support.

Instructional support in conventional strategy covers many individual practices such as offering procedure and worked-examples (Wise & O'Neil, 2009), feedback and practices (Clark, 2009), and evaluation (Kintsch, 2009). In the application of guidance and feedback, game developers can integrate rules and learning objectives in a format of guidance within a game. At the beginning of the game, the instructions and rules need to be provided to players, and the options for help in the game should be emphasized. The guidance can be provided when players explore new materials or when they encounter difficulties. Players can be provided with the options for using the guidance whenever they need information or help. The guidance can include pictures, audio, and text format so that all types of learners can utilize the guidance. Feedback on wrong answers or mistakes can be provided as explanatory feedback. At the end of the game, a summary or explanation of the content and learning objective can be utilized so that players develop a better understanding of the subject explored in the game.

Jin and Low (2011) mentioned that redundancy of information provided may negatively impact learning. The redundancy of guidance, instruction, and feedback may increase players' reluctance to use the feedback functions in the game. The design of guidance should actively consider players' preferences and give the option for when and how to utilize guidance in the game. Good guidance only provides the learning principles as the instruction at the beginning so that players understand the rule to follow. In the middle of the game, guidance should be provided in an interactive way so that players control on when and how to use the guidance. Games should not give too much negative feedback or warning to avoid mistakes.

The key component of instructional support is to provide students appropriate support so that students are motivated to learn (Duffy, 2009). Guided practice (Kintsch, 2009) and tutorial (Kerr, 1995) in conventional practices can be applied in educational games. The right

combination of various forms of instructional support needs to be studied in the gaming environment so that students are motivated to learn through games. This study extends the studies on feedback (Moreno & Mayer, 2005) and advisement (Van Eck & Dempsey, 2002) to further investigate guided practices within games. This study combines several forms of instructional support that can be implemented in games.

This study attempts to examine guided practice and feedback in an educational game. Thus, beyond the feedback, students are prompted to the next knowledge level based on their previous game performance. Students advance to the next level of game with higher difficulties if they perform correctly, or students play at the same level of difficulty if they are not proficient on the current knowledge. Results of this study will increase an understanding of how instructional support elements in specific subject materials can be implemented in educational games. The finding helps game developers and educators effectively utilize instructional support so that instructional goal can be integrated into an educational game.

### **Conclusion**

Results of this research can be applied from two perspectives, game designers who design educational games and educators who apply game-based learning in schools. From game developers' perspective, an educational game needs to foster enjoyment and be motivational. From an educator's perspective, game-based learning should be motivational and be able to achieve learning goal. Therefore, application of this research needs to meet the needs from both sides. This study utilized motivational theories to examine components that can be applied to design a motivational game. This study applied instructional supports to evaluate practices to implement game-based learning. Results of this study will benefit both game designers and educators when they design an educational game or apply game-based learning.



## **CHAPTER 3**

### **METHOD**

Over the past two decades, technological advancements have had an impact on the fundamental means of teaching and learning by providing computer and Internet-based environments that are both interactive and entertaining. Game-based learning, which engages students in the interactive and entertaining environment of computer games, has been brought to the attention of researchers, educators, and game developers. Multiple empirical studies have shown positive results when using game-based learning in specific subjects such as computer science (Papastergiou, 2009), social studies (Abrams, 2009; Huizenga, Admiraal, Akkerman, & Ten Dam, 2009), and mathematics (Ke, 2008). Effects of game-based learning can be studied across different subjects such as that represented by the current science-technology-engineering-mathematics (STEM) programs found at the elementary and secondary through postgraduate levels (U.S. Department of Education, 2007). Clark and Ernst (2009) found that gaming brings technology to other STEM subjects, as well as career awareness to classrooms. Evidences indicated that game-based learning can be studied across technology and mathematics, as well as career-related courses.

The subjects of technology, mathematics and career skills are important areas in high school career and technical education (CTE) curriculum. Career and technical education includes educational activities that teach academic and technical knowledge and skills for employment in the Carl D. Perkins Career and Technical Education Act (2006). Mathematics is a major employable skill that career and technical education attempts to improve in its curriculum. Stone,

Alfeld, and Pearson (2008) demonstrated a math-enhanced model to integrate mathematics in career and technical education curriculum in order to introduce mathematics concepts in career-related contexts. The ultimate goal of the model was to help students understand traditional mathematics examples and succeed in formal assessments. Wu and Greenan (2003) indicated that career and technical educational curriculum should integrate generalizable mathematics skills in order to facilitate the transition of learners from CTE to educational and practical skills. It is necessary for researchers to engage in further investigation on the effects of game-based learning of mathematics beyond career and technical education contexts by integrating generalizable mathematics problems in CTE curriculum.

### **Purpose Statement and Research Questions**

The purpose of this experimental study was to examine the interactive effects of instructional support and game-based learning of high school mathematics. Instructional support referred to any type of assistance that helps students learn and included guidance, explanations, directions, and other types of assistance (Tobias et al., 2011). This study focused on the use of a computer game as the vehicle of instructional support. The computer game, *MathFighter*, was a researcher-developed game that integrated mathematics concepts. The control condition was learning without participation in a computer game or receipt of instructional support. Three experimental conditions were (a) learning mathematics with instructional support in a non-gaming environment, (b) game-based learning of mathematics with instructional support consisting of guided practice and feedback, and (c) game-based learning of mathematics without instructional support.

The dependent variable, motivation, included both extrinsic and intrinsic motivation, where extrinsic motivation referred "to the performance of an activity in order to attain some

separable outcome” and intrinsic motivation referred “to doing an activity for the inherent satisfaction of the activity itself” (Ryan & Deci, 2000b, p. 72). According to Ryan and Deci (2000b), three basic psychological needs—relatedness, competence, and autonomy—are of central importance in transforming extrinsic motivation into intrinsic motivation so that external values can be “evaluated and brought into congruence with one’s other values and needs” (p. 73). Relatedness refers to the feeling of belongingness and connectedness with others. Competence refers to the feeling of competency with respect to an activity. Autonomy refers to a sense of choice and freedom from external pressure. Relatedness, competence, and autonomy were examined as indicators of intrinsic and extrinsic motivation.

In this study, the following research questions were addressed:

1. What was students’ level of enjoyment toward computer games with or without instructional support?
2. What was students’ academic achievement on mathematics based on whether game-based learning or instructional support was provided?
3. What were the characteristics of students’ motivation toward mathematics based on whether game-based learning or instructional support was provided when measured on the motivational factors of autonomy, competence, and relatedness?
4. What were the differences of students’ level of game enjoyment toward computer games with or without instructional support?
5. What were the interactive effects of game-based learning and instructional support on students’ academic achievement?

6. What were the interactive effects of game-based learning and instructional support on students' motivation toward mathematics when measured on the motivational factors of autonomy, competence, and relatedness?

### **Design**

A pretest-posttest control group design with random assignment (Gall, Gall, & Borg, 2007) was used to evaluate career and technical education (CTE) students' academic achievement on game-based learning of high school mathematics, while a posttest-only control-group design with random assignment was used to evaluate their game enjoyment and the motivational effects. Participants were randomly assigned to either a control group or one of three treatment groups prior to treatment administration. Participants in the control group (Group 1) engaged in learning without computer game or instructional support, and those in one of the three experimental conditions engaged in learning mathematics with instructional support in non-gaming environment (Group 2), game-based learning of mathematics with instructional support (Group 3), or game-based learning of mathematics without instructional support (Group 4).

The experiment was administered over three sessions. Participants in the four groups took a mathematics pretest at the beginning of the first session and a mathematics posttest at the end of the last session. Participants in the two game-based learning groups (Groups 3 and 4) took the *Game Play Questionnaire* after each of the three sessions. Participants in the control group completed the *Basic Psychological Needs Scale* at the beginning of each session, while those in the three treatment groups completed the same questionnaire at the end of each session.

### **Pretest-Posttest and Posttest-only Control-group Designs**

Campbell and Stanley (1963) described three true experimental designs: pretest-posttest control-group, Solomon four-group, and posttest-only control-group. A pretest-posttest control

group design includes “at least two groups of research participants, one of which is called the control group” (Gall et al., 2007, p. 405). The control group does not receive treatment or receives an alternate treatment that is different from the treatment group(s). In a pretest-posttest control-group design, participants are randomly assigned to control and experimental groups, both groups are administered a pretest, a treatment is administered to the experimental group only, and then both groups complete a posttest. A Solomon four-group design expands the pretest-posttest control group design by adding two groups without pretests, one with treatment, and one without treatment.

A posttest-only control group design works in the same way as a pretest-posttest control group design except that the pretest is eliminated. Gall et al. (2007) described the steps of a posttest-only control group design as (a) random assignment of participants to control or experimental groups, (b) treatment administered to an experimental group and treatment withheld from a control group, and (c) a posttest administered to both groups. A posttest-only design is recommended when administration of a pretest is impossible or may have an effect on experimental result.

### **Design Options: Advantages and Disadvantages**

Campbell and Stanley (1963) argued that a pretest is not essential to a true experimental design because, “within the limits of confidence stated by tests of significance, randomization can suffice without the pretest” (p. 25). Randomization refers to the procedure to “assign each subject to a treatment condition completely at random” (Keppel & Wickens, 2004, p. 8). Keppel and Wickens (2004) stated that randomization controls the time of the testing and the environmental factors of the experiment simultaneously. Any preexisting differences among treatment and control groups are controlled through randomization without concern for variation

of intelligence, emotionality, attitude, background, and prior experiences of participants. In other words, bias is equally spread between both groups.

Gall et al. (2007) argued that randomization may not fully eliminate the initial differences between control and experimental groups, causing posttest scores to reflect something other than treatment or lack of treatment. Keppel and Wickens (2004) argued that some accidental differences among groups cannot be eliminated and “groups will never be exactly equivalent with regard to environmental features or to differences among subjects” (p. 9). Gall et al. suggested using large sample sizes because “random assignment is most effective in equating groups when large numbers of research participants are involved” (p. 409). But Keppel and Wickens stated that “we can never run sufficiently large number of subjects to guarantee a perfect balancing of every nuisance variable” (p. 9).

Another disadvantage of the posttest-only design is that participants cannot be measured in subgroups to determine the effects of treatment on individuals at different levels (Gall et al., 2007). Campbell and Stanley (1963) suggested that the pretest score can be used for leveling or as a covariate, which makes a pretest-posttest design more powerful. Gall et al. (2007) stated that a third disadvantage of the posttest-only design is the issue of differential attrition during the experiment, i.e., when participants drop out of the experiment before the end of the experiment. Differences in posttest results between treatment and control groups may come from different characteristics of the two groups. Campbell and Stanley stated that pretest score provides information to explain the differential mortality between control and experimental groups.

An advantage of posttest-only design is the elimination of the threat to external validity on interaction of testing and treatment. Campbell and Stanley (1963) stated that a pretest may sensitize participants to the problem, increasing the educational effect of the treatment or

resulting in the treatment being effective only on the pretest group. Gall et al. (2007) noted that pretesting on intrinsic motivation might sensitize participants by affecting their behavior in an experiment. Therefore, a posttest-only design can work well in circumstances where a pretest may threaten external validity.

Another advantage of a posttest-only design is the simplification of the design over a pretest-posttest or Solomon four-group design. Campbell and Stanley (1963) stated that the latter experimental designs can double the efforts of an experiment, and that the extra gains from these designs may not be worth the extra effort. Compared to a pretest-posttest design, a posttest-only design eliminates pretest procedures, and is the simplest version of the three true experimental designs. A posttest-only design may work sufficiently unless there is a serious concern about the randomization process.

### **Selected Design for This Study**

I chose a pretest-posttest control-group design for evaluating students' academic achievement because the threat of pretest would not be presented if the experiment was administered in regular classrooms and the assessment materials were those usually used (Campbell & Stanley, 1963). I chose a posttest-only control-group design for evaluating game enjoyment and student motivation because the threat to external validity when using a pretest was a critical concern. Gall et al. (2007) recommended this experimental design for intrinsic motivation research, and Campbell and Stanley (1963) supported this design for attitude studies. Campbell and Stanley stated that a posttest-only control-group design does not have any inherent threat to internal validity. Since this study focused on student intrinsic motivation and tried to evaluate intrinsic motivation after treatment, a pretest could have sensitized participants regarding motivation. Therefore, a pretest was not appropriate for this study. Further, the

disadvantage of a posttest-only design was controlled by random assignment and use of a large sample size. This study compared the motivational effects of instructional support with or without game-based learning by recruiting participants with similar background and knowledge levels from career and technical education classes. Randomization and large sample size were deemed sufficient to equate control group and treatment groups.

### **Internal and External Validity**

Campbell and Stanley (1963) listed eight threats to internal validity and four threats to external validity. Internal validity refers to “the extent to which extraneous variables have been controlled by the researcher, so that any observed effect can be attributed solely to the treatment variable” (Gall et al., 2007, p. 383), and includes history, maturation, testing, instrumentation, regression, selection, mortality, and interaction of selection as sources of internal invalidity. Gall et al. defined external validity as “the extent to which the findings of an experiment can be applied to individuals and settings beyond those that were studied” (p. 388). Campbell and Stanley listed interaction of testing and treatment, interaction of selection and treatment, reactive arrangement, and multiple treatment interferences as sources of external invalidity.

Although Campbell and Stanley (1963) suggested that internal validity is controlled in true experimental designs by randomization, several threats to internal validity have been addressed in this study. History refers to the threat due to other events besides the treatment that might impact research participants. Randomization can control this threat generally if members of all research groups experience similar history. However, Campbell and Stanley recommended controlling the threat of intrasession history, a threat that irrelevant events impact participants differently if the control and treatment groups participate in different sessions. In this experiment, random assignment was applied to reduce the threat of history. Furthermore, the experimental



context was similar for both control and experimental groups in each session. Participants in four randomly assigned groups completed the assigned tasks during regularly scheduled classes in similar classrooms, under the supervision of regular classroom teachers. The similar experimental context reduced the threat of intrasession history.

According to Campbell and Stanley (1963), threats of maturation and testing are controlled in a true experimental design because randomization equally allocates the threat to control and experimental groups. Randomization rules out the threat of regression, selection, and interaction of selection and maturation. However, the threat of mortality was addressed in this study. Mortality refers to “the phenomenon of losing research participants during the course of an experiment” (Gall et al., 2007, p. 386). When experimental treatments are spread out over several sessions, the different sessions for pretest, treatment, and posttest may cause mortality. Gall et al. suggested minimizing mortality by randomly assigning students to control or treatment groups and by making treatments equally desirable. I controlled this potential threat by developing the experiment with random assignments. Students did not favor one treatment over the other because they were advised not to discuss their treatments until the completion of the experiment. Students were advised that they would have the option to try other treatments after the experiment. Students were also advised that a bonus of a participation grade would be given if they participated in all sessions.

According to Campbell and Stanley (1963), one advantage of a posttest-only design is the absence of the threats of interaction of pretest and treatment. Even though the interaction of pretest was not a concern in this study since audience is unlikely to be sensitized to the mathematics assessment, other threats existed to external validity. The threat of interaction of selection and treatment refers to the possibility of using unique population for the experiment

and control groups. I controlled the threat of selection and treatment by selecting more classes within a school so that students were not limited to any specific group. I recruited eight classes from career and technical education classes. Students in each class were randomly assigned to either the control or one of three experimental groups.

Another potential threat to external validity was the threat of reactive arrangement, a situation where participants behave differently when they realize that they are participants in an experiment with different treatments (Campbell & Stanley, 1963). Campbell and Stanley (1963) mentioned that the presence of strangers in a classroom may create expectations of the unusual, and randomization will not nullify this effect. The experiment can be conducted by regular classroom teachers, thereby reducing any irregular impression that may affect results. I controlled the potential threats using several approaches. First, experiment proctors were regular classroom teachers with whom the students were familiar. Second, proctors advised students that they would have an opportunity to try all treatments after the experiment. Third, students were advised not to interact with other groups before the completion of the experiment. Although I expected participants to realize that other students were in different treatment groups, I expected that the threat was controlled at a minimal level in that the role of regular classroom teachers as proctors would reduce the irregular impression.

## **Treatment**

### **Treatment Process**

This experiment included four conditions. Participants were randomly assigned to either a control or one of three treatment groups. Participants in the control group engaged in learning without exposure to a computer game or instructional support, while those in one of the three experimental groups engaged in (a) learning mathematics with instructional support in a non-

gaming environment, (b) game-based learning of mathematics with instructional support, or (c) game-based learning of mathematics without instructional support. Mathematics in this study referred to high school geometry in Mathematics I of Georgia Performance Standards (GPS) developed by Georgia Department of Education (2006). All materials related to mathematics were designed and validated by a focus group of five certified mathematics teachers in the secondary school where the experiment was administered. The focus group was selected to include four teachers who were teaching the same mathematics content of the experiment during this semester and one department chairperson.

Two versions of the mathematics computer game with or without instructional support elements were designed for this study. The same instructional support elements were used with the non-gaming treatment group. A treatment manual was developed to guide experiment administration so that all treatments were standardized. A short test was developed to examine the usability and effectiveness of the computer game, instructional procedures, software installation, appropriate classroom setting, practical issues of related equipment, and time frame of the treatments. The *Game Play Questionnaire*, *Basic Psychological Needs Scale* (BPNS), and mathematics assessment were administered after the treatment. From observations, student interviews, and results of the questionnaire, adjustments were made so that (a) a short introduction of the tools was added at the beginning of the game, (b) the software of Flash Players was installed on all computers for this experiment, (c) scripts were added to the experiment manual so that proctors' instruction was standardized, (d) the time allocation for completion of mathematics assessment was expanded to 35 minutes, and (e) the time allocation for completion of the game play questionnaire and BPNS was shortened to 15 minutes.

The treatment procedure was designed to simulate processes that reflect the same mathematics curriculum found in regular high school instructions. This experiment was administered on three separate days based on the AB block schedule of a high school mathematics class, meaning that students attended each session for 90 minutes per class every other day. In this experiment, student attended the first session on Monday, continued the second session on Wednesday, and completed the third session on Friday.

Proctors followed an experiment manual to administer treatments. All participants were randomly assigned to either the control or one of three treatment groups before the first session. At the beginning of the first session, all participants went to their assigned classrooms and took the mathematics pretest. Proctors distributed written instructions to each participant after the assessment. Participants in the control group took the *Basic Psychological Needs Scale* questionnaire before working on their assignment. Participants in each of the three treatment groups worked on their assignments and took the *Basic Psychological Needs Scale* questionnaire after the completion of the treatment. Participants in the two game-based learning groups also completed the *Game Play Questionnaire*. All participants were asked to stop their work and log off their computers at the end of the class session. Participants followed the same procedure on treatments and questionnaire in the second and third sessions. Before the end of the third session, all participants completed the mathematics posttest. The administrator evaluated the experiment process based on the fidelity checklist to ensure that all experimenters follow the same protocol to implement the experiment and reduce variability in administration. The fidelity checklist was developed based on the framework provided by Bellg et al. (2004) and the items listed by Borrelli et al. (2005).

## **Treatment Validity and Reliability**

Cook and Campbell (1979) expanded Campbell and Stanley's (1963) internal and external validity by adding the concept of construct validity. Construct validity refers to "the possibility that the operations which are meant to represent a particular cause or effect construct can be construed in terms of more than one construct" (p. 59). Shadish, Cook, and Campbell (2002) stated that construct validity relates to the understanding of constructs and assessing them. Shadish et al. emphasized that (a) a construct is a central means to connect operation to theory and to practical action, (b) construct labels carry social, political, and economic implications that shape perception, and (c) the defense of basic constructs is a basic task of all science. Cook and Campbell differentiated construct validity from external validity in that external validity is concerned with the "specific population of persons, settings, and times that have a grounded existence" (p. 82), while construct validity is related to a specified construct. They stated that the essence of both external validity and construct validity is about generalization, and the two validities are highly related and are difficult to clarify. Shadish et al. identified 14 threats to construct validity.

When studying treatment, a similar view to construct validity is ecological validity as defined by Bracht and Glass (1968). I analyzed the threat to ecological validity because it is more related to treatment in this study. Ecological validity handles several threats. First, explicit description of the experimental treatment is needed so that other researchers have a description of the details of the experimental treatment and can reproduce the treatment. If the description is too vague, the treatment cannot be accurately reproduced and experimental findings may not be generalizable. Solomon, Cavanaugh, and Draine (2009) suggested developing a manual so that the treatment can be delivered in a standardized manner. In this study, I developed a treatment

manual to standardize the treatment procedure, provide guidance on training, and monitor the treatment administration.

Second, the Hawthorne effect, novelty and disruption effects, and experimenter effects are all related to the delivery of a treatment (Cook & Campbell, 1979). The Hawthorne effect refers to situation where participants improve their performance because they are aware of being involved in an experiment, and they are receiving special attention. Novelty and disruption effects may occur because the treatment is different from the regular instructional environment. Experimenter effects refer to experimenter bias, “Researchers’ expectations about the outcomes of their experiments that are unintentionally transmitted to participants” (Gall et al., 2007, p. 394). In this study, steps to control the threat of reactive arrangement on external validity were determined to be sufficient to minimize these threats.

Third, the interaction of history and treatment refers to a situation that experimenters possess the impression of the superiority of treatment over control condition, demonstrating the impression to participants and influencing experiment results. I controlled this threat by instructing that all groups worked on their assigned treatments without knowing the procedure of other groups. Proctors were advised that it was not hypothesized that one treatment was superior to others and all treatments were different forms of instruction support. Further, teachers did not identify the groups as control or treatment groups during the experiment. In the proctors’ procedure manual, the groups were identified as Group One, Two, Three and Four. The differences of treatment procedure were not disclosed to other students during the experiment. In this way, participants would not have the impression that their treatment was superior or inferior to other treatments. The terms *control* and *treatment* group were only used in the data analysis.

Shadish et al. (2002) discussed the reliability of treatment implementation as one of the threats to statistical conclusion validity. The authors argued that treatment implementation may differ from one person to another and from occasion to occasion. They suggested that the threat can be controlled by “using all the available opportunities to make the treatment and its implementation as standard as possible across occasions of implementation” (p. 43). The reliability can be achieved with the standardized procedure in all experimental stages. A treatment manual and fidelity checklist were developed to guide the treatment process in this study.

### **Treatment Fidelity**

Treatment fidelity refers to the idea that “the treatment conditions, as implemented, conform to the researcher’s specifications for the treatment” (Gall et al., 2007, p. 395). In some situations, investigators design the experiment and analyze data, while experimenters administer the treatment and collect data. However, an experiment may involve several experimenters who administer treatments at different time and physical settings. A procedure is necessary to ensure that all experimenters follow the same protocol to implement the experiment and reduce variability in administration.

Mowbray, Holter, Teague, and Bybee (2003) recommended three steps in establishing fidelity criteria including identifying and specifying fidelity criteria, collecting data, and examining the indicators in terms of reliability and validity. Fidelity criteria should include the specification of the treatment, the content and procedure of the treatment, and the roles and qualifications of the experimenters. The authors recommended three methods to develop the criteria: (a) drawing from an existing model, (b) gathering expert opinion, and (c) drawing from quantitative research. The first method includes sources such as treatment protocols, program

manuals, and existing models, which are highly recommended because of established efficacy and effectiveness. The second method includes expert opinions such as surveys and literature reviews. The third method includes the opinions of users and advocates in the field.

Measuring fidelity refers to methods to quantify the fidelity criteria and the administration of the treatment to achieve its stated purpose. Common practices include rating fidelity criteria by experts and administering surveys or interviews by experimenters. Mowbray et al. (2003) mentioned that raters observe experimenters' implementation of the fidelity criteria and score each fidelity measurement based on the checklist so that a standardized assessment can be achieved. Experimenters may score their practices in surveys or interviews based on the established checklist. However, the authors argued that these practices are subjective and may cause issues due to experimenter or rater bias. Finally, the validity and reliability of fidelity criteria can be assessed through several approaches. The authors listed five different approaches including examining kappa coefficients and Cronbach's alpha coefficients and comparing differences across types of programs, convergent validity, and relationships between measures and outcomes.

Mills and Regan (2000) developed a tool to assess and validate the fidelity of an integrated learning system in classrooms. The initial components were identified by reviewing educational software vendor documentation and interviewing software developers. A focus group developed and refined the components after comparing them with the software documentation. The finalized components were tested in a pilot study and data were collected and analyzed. In their study, 15 components were developed in the finalized version and five levels of variation using a Likert-type scale were used to evaluate each component. The components in Mills and Regan's tool can be summarized as (a) introduction of the design to



teachers, (b) training on the design, (c) planning the implementation process, (d) facilitation of the design, and (e) data collection. For each component, five points of variations can be used to quantify the data. Scores were assigned to the ideal use, high acceptable, acceptable, minimal, and unacceptable ratings, from the highest to the lowest. This tool was utilized in this study because of the nature of the tool for technology in classroom application.

Bellg et al. (2004) developed a 5-part framework to assess treatment fidelity in health behavior studies. The framework included (a) description of treatment, (b) training providers, (c) delivery of treatment, (d) receipt of treatment, and (e) enactment of treatment skills. The treatment should be clearly defined and described. Bellg et al. stated that treatment fidelity related to design intends to ensure that all elements in the treatment are defined and specified. Treatment providers should be adequately trained to deliver the treatments. Treatment delivery should be implemented by following procedures and protocols to standardize the delivery. Receipt of treatment improves the participants' ability to understand treatment-related behaviors and cognitive strategies. Enactment of treatment skills improves participants' ability to perform treatment-related skills.

Borrelli et al. (2005) expanded the treatment fidelity framework by evaluating practices implemented in other studies and integrating previous practices into the framework. The authors listed practices utilized by other researchers in each of Bellg et al.'s (2004) five categories, and detailed practices for the entire framework. They stated that information on the treatment and comparison conditions, the process of description, standardization, assessment, and documentation in regard to the training of providers should be provided. The methods to deliver treatments and the treatment manual were suggested, and items used to assess participant's knowledge on treatments and their performances were recommended.

Based on the analysis of previous works on treatment fidelity, I adopted the approach of building a fidelity checklist. The framework provided by Bellg et al. (2004) was adopted as the template to build the structure of the check list. The items used by Borrelli et al. (2005) were adopted to cover the detailed criteria within the structure. Items in Mills and Regan's (2000) criteria were integrated in the list to add logics of technology treatment in classroom environment. Finally, the content in treatment manual was incorporated in the checklist.

### **Treatment Development**

#### **Step 1: Selection of Design Components**

In an experiment, the selection of pretest, control, treatment, and posttest should be aligned with the research purpose. Solomon et al. (2009) suggested that researchers select the intervention(s) to be delivered and assessment(s) to be utilized. Researchers can select simple or a combination of interventions. Decisions also need to be made on whether to use a pretest and how to use posttests. Internal and external validity must be considered in the selection of a design. In this study, mathematics computer games and instructional support were integrated as interventions. Four conditions were included. The control condition did not include any intervention. The two game-based learning conditions included the mathematics game either with or without instructional support. A non-gaming condition included instructional support of mathematics.

**Game.** I designed two versions of mathematics computer game with or without instructional support. I did not use an existing game for this research because (a) I could implement specific forms of instructional support in a self-developed game, (b) I could integrate specific mathematic concepts in the game, (c) it was difficult to get permission to modify

commercial games, and (d) small flash games would be technically practical for use in classrooms.

I designed a game that served as a vehicle to apply instructional support and mathematics. The game followed the story of a virtual figure attacking the castle of a villain who ruled over a kingdom. Players needed to destroy the castle by casting wires to connect explosive devices on the castle. The length of wire needed to be calculated by following mathematics concepts so that the wires attached to the explosive devices were successfully connected to explode. After players destroyed the castle, the villain escapes to the next castle, and players continue to attack the next castle. Players were required to use different mathematics concepts to calculate the length of the wire at each new level.

At the beginning of the game, players were provided with an option to choose from three modes, including survival, adventure, and learning. The survival mode was the mathematics game with instructional support, adventure mode was the game without instructional support, and learning mode was an instruction of the game. When selecting survival mode, players entered level 1 of a virtual world. An animated instruction of how to calculate the distance between two points on a coordinate was demonstrated. Players entered the game after the instruction and used the right and left arrow keys to move forward and backward while using the mouse to shoot monsters. When reaching the castle, players used the coordinate tool to calculate the distance between two bombs on the wall. Players entered the distance in the gun setting and pressed the button to shoot. If the distance was correct, the castle was destroyed and players moved to the next level. If the distance was wrong, the animated instruction was played, and players stayed in the same castle and tried again. Levels 2, 3, and 4 were the same in game design, and players applied different mathematics concepts to calculate the distance of bombs. Animated

instruction, feedback, and guided practice were not provided in adventure mode, while the game flow was the same as that of survival mode. The storyboard of the game was demonstrated in Appendix E.

Many motivational factors were implemented in the game. A virtual world and imaginary figures were designed to provide a sense of fantasy (Rieber, 1996) and immersion (Yee, 2006). Players can learn to master current level and then advance to the next level of the game, increasing motivational factors of challenge, mastery, and achievement (Dickey, 2007; Rieber & Noah, 2008; Yee, 2006). Student engagement and student-centered approaches (Gee, 2003, 2007; Prensky, 2001) were implemented in the game so that students controlled the pace of playing and learning.

**Mathematics.** I used high school geometry in Georgia Performance Standard for Mathematics I (Georgia Department of Education, 2006), which can be found at the Georgia Standards web site. The standards included the distance between two points (MM1G1.a), the distance between a point and a line (MM1G1.b), and application of the Pythagorean Theorem (MM1G1.d). The mathematics content in this study was validated by a focus group of five mathematics teachers in a secondary school. The focus group evaluated whether each level of the game met specified mathematics standards, whether the sequence of the mathematics content matched the game flow, and whether the directions and feedback were appropriate to solve the mathematics problems in the game. Similar mathematics content was used in the non-gaming treatment in which guided mathematics practice problems were developed.

**Instructional support.** The instructional support elements of guided practice and feedback were implemented in selected treatments. Guided practice facilitates students' learning by offering appropriate level of instruction and advancing learning activity based on the result of

the assessment. Feedback provides explanations of the right or wrong answers. In this study, participants received animated instruction on a specific standard prior to the assignment. When working on the assigned problems, participants either continued to the next level of learning if satisfactory results were obtained or practiced similar questions if they did not give the right answer. Feedback was provided for all wrong answers by showing the animated instruction on the specific standard. The same instructional support elements were applied for groups of game treatment with instructional support (Group 3) and guided mathematics practice without game (Group 2).

### **Step 2: Design Four Treatments**

The control condition consisted of having students learn without the treatment of a computer game or instructional support, while the three experimental conditions were learning mathematics with instructional support in non-gaming environment, game-based learning of mathematics with instructional support of guided practice and feedback, or game-based learning of mathematics without instructional support. The four groups were identified as Group 1, 2, 3, and 4, respectively.

**Group 1: Learning mathematics without game or instructional support.** Students worked on a research assignment about personality, career, and mathematics skills. Students were asked to describe career options based on results of a personality test and examine the importance of mathematic skills related to the career by using PowerPoint software.

**Group 2: Learning mathematics with instructional support in a non-gaming environment.** Students worked on a web-based mathematics practice. At the beginning of the assignment, instructions of how to solve the mathematics problems were provided. When

working on the mathematics problems, students were provided with guided practice and feedback.

**Group 3: Game-based learning with instructional support.** Students played a version of the computer game *MathFighter* with instructional support. Instructions on how to solve the mathematics problems was provided at the beginning of the game. When playing the game, players were provided with guided practice and feedback. Players continued to the next level after completing the current level.

**Group 4: Game-based learning without instructional support.** Students played a version of the computer game *MathFighter* without instructional support. Players entered the game directly with introduction of game mission and tools. Guided practice or feedback was not provided. Players had the options to play different levels of the game at own choice.

### **Step 3: Design Randomization Procedures**

Solomon et al. (2009) stated that the premise for randomization is the planned and known chance for a participant to be assigned to a condition. Solomon et al. suggested that only mathematically-based procedures can be truly referred to as random and that a computerized random number generator makes the process easy and accessible. They suggested that larger sample sizes make each group more generalizable to the targeted population and ensure equal distributions of individual characteristics to each group in the sample. In this study, each participant was assigned a unique identifier so that personal information was not identifiable. Each participant was assigned to one of four groups by using computer-generated random numbers.

#### **Step 4: Develop Treatment Manual**

Solomon et al. (2009) outlined a framework for developing an intervention or treatment manual including (a) a description of the rationale for the intervention, (b) factors that lead to the intervention based on theory, (c) a description of the target population, (d) the goal of the intervention, (e) indications of other approaches, (f) elements of the intervention, (g) the client-provider relationship, (h) structure of the intervention, (i) guidelines for assessing progress, (j) guidelines for dealing with common issues, (k) relationships with supporters, (l) guidelines for transition to other services, (m) selection process of providers, (n) provider training, and (o) supervision of providers.

I developed a treatment manual to guide the experiment. An introduction of the rationale, purpose, targeted population, and theoretical framework was provided at the beginning of the manual. Related personnel, responsibilities, and training procedure were described. Randomization procedure was thoroughly specified. The activity of proctors, the script of instructions, the time frame of treatments, and the administration of instruments were depicted for each group and each session.

The implementation of the experiment was evaluated using a fidelity checklist. The administrator scored each item of the checklist after each session of the treatments, based on observations of treatment administration and input from proctors. They agreed that the treatment design was thoroughly described in the treatment manual. They also agreed that (a) training met the ideal rating, (b) treatment delivery was highly acceptable, (c) participants showed acceptable ability to perform the tasks, and (d) not all participants performed the tasks appropriately, but the general performance was acceptable in this experiment. Proctors provided extra information on the fidelity checklist, including observations of students' behavior on treatment and

administration of instrument. Fidelity checklist demonstrated that the administration of this experiment was reliable.

### **Participants**

Participants were students who were enrolled in career and technical education classes in an urban Atlanta high school. Keppel and Wickens (2004) stated that the sample size of an experimental study is related to effect size, power, and alpha level. Effect size refers to “a quantity that measures the size of an effect as it exists in the population, in a way that is independent of certain details of the experiment such as the sizes of the samples used” (Keppel & Wickens, 2004, p. 159). Keppel and Wickens suggested using omega squared ( $\omega^2$ ) to measure the effect size in a population. Power refers to “the probability of rejecting the null hypothesis when a specific alternative hypothesis is true” (p. 47). The higher the power, the less likely researchers are to make a Type II error that retaining null hypothesis given null is false.

Keppel and Wickens (2004) suggested that an experiment could use a similar study as a model to calculate an estimate of effect size, using the formula  $(a-1)(F-1)/((a-1)(F-1) + an)$ , where  $a$  represents number of groups,  $n$  represents the number of participants in each group, and  $F$  represents the  $F$  ratio in the similar study. The effect size ( $\omega^2$ ) of .06 was obtained based on a prior study of gaming and motivation ( $F(1, 84) = 12.44$ ) with two groups (Papastergiou, 2009). The effect size ( $\omega^2 = .06$ ) falls in the definition of medium effect size, meaning that 6 percent of variance exists between the sample and the population. Keppel and Wickens (2004) stated that a medium effect size was equivalent to Cohen’s description of effects ( $d \approx .5$ ) that are apparent to careful observation.

Keppel and Wickens (2004) provided a table to estimate sample size based on the estimated omega squared, experimental groups, and power at an alpha level of .05, calculated by



the program GPOWER, a general power analysis program by Erdfelder, Faul, and Buchner (1996). In this experiment, a sample size of 176 was required based on a desired high power of 80%, medium effect size ( $\omega^2$ ) of .06, and 4 groups at significance of .05, based on Keppel and Wickens' table (p. 173). Eight career and technical education classes were invited to participate in this research, covering subjects of business management, accounting, marketing, computer science, cosmetology, and video production. Two hundred and twenty-two students volunteered to participate, signed *Minor Assent Form*, and submitted a signed *Parental Permission Form* prior to the experiment. Students over 18 years old signed the *Informed Consent Form*.

### **Instrument**

Three instruments were used in this study, including the *Basic Psychological Needs* scale (BPNS), *Game Play Questionnaire*, and a mathematics assessment. According to Deci and Ryan (2000b), autonomy, competence, and relatedness are three psychological needs that should be satisfied for motivation. The *Basic Psychological Needs* scale (BPNS) is a 21-item questionnaire developed to evaluate the three universal needs (Deci, Ryan, Gagné, Leone, Usunov, & Kornazheva, 2001). The original BPNS questionnaire was derived from the Intrinsic Motivation Inventory, and modified versions have been used for studies on work (Ilardi, Leone, Kasser, & Ryan, 1993; Kasser, Davey, & Ryan, 1992), relationships (La Guardia, Ryan, Couchman, & Deci, 2000), and school activities (Standage, Duda, & Ntoumanis, 2005).

The questionnaire has six items for competence, eight items for relatedness, and seven items for self-determination using a 7-point Likert scale (1=not at all true; 7=very true), and the Cronbach's alpha was reported as .89 (Deci et al., 2001, p. 934). The subscale for autonomy includes items 1, 4, 8, 11, 14, 17, and 20 in which items 4, 11, and 20 are worded in a negative way. The subscale for competence contains items 3, 5, 10, 13, 15, and 19 in which items 3, 15,

and 19 are worded in a negative way. The subscale for relatedness covers items 2, 6, 7, 9, 12, 16, 18, and 21 in which items 7, 16, and 18 are worded in a negative format. Examples of questions were, “I feel like I can pretty much be myself” (autonomy), “I feel a sense of accomplishment from what I do” (competence), and “People I interact with tend to take my feelings into consideration” (relatedness).

Four game enjoyment items in the *Game Play Questionnaire*, developed by Ryan, Rigby and Przybylski (2006), were used to evaluate students’ game experience for the two game-based learning treatment groups. Ryan et al. reported the reliability of scores obtained for game enjoyment ( $\alpha=.95$ ). An example of game enjoyment question was “I enjoyed playing the game very much.” A copy of the *PBNS* and *Game Play Questionnaire* are included in Appendix C.

An assessment on the mathematics content in the game was used to evaluate participants’ academic achievement. The assessment was adopted from *Georgia Mathematics I Test Preparation and Practice*, published by McDougal Littell (Author, 2007) and used by teachers of the focus group with approved copyrights. The assessment evaluated students’ academic achievement on specific content of geometry in Georgia Performance Standards of Mathematics I. The focus group member validated the questions and indicated that all questions correctly measure the mathematics materials covered in the specific standards used in this research.

### **Procedure**

University of Georgia requires researchers to apply for approval from the Institutional Review Board (IRB) when research involves human subjects. There are different application procedures based on the design and risks of a study. The IRB procedure for administrative review was applied to this research because this study was to test normal educational practices in

a regular classroom setting. The IRB application was filed on February 8, 2012, attached with a copy of research design, procedure, instrument, *Minor Assent Form*, *Parental Permission Form*, and *Informed Consent Form for Individuals over 18*. All involved co-investigators participated in CITI training and signed the Individual Investigator Agreement prior to the application.

After the Institutional Review Board (IRB) approval was received on March 22, 2012, all volunteered classes were contacted with the approval from the Fulton County School Systems and the principal of the high school that the experiment was administered. Volunteers from eight career and technical education classes were addressed with the purpose and procedure of this research, 206 students signed Minor Assent Form and 16 signed Informed Consent Form for Individuals over 18. A cover letter addressing the goal and procedure of this research and the Parental Permission Form were distributed for approval from minors' parents or guardians. One hundred and seventy minors returned signed Parental Permission Form and participated in the research while 10 volunteers over 18 years old participated.

The first session was administered on March 26, 2012. Each participant was assigned with a unique identifier at the beginning of the session. The class roster related to students' identity was collected and destroyed after students received their assigned group and computer lab number. The collected data was related to each student's identifier instead of their authentic identification so that participants' privacy was protected. Proctors followed the experiment manual to administer the treatment and instrument. The data was collected and keyed in a spreadsheet after each session. The second session was administered on March 28, 2012. The last session was completed on March 30, 2012. The data was organized and sorted on April 2, and analyzed on April 5, 2012. Table 3.1 illustrates the related items of treatment manual, fidelity check list, instruments, treatment snapshots, and related documentation in Appendices.

Table 3.1

*Experimental Treatment, Instruments, and Contact Documentation in Appendix*

Experimental Items	Appendices
Treatment manual	Appendix A
Fidelity checklist	Appendix B
Game play questionnaire	Appendix C
Basic psychological needs scale	Appendix C
Mathematics assessment	Appendix D
Game snapshots	Appendix E
Student Treatment procedures	Appendix F
Parents Contacts and permissions	Appendix G
School System Contacts and Permission	Appendix G

### **Data Analysis**

A desired power of 80%, medium effect size ( $\omega^2$ ) of .06, and a significance of .05 were planned based on the sample size (Keppel & Wickens, 2004, p. 173). Effect size refers to “a quantity that measures the size of an effect as it exists in the population, in a way that is independent of certain details of the experiment such as the sizes of the samples used” (Keppel & Wickens, 2004, p. 159). Keppel and Wickens (2004) suggested using omega squared ( $\omega^2$ ) to measure the effect sizes in a population. Power refers to “the probability of rejecting the null hypothesis when a specific alternative hypothesis is true” (p. 47). The higher the power is, the less likely it is to make a Type II error that retaining null hypothesis given null is false. The alpha level was set to .05 to decrease the chance of making Type I error of reporting no statistically significant differences when significance was found (Keppel & Wickens, 2004). Table 3.2 demonstrates the research questions and data analysis procedures of this study.

The first research question examined the game enjoyment level of students who play mathematics games. Participants played one of two versions of mathematics games with or without instructional support in three sessions and took a 4-item game enjoyment questionnaire after each session. Each item of the questionnaire was assigned a value that ranged from 1 to 7 to represent least to most game enjoyment based on the game enjoyment scales. The dependent variable of game enjoyment was examined by using the average of four item scores to represent a participant's game enjoyment level. Mean scores and standard deviations for each session were reported. The general pattern of the data was described.

The second research question examined participants' academic achievement. Participants in all groups were administered a 15-item mathematics pretest at the beginning of Session 1 and a posttest at the end of Session 3. Scores of the tests ranged from 0 to 15, representing the number of correct answers. The scores of both pretest and posttest were examined. Mean scores and standard deviations of pretest and posttest were reported. The general pattern of the data was described.

The third question examined participants' motivation through three psychological needs. The basic psychological needs scales (BPNS) questionnaire were administered for all groups in each of three sessions, and the three dependent variables of autonomy, competence, and relatedness were examined through the data collected. The questionnaire included 21 items, and each item was assigned a value that ranged from 1 to 7 to represent from least to most autonomous, related, or competent. The items of each factor were sorted, and each factor was examined for three sessions separately. Means scores and standard deviations of each factor for each session were reported. The general pattern for each factor was described separately.

The fourth research question examined the differences of participants' level of game enjoyment with or without instructional support for each treatment session. Keppel and Wickens (2004) stated that a *t*-test is "more easily adapted to groups with unequal sample sizes or variances" and "statistical software programs analyze single-df comparisons this way" (p. 71). A series of *t*-tests were used in this study because two groups were involved in the comparison. Keppel and Wickens (2004) suggested controlling the familywise error rate by picking a per-comparison rate (priori alpha level) and dividing this value by the number of tests. The priori alpha level for this question was preserved .05 and the alpha level was adjusted to .017 using the Bonferroni procedure to reduce the likelihood of Type I error (Huck, 2004).

The fifth research question examined the interaction of game and instructional support on participants' academic achievement. A  $2 \times 2$  analysis of variance (ANOVA) was used to evaluate the initial differences among four treatment groups based on the pretest scores. Since no statistically significant differences were found among four treatment groups on the pretest, a  $2 \times 2$  analysis of variance (ANOVA) was used to examine the interaction of game and instructional support on academic achievement based on the posttest scores. A priori alpha level of .05 was preserved for this test and the alpha level was adjusted to .025 using Bonferroni procedure to reduce Type I error. The interaction found in this test was further analyzed based on the graph of interaction.

The sixth research question examined the interaction of game and instructional support on motivation. A series of two-way analysis of variance (ANOVA) were conducted to examine each of the three motivational factors of autonomy, competence, and relatedness. For each of the three motivation factors, the interaction of the two independent variables was examined per each of three treatment sessions. If no statistically significant interaction was indicated, univariate

follow-up tests were conducted on each of the independent variables separately to examine possible main effects. Otherwise, the interaction would be graphed and examined. Table 3.2 summarized the questions and data analysis procedures.

Table 3.2

*Statistical Procedures of Data Analysis*

Questions of study	Independent variables	Dependent variables	Data analysis
What was students' level of enjoyment toward computer games with or without instructional support?	With or without instructional support	Game enjoyment	Mean, standard deviation
What was students' academic achievement on mathematics based on whether game-based learning or instructional support was provided?	Group 4 levels	Academic performance	Mean, standard deviation
What were the characteristics of students' motivation toward mathematics based on whether game-based learning or instructional support was provided when measured on the motivational factors of autonomy, competence, and relatedness?	Group 4 levels	Autonomy, relatedness, competence	Mean, standard deviation
What were the differences of students' level of game enjoyment toward computer games with or without instructional support?	With or without instructional support	Game enjoyment	3 <i>t</i> -tests
What were the interactive effects of game-based learning and instructional support on students' academic achievement?	Group 4 levels	Academic achievement	2 two-way ANOVA
What were the interactive effects of game-based learning and instructional support on students' motivation toward mathematics when measured on the motivational factors of autonomy, competence, and relatedness?	Group 4 levels	Autonomy, relatedness, competence	A series of two-way ANOVA

Huck (2004) stated that the practical significance should be considered against statistical significance to evaluate the meaningfulness of findings. Huck suggested using a priori power

analysis for the purpose of determining the power sample size, and recommended reporting the effect size and power from existing sample data to demonstrate the practical significance. Based on Keppel and Wickens (2004), the effect size was reported as small ( $\eta^2 \approx .01$ ), medium ( $\eta^2 \approx .06$ ), or large ( $\eta^2 \approx .15$ ). The effects were equivalent to Cohen's  $d$  in value of .25, .5, and .8, respectively. The effect size and power were reported for statistical significances found in this study.



## CHAPTER 4

### ANALYSIS OF DATA

The purpose of this experimental study was to examine the interactive effects of instructional support and game-based learning of high school mathematics. Instructional support referred to any type of assistance that helps students learn and included guidance, explanations, directions, and other types of assistance (Tobias, Fletcher, Dai, & Wind, 2011). This study focused on the use of a computer game as the vehicle of instructional support. The computer game, *MathFighter*, was a researcher-developed game that integrated mathematics concepts. The control condition was learning without participation of computer game or receipt of instructional support. Three experimental conditions were (a) learning mathematics with instructional support in a non-gaming environment, (b) game-based learning of mathematics with instructional support consisting of guided practice and feedback, and (c) game-based learning of mathematics without instructional support. The dependent variable, motivation, was defined using Ryan and Deci's (2000b) self-determination theory where three basic psychological needs—relatedness, competence, and autonomy—were examined as indicators of intrinsic and extrinsic motivation.

In this study, the following research questions were addressed:

1. What was students' level of enjoyment toward computer games with or without instructional support?
2. What was students' academic achievement on mathematics based on whether game-based learning or instructional support was provided?

3. What were the characteristics of students' motivation toward mathematics based on whether game-based learning or instructional support was provided when measured on the motivational factors of autonomy, competence, and relatedness?
4. What were the differences of students' level of game enjoyment toward computer games with or without instructional support?
5. What were the interactive effects of game-based learning and instructional support on students' academic achievement?
6. What were the interactive effects of game-based learning and instructional support on students' motivation toward mathematics when measured on the motivational factors of autonomy, competence, and relatedness?

There were 180 students who participated in the first experimental session, 167 in the second session, and 153 in the third session. Data were analyzed for 145 participants who completed all three sessions. Multiple *t*-tests (Huck, 2004) were used to evaluate the differences of each participant's game enjoyment, and a series of two-way analysis of variance (ANOVA) were used to evaluate the academic achievement and the motivational factors of autonomy, competence, and relatedness. To avoid an inflated probability of Type I error, the alpha level was adjusted by using the Bonferroni procedure for each test while the priori alpha level was maintained at the .05 level.

### **Research Question 1: Game Enjoyment**

The first research question examined the game enjoyment level of students who played mathematics games. Participants played one of two versions of mathematics games with or without instructional support in three sessions and took a 4-item game enjoyment questionnaire after each session. Each item of the questionnaire was assigned a value that ranged from 1 to 7

that represented least to most game enjoyment. The variable of game enjoyment was examined by using the average of the four item scores to represent a participant's level of game enjoyment.

Mean scores and standard deviations for each session are reported in Table 4.1. The higher the mean scores, the more game enjoyment. The data did not show an increase of participants' overall game enjoyment level over the three sessions. Similarly, mean scores did not increase for the treatment group that received instructional support. Mean scores for the treatment group without instruction support increased slightly in Session 3 compared to Session 2, but the Session 3 level was still not higher than Session 1. Thus, a general pattern emerged, depicting that the level of game enjoyment was not increasing over the three sessions for both groups.

Table 4.1

*Means and Standard Deviations of Game Enjoyment in Three Sessions*

Participants	<i>N</i>	Session 1		Session 2		Session 3	
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Instructional support	34	4.11	.80	3.93	.95	3.79	1.69
No instructional support	35	4.40	1.05	4.07	.96	4.10	1.37
Overall	69	4.26	.94	4.00	.95	3.95	1.53

Practically, these results revealed that participants in both groups did not report game enjoyment through the treatment sessions. The means scores of both groups were close to 4.00 in all three sessions, indicating that participants' game enjoyment level was neutral. However, the standard deviation was much larger in Session 3 ( $SD = 1.53$ ) than in Session 1 ( $SD = .94$ ) and 2 ( $SD = .95$ ), indicating that participants' game enjoyment was more variable in Session 3. The

variable pattern was consistent for both groups, showing that some participants enjoyed their game treatments more than others in the same group.

### **Research Question 2: Academic Achievement**

The second research question examined participants' academic achievement on mathematics. Participants in all groups were administered a 15-item mathematics pretest at the beginning of Session 1 and a posttest at the end of Session 3. Scores of the tests ranged from 0 to 15, representing the number of correct answers. Participants completed the tests within 35 minutes, and the number of corrected answers represented a participant's academic achievement score. The scores of both pretest and posttest were examined.

Mean scores and standard deviations of pretest and posttest are reported in Table 4.2. The higher the mean scores, the better the academic achievement. The data did not show an overall increase of mean scores in posttest, and the general pattern of mean scores between pretest and posttest showed similarity for all groups except the group that received the game treatment without instructional support. Mean scores increased slightly in the posttest of this group, but the standard deviation ( $SD = 2.58$ ) showed that academic achievement of this group was more variable than other groups. This finding could indicate that high scores of a few participants in the posttest contributed to the increased mean score for the group as a whole.

The overall pattern for other groups consistently indicated that participants' academic achievement did not increase after treatment. All mean scores in Table 4.2 centered around 5.00, indicating that participants answered approximately 33 percent of the questions correctly. Mean scores of pretest and posttest showed no practical difference on participants' achievement, demonstrating that participants' academic achievement was not changed through the treatments.

Table 4.2

*Means and Standard Deviations of Pretest/Posttest on Academic Achievement*

Participants	<i>N</i>	Pretest		Posttest	
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Control (Group 1)	39	4.64	2.44	4.23	1.83
Instructional support without game (Group 2)	37	5.30	1.90	5.16	2.11
Instructional support with game (Group 3)	34	4.94	2.20	4.56	2.03
Game without instructional support (Group 4)	35	4.91	1.69	5.26	2.58
Overall	145	4.94	2.08	4.79	2.17

### Research Question 3: Motivation

The third research question examined participants' motivation through three psychological needs. The *Basic Psychological Needs Scales* (BPNS) was administered to all groups in each of three sessions, and the three dependent variables of autonomy, competence, and relatedness were examined through the data collected. The BPNS included 21 items, each item assigned a value that ranged from 1 to 7 to represent from least to most autonomous, related, or competent, respectively. The items of each factor were organized, and each factor was examined for the three sessions separately.

Higher mean scores reflect more autonomous, related, or competent perspectives. The data for autonomy showed a consistent pattern for all groups. Means scores of all groups did not show apparent difference within any session or between sessions except those of Group 2 (instructional support without game). The mean scores of Group 2 were 5.12 in Session 2 and 5.23 in Session 3, which were higher than the scores of other groups in the same session. Group 2 had the most change from 4.90 in Session 1 to 5.23 in Session 3, while changes of other groups

were much smaller. Standard deviations did not show obvious differences between all groups in each session. The most obvious differences in standard deviation was showed between Group 4 ( $SD = .84$ ) and Group 2 ( $SD = 1.17$ ) in Session 3. The differences of standard deviation between all groups in other sessions were much small.

The data for relatedness showed a consistent pattern for all groups. The mean scores between groups were not obviously different in Session 1, ranged from 4.28 to 4.51. In Session 2, Group 2 ( $M = 5.13$ ) had the highest mean scores compared to the lowest by Group 4 ( $M = 4.58$ ). In Session 3, Group 2 ( $M = 5.36$ ) had the highest mean scores compared to the lowest by Group 4 ( $M = 4.88$ ). Means scores of all groups steadily increased through all three sessions. Group 2 had the most changes from 4.40 in Session 1 to 5.36 in Session 3, while the changes of other groups were much smaller and consistent. The standard deviations did not show big differences between all groups in Session 3. The most obvious difference of standard deviation was showed between Group 1 ( $SD = .66$ ) and Group 4 ( $SD = 1.45$ ) in Session 2.

The data for competence showed a consistent pattern for all groups. The mean scores between groups were not obviously different in Session 1, ranged from 4.10 to 4.42. In Session 2, Group 2 ( $M = 5.12$ ) had the highest mean scores compared to the lowest by Group 4 ( $M = 4.31$ ). In Session 3, Group 2 ( $M = 5.44$ ) had the highest mean scores compared to the lowest by Group 4 ( $M = 4.85$ ). Means scores of all groups steadily increased throughout three sessions, and the increasing rate did not show big difference between groups. The most obvious difference of standard deviation was showed between Group 3 ( $SD = .96$ ) and Group 4 ( $SD = .59$ ) in Session 1. Means scores and standard deviations of each factor for each session are reported in Table 4.3.

Table 4.3

*Means and Standard Deviations of Autonomy, Relatedness, and Competence*

Participants	<i>n</i>	Session 1		Session 2		Session 3	
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Autonomy							
Control (Group 1)	39	4.86	.78	4.80	.95	5.01	1.05
Instructional support without game (Group 2)	37	4.90	.79	5.12	.88	5.23	1.17
Instructional support with game (Group 3)	34	4.84	1.09	4.53	.80	4.84	1.14
Game without instructional support (Group 4)	35	4.85	.75	4.41	1.00	4.76	.84
Relatedness							
Control (Group 1)	39	4.51	.54	4.96	.66	5.23	.89
Instructional support without game (Group 2)	37	4.40	.77	5.13	.92	5.36	1.04
Instructional support with game (Group 3)	34	4.43	1.00	4.65	.74	5.09	1.17
Game without instructional support (Group 4)	35	4.28	.83	4.58	1.45	4.88	1.00
Competence							
Control (Group 1)	39	4.13	.78	4.88	.93	5.16	1.05
Instructional support without game (Group 2)	37	4.42	.76	5.12	.83	5.44	1.06
Instructional support with game (Group 3)	34	4.31	.96	4.50	.91	5.10	1.20
Game without instructional support (Group 4)	35	4.10	.59	4.31	.99	4.85	.90

Mean scores of autonomy, relatedness, and competence demonstrated consistent patterns between groups. Group 2 demonstrated higher mean scores in Session 2 and 3 for all factors, indicating that participants in Group 2 had higher levels of motivation. However, the higher mean scores should be further discussed when motivation level is evaluated practically. The

scores in this research came from the *Basic Psychological Needs Scale* (BPNS) in which number 4.00 represents neutral, 5.00 represents autonomous, related, or competent, and 6.00 represents very autonomous, related, or competent. Therefore, the scores should be discussed both statistically and practically. For example, mean scores between Group 2 ( $M = 5.23$ ) and Group 4 ( $M = 4.76$ ) in Session 3 should be discussed on whether differences showed a meaningful variation among participants' level of autonomy. In this study, none of the mean scores for any motivation factor showed practical differences from the value of 5.00 between different groups in any session, indicating that all participants reported autonomous, competence, and relatedness in all sessions based on *Basic Psychological Needs Scale* (BPNS).

#### **Research Question 4: Instructional Support and Game Enjoyment**

The fourth research question examined the differences of participants' level of game enjoyment with or without instructional support for each treatment session. A series of  $t$ -tests were used to evaluate the differences between two groups for each session. The a priori alpha level for this question was preserved at .05 by adjusting the alpha level to .017 using the Bonferroni procedure to reduce the likelihood of Type I error. Among participants ( $n=69$ ) who received the treatment of computer games, the game enjoyment level of the group ( $n=34$ ) with instructional support was not significantly different from the group ( $n=35$ ) without instructional support in Session 1 [ $t(67) = -1.31, p = .38$ ], Session 2 [ $t(67) = -.60, p = .90$ ], and Session 3 [ $t(67) = -.85, p = .24$ ]. Thus, presence or absence of instructional support within the computer game did not impact participants' game enjoyment.

#### **Research Question 5: Game and Instructional Support on Academic Achievement**

The fifth research question examined the interaction of game and instructional support on participants' academic achievement. A  $2 \times 2$  analysis of variance (ANOVA) evaluated the initial



differences among four treatment groups based on pretest scores. As seen in Table 4.4, no statistically significant differences were found among four treatment groups. Therefore, given this initial equivalence of groups, any differences in posttest scores could be attributed to the treatment conditions rather than pre-existing differences.

Table 4.4

*Analysis of Variance for Pretest on Academic Achievement*

Source	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P</i>
Game	1	.06	.01	.905
Instructional support	1	4.22	.97	.326
Game x Instructional support	1	3.58	.82	.366
Error	141	4.35		

Since no statistically significant differences were found among four treatment groups on the pretest, a  $2 \times 2$  analysis of variance (ANOVA) examined the interaction of game and instructional support on academic achievement of the posttest scores. The a priori alpha level of .05 was preserved by adjusting the alpha level to .025 using the Bonferroni procedure to reduce Type I error. As seen in Table 4.5, a statistically significant interaction was found between game and instructional support,  $F(1,141) = 24.00, p < .05$ . However, the statistically significant interaction was of minimal practical significance when effect size and power were considered. The effect size ( $\eta^2=.04$ ) of the interaction indicated that a small proportion of variance in the dependent variable explained by the independent variable. The power of .62 indicated that the test was capable of detecting the interaction slightly more than half of the time.

Table 4.5

*Analysis of Variance for Posttest on Academic Achievement*

Source	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Game	1	1.62	.35	.555
Instructional support	1	.49	.11	.745
Game x Instructional support	1	24.00	5.20	.024
Error	141	4.62		

Figure 4.1 displays the interaction between game and instructional support on academic achievement. When this interaction was graphed, it was found that the instructional support without game group ( $M = 5.16$ ) and game without instructional support group ( $M = 5.26$ ) had higher academic achievement than the game and instructional support group ( $M = 4.79$ ) and control group ( $M = 4.23$ ). The data indicated that instructional support or game made statistical differences on participants' academic performance individually but did not show statistical difference under the condition that both factors were integrated or absent. However, the differences were of minimal practical significance because all mean scores of four groups represented low academic achievement where approximately 33 percent of the questions were correctly answered in the posttest.

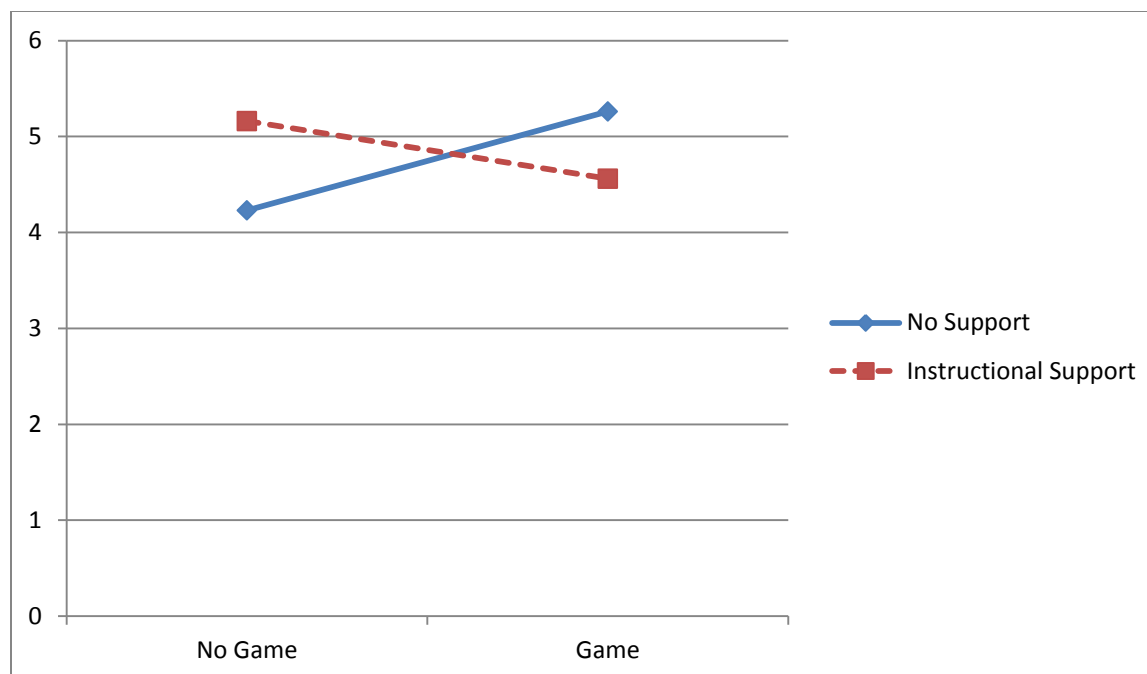


Figure 4.1. Interaction of game and instructional support on academic achievement.

### Research Question 6: Game and Instructional Support on Motivation

The sixth research question examined the interaction of game and instructional support on motivation. A series of two-way analysis of variance (ANOVA) procedures were conducted to examine each of the three motivational factors of autonomy, competence, and relatedness. For each of the three motivation factors, the interaction of the two independent variables was examined for each of three treatment sessions. If no statistically significant interaction was indicated, univariate follow-up tests were conducted on each of the independent variables separately to examine possible main effects. If the interaction was significant, it would be graphed and examined.

#### Need for Autonomy

A  $2 \times 2$  analysis of variance (ANOVA) was conducted to examine the interaction of game and instructional support on motivational factor of autonomy per session. The a priori alpha level of .05 was preserved by adjusting the alpha level to .017 using the Bonferroni

procedure to reduce the possibility of committing a Type I error. As seen in Table 4.6, no statistically significant interaction was found between game and instructional support in any of the three experimental sessions. ANOVA tests performed on game and instructional support did not yield significant main effects in Session 1 and 3.

Table 4.6

*Analysis of Variance for Autonomy*

Source	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Session 1				
Game	1	.05	.07	.794
Instructional support	1	.01	.01	.926
Game x Instructional support	1	.02	.02	.878
Error	141	.74		
Session 2				
Game	1	8.71	10.49	.001
Instructional support	1	1.75	2.11	.149
Game x Instructional support	1	.32	.39	.534
Error	141	.83		
Session 3				
Game	1	4.11	3.68	.057
Instructional support	1	1.34	1.20	.275
Game x Instructional support	1	.27	.24	.627
Error	141	1.12		

A statistically significant difference was found for the main effect of game in Session 2,  $F(1,141) = 10.49, p < .01$ , although no difference was found for the main effect instructional support in the same session. Huck (2004) stated that researchers directly interpret the result of main effects without using follow-up tests if only two levels are associated with the factor.

ANOVA results indicated that game treatments produced statistically significant differences on

participants' level of autonomy. Two game treatment groups ( $M = 4.47$ ) had lower levels of autonomy than the two non-game groups ( $M = 4.96$ ).

The statistically significant differences were also practically significant when the effect size and power were considered. The effect size ( $\eta^2 = .069$ ) reflected a medium (Keppel & Wickens, 2004) level of variability in the level of autonomy explained by the game treatment. The power of .90 indicated that the differences would be capable of being detected 90 percent of the time with an effect of this size.

### **Need for Relatedness**

A  $2 \times 2$  analysis of variance (ANOVA) was conducted to evaluate the interaction of game and instructional support on motivational factor of relatedness per session. The a priori alpha level of .05 was preserved by adjusting the alpha level to .017 using the Bonferroni procedure to reduce the possibility of committing a Type I error. No statistically significant interaction was found between game and instructional support in any of the three experimental sessions. ANOVA tests performed on game and instructional support did not yield significant main effects for Session 1 or 3.

A statistically significant difference was found for the main effect of game in Session 2,  $F(1,141) = 6.96, p < .01$ , although no difference was found for main effects of instructional support in the same session (see Table 4.7). The statistical differences were compared without using follow-up tests because only two levels were associated with the factor (Huck, 2004). ANOVA results indicated that game treatments produced statistically significant differences on participants' level of relatedness. The two game treatment groups ( $M = 4.61$ ) had lower level of relatedness than the two non-game groups ( $M = 5.04$ ).

Table 4.7

*Analysis of Variance for Relatedness*

Source	<i>Df</i>	<i>MS</i>	<i>F</i>	<i>P</i>
Session 1				
Game	1	.36	.57	.451
Instructional support	1	.01	.02	.897
Game x Instructional support	1	.65	1.02	.313
Error	141	.63		
Session 2				
Game	1	6.76	6.96	.009
Instructional support	1	.56	.58	.450
Game x Instructional support	1	.11	.12	.734
Error	141	.97		
Session 3				
Game	1	3.53	3.38	.068
Instructional support	1	1.01	.96	.328
Game x Instructional support	1	.07	.06	.802
Error	141	1.04		

The statistically significant effect did not translate into practical importance when the effect size and power were considered. The effect size ( $\eta^2=.05$ ) reflected a small (Keppel & Wickens, 2004) percentage of variability in the level of relatedness explained by game treatment. The power of 1.0 indicated that the differences would be capable of being detected 100 percent of the time with an effect of this size.

### **Need for Competence**

A  $2 \times 2$  analysis of variance (ANOVA) was conducted to examine the interaction of game and instructional support on motivational factor of competence per session. The a priori alpha level was preserved at level of .05 by adjusting the alpha level to .017 using the Bonferroni

procedure to reduce the possibility of committing a Type I error. As seen in Table 4.8, no statistically significant interaction was found between game and instructional support in any of the three experimental sessions. ANOVA tests performed on game and instructional support did not yield significant main effects in Session 1 or 3.

Table 4.8

*Analysis of Variance for Competence*

Source	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>
Session 1				
Game	1	.21	.34	.560
Instructional support	1	2.21	3.62	.059
Game x Instructional support	1	.05	.09	.769
Error	141	.61		
Session 2				
Game	1	12.74	15.18	.000
Instructional support	1	1.62	1.93	.167
Game x Instructional support	1	.04	.04	.839
Error	141	.84		
Session 3				
Game	1	3.81	3.40	.067
Instructional support	1	2.45	2.19	.142
Game x Instructional support	1	.01	.01	.935
Error	141	1.12		

A statistically significant difference was found for the main effect of game in Session 2,  $F(1,141) = 15.18, p < .01$ , although differences were not found for main effects of instructional support in the same session. The result of the statistically significant main effect was compared without using follow-up tests because only two levels were associated with the factor (Huck, 2004). ANOVA results indicated that game treatments made statistically significant differences

on participants' levels of competence. The two game treatment groups ( $M = 4.40$ ) had lower level of competence than the two non-game groups ( $M = 5.00$ ).

The statistically significant difference was also of practical importance when the effect size and power were considered. The effect size ( $\eta^2 = .26$ ) reflected a large (Keppel & Wickens, 2004) percentage of the variability in the level of competence explained by the game treatment. The power of 1.0 indicated that the differences would be capable of being detected 100 percent of the time with an effect of this size.

### **Summary**

Results of this study indicated that instructional support within a game did not make a difference on participants' game enjoyment level. Participants' game enjoyment level was low. Participants' academic achievement was significantly impacted by the interaction of game and instructional support, but the interaction was not practically important. When instructional support was provided, the academic achievement of the game group was not different from that of the non-game group. All groups performed low academic achievement in this study. Participants' motivation level was not significantly impacted by the interaction of game and instructional support. Game treatment showed a consistent pattern of significant main effect on three motivation factors during the second session, indicating that game impacted participants' motivation. However, the main effect did not show practical importance on all factors when the effect size and power were evaluated. Based on Keppel and Wickens (2004), the data showed small effect for relatedness, medium effect for autonomy, and large effect for competence. The effect size was equivalent to Cohen's  $d$  value of .25, .50, .80, respectively.



## **CHAPTER 5**

### **RESULT, DISCUSSION, AND RECOMMENDATION**

This chapter revisits the rationale, purpose, and questions of this study. The research method and experimental process are reviewed and critiqued. Finally, results and implications of this study are discussed, and recommendations for future studies are suggested.

#### **Rationale, Purpose, and Research Questions**

Over the past two decades, technological advancements have had an impact on the fundamental means of teaching and learning by providing computer and Internet-based environments that are both interactive and entertaining. Game-based learning, which engages students in the interactive and entertaining environment of computer games, has been brought to the attention of researchers, educators, and game developers. Multiple empirical studies have shown positive results when using game-based learning in specific subjects such as computer science (Papastergiou, 2009), social studies (Abrams, 2009; Huizenga, Admiraal, Akkerman, & Ten Dam, 2009), and mathematics (Ke, 2008). Effects of game-based learning can be studied across different subjects such as that represented by the current science-technology-engineering-mathematics (STEM) programs found at the elementary and secondary through postgraduate levels (U.S. Department of Education, 2007). Clark and Ernst (2009) found that gaming brings technology to other STEM subjects, as well as career awareness to classrooms. Evidences indicated that game-based learning can be studied across technology and mathematics, as well as career-related courses.

The subjects of technology, mathematics and career skills are important areas in high school career and technical education (CTE) curriculum. Career and technical education includes educational activities that teach academic and technical knowledge and skills for employment in the Carl D. Perkins Career and Technical Education Act (2006). Mathematics is a major employable skill that career and technical education attempts to improve in its curriculum. Stone, Alfeld, and Pearson (2008) demonstrated a math-enhanced model to integrate mathematics in career and technical education curriculum in order to introduce mathematics concepts in career-related contexts. The ultimate goal of the model was to help students understand traditional mathematics examples and succeed in formal assessments. Wu and Greenan (2003) indicated that career and technical educational curriculum should integrate generalizable mathematics skills in order to facilitate the transition of learners from CTE to educational and practical skills. It is necessary for researchers to engage in further investigation on the effects of game-based learning of mathematics beyond career and technical education contexts by integrating generalizable mathematics problems in CTE curriculum.

The purpose of this experimental study was to examine the interactive effects of instructional support and game-based learning of high school mathematics. Instructional support referred to any type of assistance that helps students learn and included guidance, explanations, directions, and other types of assistance (Tobias et al., 2011). This study focused on the use of a computer game as the vehicle of instructional support. The computer game, *MathFighter*, was a researcher-developed game that integrated mathematics concepts. The control condition was learning without participation in a computer game or receipt of instructional support. Three experimental conditions were (a) learning mathematics with instructional support in a non-gaming environment, (b) game-based learning of mathematics with instructional support

consisting of guided practice and feedback, and (c) game-based learning of mathematics without instructional support.

The dependent variable, motivation, included both extrinsic and intrinsic motivation, where extrinsic motivation referred "to the performance of an activity in order to attain some separable outcome" and intrinsic motivation referred "to doing an activity for the inherent satisfaction of the activity itself" (Ryan & Deci, 2000b, p. 72). According to Ryan and Deci (2000b), three basic psychological needs—relatedness, competence, and autonomy—are of central importance in transforming extrinsic motivation into intrinsic motivation so that external values can be "evaluated and brought into congruence with one's other values and needs" (p. 73). Relatedness refers to the feeling of belongingness and connectedness with others. Competence refers to the feeling of competency with respect to an activity. Autonomy refers to a sense of choice and freedom from external pressure. Relatedness, competence, and autonomy were examined as indicators of intrinsic and extrinsic motivation.

In this study, the following research questions were addressed:

1. What was students' level of enjoyment toward computer games with or without instructional support?
2. What was students' academic achievement on mathematics based on whether game-based learning or instructional support was provided?
3. What were the characteristics of students' motivation toward mathematics based on whether game-based learning or instructional support was provided when measured on the motivational factors of autonomy, competence, and relatedness?
4. What were the differences of students' level of game enjoyment toward computer games with or without instructional support?

5. What were the interactive effects of game-based learning and instructional support on students' academic achievement?
6. What were the interactive effects of game-based learning and instructional support on students' motivation toward mathematics when measured on the motivational factors of autonomy, competence, and relatedness?

### **Review of Research Design and Experiment Process**

Pretest-posttest control group design with random assignment was used to evaluate students' academic achievement, while posttest-only control-group design with random assignment was used (Gall, Gall, & Borg, 2007) to evaluate students' game enjoyment and the motivational effects of instructional support in game-based learning of high school mathematics. All participants were randomly assigned to either a control group or one of three treatment groups. Participants in the control group engaged in learning without treatment of computer game or instructional support, and those in one of the three experimental conditions engaged in (a) learning mathematics with instructional support in non-gaming environment, (b) game-based learning of mathematics with instructional support of guided practice and feedback, or (c) game-based learning of mathematics without instructional support.

Mathematics in this study referred to high school geometry in Mathematics I of Georgia Performance Standards (GPS) developed by Georgia Department of Education (2006). All materials related to mathematics were designed and validated by a focus group of five certified mathematics teachers in a secondary school. Two versions of the mathematics computer games with or without instructional support elements were designed for this study. The same instructional support elements were used with the non-gaming treatment group. The treatment procedure was designed to simulate processes that reflect the same mathematics curriculum

found in regular high school instructions. The treatments were administered in three separate days based on AB block schedule of a high school mathematics class, meaning that students attended each session for 90 minutes per class every other day. In this experiment, student attended the first session on Monday, continued the second session on Wednesday, and completed the third session on Friday.

A treatment manual was developed to guide the experiment administration so that all treatments were standardized. Proctors followed the manual to administer the treatments. Participants were randomly assigned to either the control or one of three treatment groups before the first session. At the beginning of the first session, all participants went to their assigned classrooms and took the mathematics pretest from McDougal Littell (Author, 2007). Proctors distributed written instructions to each participant after the assessment. The Basic Psychological Needs Scale (BPNS) questionnaire (Deci, Ryan, Gagné, Leone, Usunov, & Kornazheva, 2001) was administered prior to the treatment for the control group and after the treatment for all three treatment groups. A Game Play Questionnaire (Ryan, Rigby, & Przybylski, 2006), was administered for two game groups accompanied with the BPNS. Participants followed the same procedure on treatments and questionnaires in the second and third sessions. A posttest was administered after treatments in Session 3. At the end of each session, proctors submitted the collected questionnaires to the administrator. The administrator evaluated the experiment process based on the fidelity checklist.

Three instruments were used in this study, including the *Basic Psychological Needs* scale (BPNS), *Game Play Questionnaire*, and mathematics assessment. The *Basic Psychological Needs* scale (BPNS) is a 21-item questionnaire developed to evaluate the three psychological needs (Deci et al., 2001). The questionnaire has six items for competence, eight items for

relatedness, and seven items for self-determination in 7-points Likert scale (1=not at all true; 7=very true), and the Cronbach's alpha was reported as .89. Examples of questions were: "I feel like I can pretty much be myself" (autonomy), "I feel a sense of accomplishment from what I do" (competence), and "People I interact with tend to take my feelings into consideration" (relatedness). Four game enjoyment items in the *Game Play Questionnaire*, developed by Ryan et al. (2006), were used to evaluate students' game experience for two game-based learning treatment groups. Ryan et al. reported the reliability (alpha=.95) obtained for game enjoyment. An example of game enjoyment question was "I enjoyed playing the game very much". An assessment on the mathematics content in the game was used to evaluate participants' academic achievement. The assessment was adopted from *Georgia Mathematics 1 Test Preparation and Practice*, published by McDougal Littell (Author, 2007) and used by teachers of the focus group with approved copy rights.

Participants of the experiment came from high school students who took career and technical education classes in an urban Atlanta high school. Keppel and Wickens (2004) suggested that an experiment could use a similar study as a model to calculate an estimate of effect size, using the formula  $(a-1)(F-1)/((a-1)(F-1) + an)$ , where  $a$  represents number of groups,  $n$  represents the number of participants in each group, and  $F$  represents the  $F$  ratio in the similar study. The effect size ( $\omega^2$ ) of .06 was obtained based on a prior study of gaming and motivation ( $F(1, 84) = 12.44$ ) with two groups (Papastergiou, 2009). Keppel and Wickens provided a table to estimate sample size based on the estimated omega squared, experimental groups, and power at an alpha level of .05, calculated by the program GPOWER, a general power analysis program by Erdfelder, Faul, and Buchner (1996). In this experiment, a sample size of 176 was required

based on a desired high power of 80%, medium effect size ( $\omega^2$ ) of .06, and 4 groups at a significance of .05.

After the research was approved by the Institutional Review Board (IRB), all volunteered classes were contacted with the approval from the Fulton County School Systems and the relevant principal. Volunteers from eight career and technical education classes were addressed with the purpose and procedure of the research, 206 students signed Minor Assent Form and 16 signed Informed Consent Form for Individuals over 18. A cover letter addressing the goal and procedure of the research and a Parental Permission Form were distributed for approval from minors' parents or guardians. A total of 170 minors returned signed Parental Permission Form and participated in the research, while 10 students over 18 year of age also participated and returned signed Permission Form.

There were 180 participants in the first session of this research, 167 in the second session, and 153 in the third session. The data were analyzed for 145 participants who completed all three sessions. A series of *t*-tests were conducted to evaluate the differences of game enjoyment between game treatment with and without instructional support. A series of  $2 \times 2$  analysis of variance (ANOVA) were conducted to evaluate the interaction of game and instructional support on academic achievement and motivation factors of autonomy, competence, and relatedness.

### **Discussion and Recommendations**

Prensky (2001) suggested that game enjoyment is the primary goal of game-based learning and many fun elements have been implemented in commercial games. Games are dynamic systems of formal and dramatic elements that challenge players to accomplish objectives by following rules and procedures (Fullerton, Swain, & Hoffman, 2008). For educational games, instructional content is embedded (Kafai, 2006) while instructional support

(Tobias et al., 2011) such as guidance and directions are integrated in game environment. Elements in dynamic system of games have been discussed in game design. Fullerton, Swain, and Hoffman (2008) explained that games include formal elements such as players, objectives, procedures, rules, resources, conflict, boundary, and outcome and dramatic elements such as challenge, play, premise, character, story, and world building. Educational games integrate learning objectives and instructional supports in formal and dramatic elements. Previous studies have discussed interactive learning and situated learning (Gee, 2003, 2007; Prensky, 2001) as well as feedback and guidance (Cameron & Dwyer, 2005; Moreno & Mayer, 2005) in educational games. These studies suggested great potential of game-based learning when learning strategies are integrated in game elements.

However, educational games are not, by themselves, game-based learning. Gee (2011) suggested that contexts of educational games make learning happen. Educational games that integrate game and educational elements are considered internal context while applications of educational games are considered external contexts of game-based learning. Studies on game-based learning should cover not only factors of good educational games but also application of those games. This study evaluates factors in both internal and external contexts of game-based learning because all factors may impact students' game enjoyment, academic achievement, and motivation. I studied participants' game enjoyment and academic achievement by using a researcher-developed educational game. Educational content and instructional support were integrated with a game theme and functionality. I studied the impact of the designed game on student motivation in mathematics to explore what factors may impact CTE students' motivation when generalizable mathematics was taught in career related classes. Game enjoyment, academic achievement, and motivation were three factors examined.



## Research Design

A pretest-posttest control-group design with random assignment (Gall et al., 2007) was used to evaluate students' academic achievement on mathematics, while a posttest-only control-group design with random assignment was used to evaluate students' game enjoyment and the motivational effects of instructional support in game-based learning of high school mathematics. Campbell and Stanley (1963) stated that a person's attitude is likely to be changed by a pretest, but the sensitization of a pretest is not critical if the test is an academic assessment. A posttest-only control-group design was selected for game enjoyment and motivation because pretest sensitization was a concern. The threat was not considered severe on academic achievement, leading to the selection of pretest-posttest control-group design in order to explore more information on learning. The randomization procedure was designed so that (a) each participant was first randomly assigned an identification number, and (b) each number was randomly assigned to a group. The randomization process was determined to be sufficient to equate initial differences between control and treatment groups.

Randomization would have controlled threats of history, intrasession history, and maturation. However, some issues were addressed on mortality, reactive arrangement, and population. First, some participants did not attend all three sessions. There were 145 participants who attended all sessions of treatment, although 180 participants initially submitted permission forms. There were 13 absences in session 2 and 27 absences in session 3. This absence rate showed a normal pattern in this school, and the absence was evenly distributed among the four treatment groups. Mortality was not considered a threat to the result of the experiment.

Second, the threat of reactive arrangement was a cause for concern. The threat refers to participants that behave differently based on participation. The threat was observed when some

participants mindlessly filled in the same response for all questions on a given instrument.

Participants may have behaved in this manner since they realized that they were participating in an experiment. When pursued further, it is possible that participants did not behave differently because of the experiment, but may actually represent participants' attitude toward school-related activities, in general. Regardless of the reason, this action of a few may have impacted results in that participants did not truthfully report their motivation or game enjoyment even though participants were exposed to treatments.

Carelessness could be a serious concern in a study about urban secondary school students. Research on urban school students need to be cautious about self-reported motivation or attitude. The data collected may not truthfully represent what participants have experienced in a treatment. Other approaches such as observation and interview might be a reliable supplement to help interpret data. Further, an evaluation of academic achievement could avoid the administration of pretest and posttest within a limited time span. A formal assessment such as end-of-course test (EOCT) may be a better instrument than regular pretest-posttest in evaluating academic achievement.

Third, while the sample size satisfied targeted goals, the overall sample selection was not diversified enough to generalize to all high school students. Participants in urban schools may have unique characteristics compared to other schools, and each school may possess uniqueness related to the local community. An ideal population would cover several schools in different districts to represent all types of students. However, such an attempt was not practical when different treatments were administered in a standardized format with controlled threats of internal and external validity. Treatment context and administration would be difficult to manage if different schools and school districts were involved. Therefore, researchers need to balance

population selection and threats to internal and external validity when making decisions on sample selection.

This research effectively utilized randomization procedures to equate differences among the four treatment groups. The posttest-only control group design was appropriate to evaluate participants' motivation. However, this study raised concerns on participant mortality, the impact of participant attitude on research result, and the uniqueness of the population. I suggest that the results of data from urban schools be evaluated with caution, and evidences such as observation and interview be used to interpret data, making analysis meaningful to the population.

### **Experimental Treatment**

This experiment included four conditions. Participants were randomly assigned to either a control or one of three treatment groups. Two versions of the mathematics computer game with or without the instructional support of guided practice and feedback were designed for two of the treatments. The same mathematics content and instructional support elements were developed in a format of web-based mathematics practices for the third group. A regular research assignment about personality and career related to mathematics skills was developed for the control condition without either game or instructional support. Participants in the control group engaged in learning without exposure to treatment of computer game or instructional support, while those in one of the three experimental groups engaged in (a) learning mathematics with instructional support in a non-gaming environment, (b) game-based learning of mathematics with instructional support, or (c) game-based learning of mathematics without instructional support. Another option for the control group is to work on the same mathematics content without instructional support because an interesting assignment may also impact students' motivation. I recommend the optional control condition for similar studies.

**Game.** Two versions of the mathematics game, with or without instructional support, were designed. The advantage of a self-developed game was the integration of specific mathematics contents and instructional support within the game. The disadvantage was the subjective design of the game and a lack of professional game development experience, leading to the possibility that the playfulness of this designed game became a threat to treatment reliability. However, a validated game is considerably time-consuming and impractical for many teachers to develop. I recommend that researchers modify existing and validated commercial games or include experienced game developers in the design team, if possible, when developing studies on game-based learning. A pilot study may also contribute to better game design and improve playfulness.

**Instrument.** This experiment was administered in three sessions to simulate the instruction of this mathematics content in a regular school environment. However, this approach did not completely meet the goal of this study because the administration of pretest, posttest, and questionnaires consumed some allocated treatment time. The pretest used 35 minutes of experiment time in Session 1, the posttest used the same amount of time in Session 3, and participants were exposed to a full treatment only in Session 2. This treatment process may have impacted the result of the experiment because participants did not experience an ideal level of game exposure. Replication of this experiment may consider dedicating one session for pretest and introduction of treatments, three sessions to simulate regular instruction with administration of motivation questionnaire, and one session for the posttest and summary. The separation of pretest and posttest from motivation questionnaire in different sessions could decrease the impact of the tests on participants' motivation. I recommend that experimental elements such as pretest and posttest would be administered before and after treatment sessions for future studies.

***Treatment manual.*** One critical practice in this experiment was the role of regular classroom teachers as proctors, which controlled several threats to ecological validity such as the Hawthorne effect and novelty or disruption effects. Development of a treatment manual was vital because regular teachers were not experienced on experiment administration. The treatment manual was designed with two goals, details of experiment process for other researchers to reproduce the treatment and standardized treatment process so that all proctors would administer treatments as identically as possible. The treatment manual in this research standardized proctor training, treatment delivery, and instrument administration. A few issues would be addressed on the development and utilization of treatment manual in future practice.

First, administrative support was critical to ensure the smooth flow of an experiment in a school environment. Administrative support refers to (a) directing proctors to follow the schedule of a treatment manual, and (b) solving issues that hinder experiment administration of an experiment. Even though teachers agreed to undertake proctors' responsibilities and received training on how to follow the treatment manual, teachers were found to refocus the priority due to other school tasks. Two teachers delayed the first session because they addressed their classes on tardiness under pressure from school administrators. All proctors were hesitant to continue the experiment in Session 3 because the principal unexpectedly announced that all teachers must give students the entire class period to make up missing assignments. Session 3 was administered as planned after an alternative plan was arranged to cover missing assignments. A treatment manual standardized experimental procedures, but obstacles can emerge in school environments. I recommend that a dedicated experiment administrator be appointed to coordinate unexpected problems.

Second, the treatment manual should be as detailed as possible on experimental instruction. If an instruction is vague, proctors can interpret meanings in different ways or add their own personality to instructions. For example, one proctor may announce, “A questionnaire will be administered after the treatment and please give your truthful answer to those questions” while another proctor may say, “I will give you a questionnaire after the experiment and you’d better take that questionnaire seriously.” The different expression of the same instruction may impact participants’ attitude inversely. I recommend that the instructions be written in scripts so that there is no variation when different proctors provide instructions. All scripts in an instruction should be standardized and explicit so that proctors read identical sentences to experimental groups.

Last, student assignments should be simple and easy to read. Assignments for Groups 2, 3, and 4 were visual and straightforward in this study, but those for Group 1 required intensive reading. I noticed that participants had difficulty understanding the assigned reading about their personality and related career due to low reading level. The phenomenon occurred to both regular students and English as Other Language (ESOL) students. Proctors had to provide extra help to those who did not fully understand the vocabulary. Although this phenomenon did not indicate that the experiment results were jeopardized, I recommend that researchers recognize the impact of students’ reading level on treatment.

**Data.** Game enjoyment and motivation data were collected in each of three research sessions, attempting to find a pattern on game-based learning. First, participants’ motivation may change throughout different sessions and a pattern of the variation could be further analyzed. Second, I hypothesized that participants’ game enjoyment may vary based on the phases of game exposure. When comparing participants’ motivation and game enjoyment between different

groups, finding of a pattern would be important for teachers to apply game-based learning in regular instructions more effectively. For example, teachers could control the schedule and amount of game experience to maximize learning outcomes based on the pattern of motivation and game enjoyment from game-based learning. The hypothesis was not fully explored in this research due to the original task to simulate regular instruction time of same mathematics content. If time allowed, I recommend that data on participants' game enjoyment could be collected for longer time spans so that the pattern of game enjoyment could be more descriptive and meaningful.

### **Game Enjoyment**

Both Prensky (2001) and Gee (2003, 2007) suggested that good learning practices such as interactive learning and situated learning can be implemented in good computer games. A good game integrates learning principles so that challenging problems are presented in rich virtual contexts and learners actively participate in learning with ultimate control of their learning. Prensky stated that the primary principle of game-based learning is to have fun. However, questions may be raised on the relationship between instructional support within a game and having fun. Will an educational game be fun if instructional content and support are embedded while educationally inappropriate fun elements are removed? What are the contextual factors that impact enjoyment of game-based learning? In this study, many elements discussed by Prensky and Gee were implemented in the researcher-developed mathematics games, including but not limited to virtual context and fantasy, learner-control, challenge and competition, incremental practice, student engagement, and immersion. Instructional support was embedded in the game in formats of guided practice and feedback. Participants' game enjoyment level was compared and analyzed for three sessions.

Participants' overall game enjoyment level was neutral and did not improve over three sessions, indicating that more exposure to the gaming experience did not provide consistent or increasing level of game enjoyment. However, the standard deviation was much larger in the third session than those in the first and second sessions, indicating that participants' game enjoyment was more variable in the final session. The result indicated that participants' game enjoyment did not increase but the enjoyment level substantially varied among students over time. The general pattern of neutral game enjoyment and larger variation in the last session was uniform between the treatment groups with and without instructional support. Instructional support did not make a difference in participants' game enjoyment in any session.

Game in this research did not lead to game enjoyment. When exposed to the game for more sessions, participants had substantially different game enjoyment. Instructional support embedded in the game did not impact participants' game enjoyment level. Participants did not enjoy the learning content, game theme, game functionality, and instructional support. I recommend studying factors that can impact enjoyment of game-based learning. First, Prensky (2001) and Gee (2003) suggested that commercial games did a better job of making a game fun and those enjoyable elements of commercial games should be embedded in educational games so that graphics and interaction are attractive to players. I hypothesize that graphics and sophistication were not appropriately created in this game.

As Games and Squire (2011) suggested, educators need to collaborate with commercial game developers to create better educational games. Although not all enjoyable elements in commercial games (fight, war, sexual contents) are appropriate, educationally appropriate and enjoyable content and functionalities can be integrated in educational games. Educational game developers and educators should explore how instructional support can be effectively integrated



with formal and dramatic elements (Fullerton, Swain, & Hoffman, 2008) of games so that educational elements are presented to players enjoyably.

Prensky (2001) suggested that it was easier to design a fun game than to produce an educational movie because small captivating ideas can be implemented in games with reusable codes. Gee (2003) stated that knowledge is presented with various forms of social contexts in a game. These contexts of instructional content play an important role in game enjoyment. I recommend future research on categories of commonly attractive game themes so that educational games on a specific subject could be presented in various themes. The prototype of a game suite (Games & Squire, 2011) is a good example of such an attempt because developers designed a series of games to compliment specific subjects. Although not everyone may enjoy an educational game on a particular subject, educational games in the subject can be enjoyable to more people if those games are implemented with different themes to cater to different interests. Educational game developers or educators should avoid a one-theme-covers-all approach and implement instructional content in different game themes.

Second, learners' experience is a focus of game-based learning where students can learn at their own pace, with their own learning style, and from their selected subjects (Prensky, 2001). Gee (2007) suggested that one major goal of game-based learning is to empower learners. Although this study revealed low participants' game enjoyment level, results did not present reasons for this low game enjoyment. I also want to address external factors that might impact game enjoyment. Based on flow theory (Csikszentmihalyi, 1975), external interruption and extrinsic rewards are destructive elements of true enjoyment. The learning context might have partially contributed to results of this study. It is possible that participants did not favor the game due to external interruption such as teachers' direction and school environment. It is possible that

participant would enjoy the game more if they were told that the experiment was about games. It is also possible that participants' game enjoyment level would be different if they played the game in non-school environments. Little research has been conducted to study the impact of external context of game-based learning. Therefore, further study is recommended on external factors that might impact enjoyment of game-based learning. I suggest comparing the game enjoyment of those who play the same game under different contextual conditions such as (a) in school and non-school contexts, (b) with direct supervision and without direct supervision, and (c) with partners and without partners. Results could help educators evaluate better practices of game-based learning in different contexts.

### **Academic Achievement**

Prensky (2001) discussed many elements of a good game that facilitate learning such as practice, feedback, intelligence tutoring, discovery and guided learning, task-based learning, and question-led learning. Gee (2003, 2007) also discussed game elements that facilitate learning such as exploring potential in a virtual world, growing and mastering knowledge, repeatedly practicing problem-solving skills, and transferring previous knowledge to new situations. Prensky suggested that the principle of game-based learning should be phrased as “fun first, learning second” (p. 179) and that students consider their identities to be more that of a player than of a learner. This study analyzed the effects of instructional support in mathematics games on academic achievement.

Findings did not show improved academic achievement in any of the treatment groups. Data exhibited a general pattern where participants' posttest scores actually decreased compared to pretest scores among all groups, except for the group that played the game without instructional support. The scores were more heterogeneous within this particular group,

indicating that a few high achievers may have contributed to this pattern. In general, most participants answered only one-third of the questions correctly on the posttest, indicating low mathematics achievement. Data showed a statistically significant interaction between game and instructional support on achievement, but the interaction was of little practical importance when examined effect size and power. Instructional support in this educational game did not impact participants' academic achievement. Thus, students' academic achievement was not achieved through learning principles embedded in this educational game.

A lack of significant differences between treatment groups in posttest and the generally low level of achievement lead to two possible conclusions, including (a) the posttest scores did not truthfully reflect participants' academic achievement, or (b) game and instructional support did not impact or even negatively impacted academic achievement. The first conclusion was inferred from observations of instrument administration by both administrator and proctors since some students mindlessly filled in the same response for all questions of a given instrument. This study did not specifically indicate what factors hindered participants from truthfully demonstrating their learning. Instrument administration may not be effective, or the test is lack of connection with the game. Gee (2011) suggested that game-based learning needs to be evaluated based on learning theories. It is possible that a multiple-choice test is not a good instrument to assess academic achievement of game-based learning. Future research is needed on how academic achievement of game-based learning can be truthfully assessed in a school environment.

The second possibility is that instructional support within this mathematics game did not have positive influence on high school students' academic achievement. Game-based learning has shown positive impact on students' achievement for some subjects such as computer science

(Papastergiou, 2009), social studies (Abrams, 2009; Huizenga, Admiraal, Akkerman, & Ten Dam, 2009), and mathematics (Ke, 2008). Cameron and Dwyer (2005) found statistically significant gains in achievement when feedback was provided for quiz questions in a game. Moreno and Mayer (2005) found that explanatory feedback and reflection in a game promotes learning. My study showed that the mathematics game with various levels of support did not improve academic achievement, although good learning principles were integrated within the two game versions. It appears that academic achievement cannot be generalized to all academic subjects and all grade levels.

An educational game is different from a commercial game in that learning content and instructional support are integrated. Prensky (2001) suggested that the primary goal of game-based learning is having fun and ensuring that students are motivated to learn when experiencing fun in a game. My research showed low game enjoyment and low academic achievement of game-based learning in high school mathematics. It is possible that there is a relationship between game enjoyment and academic achievement. Thus, it is possible that contextual factors that impact game enjoyment may also impact academic achievement. Future research should examine the relationship of game enjoyment and academic achievement. When studying contextual factors of game elements and game applications that impact game enjoyment, researchers should also evaluate academic effects of those factors.

## **Motivation**

This study considered motivation as important as academic achievement. Alspaugh (1998) found a dramatic achievement loss in all academic areas during the first year of high school. Rice (2001) reported that the dramatic transition from middle school to high school can negatively impact students' attitude toward mathematics. Although game-based learning has been found to

promote positive attitude in elementary schools (Ke, 2008; Sedig, 2008) and middle schools (Van Eck, 2006; Van Eck & Dempsey, 2002), this study evaluated whether similar results can be found with high schools students. Scanlon, Buckingham, and Burn (2005) argued that, beyond context, student engagement with characters and narratives, rule-based challenges, and engagement with other players are three important motivational factors in the game-based learning of mathematics. This study employed self-determination theory (Ryan & Deci, 2000b) to evaluate the three psychological needs of autonomy, relatedness, and competence as indicators of student motivation. I attempted to study whether game and instructional support had the same motivational effect on high school students and what factors may have impacted the motivation of game-based learning of high school mathematics.

The four experimental groups reflected consistent mean scores for autonomy, relatedness, and competence for each of the three experimental sessions. The treatment group of instructional support without gaming experience demonstrated higher mean scores of all factors in Sessions 2 and 3, indicating that these participants had higher levels of motivation. However, the scores should be discussed from statistical and practical perspectives. In this study, none of the mean scores of any motivation factor showed practical differences, indicating that all participants reported similar autonomy, competence, and relatedness in all sessions based on the *Basic Psychological Needs Scale* (BPNS). However, game treatment showed a consistent pattern of main effects for the three motivation factors during the second session, demonstrating that game may have negatively impacted three motivational factors. The main effects did not show practical importance on all factors when the effect size and power were evaluated. Based on Keppel and Wickens (2004), data showed a small effect on relatedness, a medium effect on autonomy, and a large effect on competence. The effect size was equivalent to Cohen's  $d$  value

of .25, .50, .80, respectively. Results showed that game had practical importance on participants' relatedness, apparent effect on autonomy, and tremendous effect on competence in the second session, but had no main effect on any factor in the other two sessions. Instructional support did not have a significant main effect on three motivational factors in any session.

Past research found that game-based learning had positive impact on student motivation in elementary schools (Ke, 2008; Sedig, 2008) and middle schools (Van Eck, 2006; Van Eck & Dempsey, 2002). My study showed that educational games may not affect student motivation for learning high school mathematics in the same way as past research has demonstrated in elementary or middle schools. Two versions of the educational game did not impact participants' motivation in the first and third sessions, and negatively impacted motivation in the second session. Is it possible, as shown in this study, that students' motivation changes in different sessions of game exposure? What is the pattern of game exposure and motivation? Little research has been conducted to study the effects of game exposure and motivation. Future research should explore the pattern of game exposure and motivation so that motivation can be related to degree of game exposure. Results will help teachers apply the appropriate degree of game exposure in instruction to achievement better motivational effects.

Being involved in playing the mathematics game may have negatively impacted participants' motivation to learn mathematics during this experiment. According to Ryan and Deci (2000b), relatedness plays a critical role in prompting behavior change. They argued that extrinsically motivated behaviors are normally not interesting and the internalization of those behaviors is more likely to occur when they are valued by members of an individual's social circle or community. People are more likely to adopt activities that they feel efficacious and competent about. Finally, a feeling of autonomy allows people to transform values into their own.

Thus, the combination of relatedness, competence and autonomy is more likely to yield the integration of an extrinsic motivation into intrinsic motivation. In my research, those participants who experienced game treatment demonstrated lower levels of relatedness, competence, and autonomy than those without game treatment in the second session, but instructional support did not impact any of motivational factors. The three factors of autonomy, competence, and relatedness will be examined individually.

Participants did not feel autonomous in this game, and game had apparent negative effects on autonomy in the second session. Gee (2007) suggested that a game empowers learners to control the game play experience. Prensky (2001) suggested that players should control the pace and subjects of game play and consider their identity as that of players rather than learners in game-based learning. Csikszentmihalyi (1975) suggested that people experience the unity between the person and activity in the state of flow and people control the activity and environment without external interruption. My study may indicate that students experienced less control and more external interruption in this experiment. Since I implemented student control in game functionality, external context of game-based learning may contribute to the low autonomy when students were directed to follow instructions and timeline in a school environment. Future research is recommended to explore how external contexts such as teachers' direction and school context impact motivational factor of autonomy in game-based learning.

Prensky (2001) and Gee (2003, 2007) suggested applying challenging problems, guided practice, and feedback in game-based learning. However, these instructional support practices in my game did not impact students' competence. My games showed negative effects on competence in the second session, indicating that other factors of internal context may have impacted students' competence. Harter (1981) suggested that motivation of competence includes

preference for challenge, curiosity, and independent mastery. White (1959) suggested that motivation of competence is moderate and persistent without immediate pressing need. Yee (2006) suggested that achievement component includes advancement to gain power and competition in game design. My games did not nurture curiosity, challenge, and independent mastery in its design. My experiment triggered pressing atmosphere when students were required by teachers to play the game for learning. Curiosity and challenging elements can be related to internal contexts of game-based learning and independent mastery and pressing environment can be related to external contexts. Future research should examine contextual factors that foster students' competence in game-based learning.

According to Ryan and Deci (2000b), extrinsically motivated behaviors are normally not interesting and the internalization of those behaviors is more likely to occur when they are valued by members of an individual's social circle or community. Relatedness is critical to prompt behavior changes. My study showed that game and instructional support did not foster relatedness in general, and the game impacted relatedness negatively in the second session. My game did not implement socializing functions effectively to foster relatedness. Yee (2006) suggested that social components of game design should implement (a) help and chat, (b) relationship, and (c) teamwork. These elements can be implemented inside an educational game, and these internal contexts of game-based learning may impact relatedness. External contexts of game-based learning such as groups and peer influence may also impact students' relatedness. Future research should examine both internal and external contexts of game-based learning that can impact motivation factor of relatedness.



## Conclusion

This study explored how game-based learning of high school mathematics and instructional support impacted students' enjoyment, academic achievement, and motivation. I first examined how learning principles and instructional support in a game impacted students' game enjoyment. Students' academic achievement was then examined via the interaction of game and instructional support. Motivational factors of autonomy, relatedness, and competence were individually examined upon the interaction of game and instructional support. Results showed no significant difference of instructional support on game enjoyment, a statistically significant interaction of game and instructional support on academic achievement, and a significant main effect of game on participants' motivation in one session. Findings were further explored in terms of practical importance.

Game-based learning of high school mathematics impacted game enjoyment, achievement, and motivation differently in the current study compared to previous studies in elementary and middle schools. Game and instructional support did not influence students' game enjoyment, achievement, and motivation in general. Recommendations for future research involve two major components of game-based learning, including game idea and functionality (internal context) and game application (external context). Game elements such as graphics and game themes may impact game enjoyment and academic achievement, and challenging functions and socializing tools may impact motivational factors of competence and relatedness. External factors such as teachers' direction, school context, and peer influence may impact game enjoyment, academic achievement, and motivational factors of autonomy, competence, and relatedness. Game enjoyment, achievement, and motivation can be interrelated in studying game-based learning because some common factors may impact all three areas.

Results of this research can be applied from two perspectives, game designers who design educational games and educators who apply game-based learning in schools. From a game developer's perspective, an educational game needs to foster enjoyment, achievement, and motivation. Game elements such as an interesting theme, sophisticated graphics, challenging game flow, and socializing tools should be implemented. However, game developers should target a specific group when designing an educational game, should satisfy common interests of the specific group, and should not expect that one game meets the needs of all students. My research suggests that instructional content and learning principles may not facilitate learning and motivation unless those learning principles are implemented in an enjoyable game design. Therefore, future research should look at internal contexts of game-based learning so that game developers can effectively integrate educational elements in game elements and create fun educational games. Future research should also examine motivation theories in game design so that students are motivated to play and learn.

From an educator's perspective, implementation of game-based learning is a major task. This research suggests that external contexts of game-based learning such as teachers' direction, school context, and peer influence may impact game enjoyment, academic achievement, and motivational factors of autonomy, competence, and relatedness. From motivation theories (Csikszentmihalyi, 1975; Harter, 1981; Ryan & Deci, 2000b; White, 1959), teachers' direction and school environment may violate their rule of autonomy and competence but grouping strategies may foster relatedness. Teachers should explore strategies that make game-based learning enjoyable and motivational while learning is guided and supervised in a school environment. External contexts of game-based learning need to be studied to understand how students' enjoyment, achievement, and motivation can be cultivated in a school environment.

As Gee (2011) suggested, a game is only software, and learning occurs in the social system around the game. Empirical research on games and learning may show the positive or negative effects of a given genre of games toward specific type of learners in a given testing context. Previous studies on learning principles (Prensky, 2001; Gee, 2003, 2007) and motivation (Yee, 2006) suggested great potential of educational games. Game-based learning has promising impact on students' achievement and motivation based on motivation theories (Csikszentmihalyi, 1975; Harter, 1981; Ryan & Deci, 2000b; White, 1959) and previous studies (Abrams, 2009; Cameron and Dwyer, 2005; Huizenga, Admiraal, Akkerman, & Ten Dam, 2009; Ke, 2008; Moreno and Mayer, 2005; Papastergiou, 2009). Game-based learning includes internal contexts and external contexts. My study examined both internal contexts that sponsor developers to design educational games and external contexts that help educators apply game-based learning. There is no perfect solution of game-based learning because the contexts of game-based learning are complicated and dynamic. However, many factors in internal and external contexts may positively impact results of game-based learning, and future research is recommended on those contextual factors.

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## APPENDICES



APPENDIX A  
TREATMENT MANUAL

## TREATMENT MANUAL

### Introduction to Experiment

**Rationale.** Many studies of instructional support in games have examined the effects of specific forms of support at the university level (Cameron & Dwyer, 2005; Leemkuil, 2006; Moreno & Mayer, 2005). Van Eck and Dempsey (2002) studied the effect of instructional support in the form of advice to students in middle school. However, few studies have been developed to examine the effect of instructional support for high school students. It is necessary to engage in research to support game-based learning with specific instructional support for high school students. This study will examine specific forms of instructional supports in game-based learning of high school mathematics.

**Theoretical background of experiment.** This study examines students' motivation in mathematics by evaluating the three psychological needs of self-determination theory (Ryan & Deci, 2000b) using the *Basic Psychological Needs Scale (BPNS)* questionnaire after students are exposed to various treatments. Self-determination theory (Ryan & Deci, 2000b) hypothesizes that intrinsic motivation can be inferred if competence and autonomy are observed. Further, if the basic needs of competence, autonomy, and relatedness are all observed, extrinsic motivation can be internalized and integrated to form intrinsic motivation. The theory posits that the three basic psychological needs can be used to indicate a student's potential intrinsic and extrinsic motivation.

**Target population.** The target population of this experiment is high school students (grades 9-12) who are enrolled in career and technical education classes.

**Goal and elements of treatment.** This experimental study is to examine the motivational effects of instructional support provided by game-based learning of high school mathematics.

This study focuses on the use of a computer game as the vehicle of instructional support. The computer game, MathFighter, is a self-developed game that integrates selected mathematics concepts. The control condition consists of learning without a treatment of computer game or any instructional support, and three different experimental conditions include (a) learning mathematics with instructional support in a non-gaming environment, (b) game-based learning of mathematics with instructional supports consisting of guided practice and feedback, or (c) game-based learning of mathematics without instructional support.

The following research questions will be answered:

1. What was students' level of enjoyment toward computer games with or without instructional support?
2. What was students' academic achievement on mathematics based on whether game-based learning or instructional support was provided?
3. What were the characteristics of students' motivation toward mathematics based on whether game-based learning or instructional support was provided when measured on the motivational factors of autonomy, competence, and relatedness?
4. What were the differences of students' level of game enjoyment toward computer games with or without instructional support?
5. What were the interactive effects of game-based learning and instructional support on students' academic achievement?
6. What were the interactive effects of game-based learning and instructional support on students' motivation toward mathematics when measured on the motivational factors of autonomy, competence, and relatedness?

## **Experiment Personnel and Responsibilities**

**Proctor.** Proctors are regular classroom teachers who teach career and technical education classes. Eight classes will be selected from all career and technology classes, covering different subjects of business management, marketing, accounting, computer application, cosmetology, and video productions. Proctors will receive training on the experiment procedure, experimental setting, and experiment administration by following this treatment manual.

**Technical support.** A technical support personnel will be recruited to check, install, and manage all computers and software needed prior to the experimental session.

**Administrator.** As researcher, I take responsibility as administrator. I will provide training to all proctors about the experimental procedure and will review this treatment manual, communicate with technical support personnel, and check the fidelity of the experiment.

**Participants.** Students who volunteer to participate in the experiment will be informed about the purpose and process of the research. A parent permission form will be distributed prior to the experiment, and students must receive written permission from parents or guardians to participate.

## **Treatment Setting**

All experimental groups will be assigned to different computer labs within the high school. A computer will be provided for each participant. Technical support personnel will help proctors set up the classrooms, connect computers to the network, and test each computer. The experimental context and equipment of the four computer labs will be checked and approved by proctors, technical support personnel, and the administrator prior to the experiment.

**Proctor Training**

The administrator will provide training to all proctors on how to develop the treatment prior to the experimental sessions. Proctors are expected to understand the rationale and goals of the experiment and be able to follow exactly the treatment manual. Proctors are advised that no treatment is hypothesized to be superior to another. Proctors are advised that the administrator monitors and evaluates the treatment process based on the fidelity checklist.

## Randomization Procedure

### **Step 1: Each participant is assigned with a unique identifier without individual information.**

- The administrator will receive a class roster from each participated class.
- The administrator will randomly assign a number to each class from class 1 to class 8.
- The administrator will open random.org website and go to Random Sequence Generator page.
- Based on how many students are available in each class, the administrator will input the number of students in the range of integers and input 1 column.
- The generator will give a series of random integers such as 3, 9, 7, etc.
- Based on the series of random numbers, the administrator sequentially assigns each student a unique identifier starting from 01. For example, the 3rd student in class 5 will have an identifier of 501 and the 9th will be 502.
- The administrator will record the number on the student roster.

### **Step 2: Each participant is randomly assigned to either the control or one of three treatment groups.**

- The administrator will open random.org website and go to Random Sequence Generator page.
- The administrator will input the number of students per class in the range of integer and input 4 columns.
- The generator will return 4 sets of random numbers based on the number of students available in each class. For example, the generator outputs (a) 2, 8, 13, 19, and 20 in column 1; (b) 4, 7, 11, 16, and 18 in column 2; (c) 1, 5, 6, 9, and 17 in column 3; and (d) 3, 10, 12, 14, and 15 in column 4, given that 20 students are available in class 5.
- Based on the result, the administrator will assign students of 502, 508, 513, 519, and 520 to the control group. The students in column 2, 3, and 4 will be assigned to group 2, 3, and 4, respectively.
- The administrator will create a badge with the unique identifier, the group number, the computer lab number, and experiment schedule for each student. The administrator will put the student roster and all badges in an envelope for each class.

## **Treatment Procedure**

### **Session 1: Control Group (Group 1)**

1. Administrator distributes the envelopes of student roster and badges and the envelope of pretest, student treatment procedure, and the BPNS questionnaire to each computer lab prior to the experiment session.
2. Students go to their regular class rooms at the beginning of the first session. When the class starts, proctors open the badge envelope and distribute the badge to each student based on the numbers on the class roster. Administrator collects the rosters and destroys them to protect the confidentiality of participants.
3. All students go to their assigned computer labs. Proctor in each computer lab distributes the mathematics pretest. Proctor announces, "Attention, all students. Please complete the pretest truthfully and I will collect them in 35 minutes. This pretest will not be recorded as your academic assessment. Is there any question? If not, let's begin."
4. When the time reaches 35 minutes, proctor announces, "Attention, all students. Time is up and I will collect your pretest. Please stay quiet while I collect your test." Proctor collects the pretest.
5. Proctor distributes the BPNS questionnaire to each student, and announces, "Attention, all students. Please truthfully answer all questions on this questionnaire. You have 15 minutes to complete it. Is there any question? If not, let's begin."
6. When the time reaches 15 minutes, proctor announces, "Attention, all students. Time is up and I will collect your questionnaire. Please stay quiet while I collect your questionnaire." Proctor collects the questionnaire.

7. Proctor distributes Group 1 treatment procedure to each participant. Proctor announces, “Attention, all students. All treatments are different in this experiment, but you will have the opportunity to experience all other treatments after the last session. When you work on your assignment, you are allowed to communicate with other students. Our session will end when the bell rings for this period. Do you have any question? If not, let’s start.” If a student has a question that proctor cannot answer, administrator will give the answer.
8. Proctor monitors the treatment and solves any issue that students may have. If there is an issue that proctor is not certain, administrator offers the solution.
9. When the bell rings, proctor announces, “Attention, all students. This session of experiment is over. Please save your work, log off your computer and go to your next class. Thanks for your participation.”

### **Session 1: Three Treatment Groups**

1. Administrator distributes the envelopes of student roster and badges and the envelope of pretest, student treatment procedure of each group, and the BPNS questionnaire (and game play questionnaire to Group 3 and 4) to each computer lab prior to the experiment session.
2. Students go to their regular class rooms at the beginning of the first session. When the class starts, proctors open the badge envelope and distribute the badge to each student based on the numbers on the class roster. Administrator collects the rosters and destroys them to protect the confidentiality of participants.
3. All students go to their assigned computer labs. Proctor in each computer lab distributes the mathematics pretest. Proctor announces, “Attention, all students.



Please complete the pretest truthfully and I will collect them in 35 minutes. This pretest will not be recorded as your academic assessment. Is there any question? If not, let's begin."

4. When the time reaches 35 minutes, proctor announces, "Attention, all students. Time is up and I will collect your pretest. Please stay quiet while I collect your test."

Proctor collects the pretest.

5. Proctor distributes treatment procedure to each participant. Proctor announces, "Attention, all students. All treatments are different in this experiment, but you will have the opportunity to experience all other treatments after the last session. When you work on your assignment, you are allowed to communicate with other students. We will stop the treatment at around 20 minutes before the bell rings. Do you have any question? If not, let's start." If a student has a question that proctor cannot answer, administrator will give the answer.
6. Proctor monitors the treatment and solves any issue that students may have. If there is an issue that proctor is not certain, administrator offers the solution.
7. When time reaches 20 minutes before the bell rings, proctor distributes the BPNS questionnaire (and game play questionnaire to Group 3 and 4) to each student, and announces, "Attention, all students. Please truthfully answer all questions on this questionnaire. You have 15 minutes to complete it. Is there any question? If not, let's begin."
8. When the time reaches 15 minutes, proctor announces, "Attention, all students. Time is up and I will collect your questionnaire. Please stay quiet while I collect your questionnaire." Proctor collects the questionnaire.

9. When the bell rings, proctor announces, “Attention, all students. This session of experiment is over. Please log off your computer and go to your next class. Thanks for your participation.”

### **Session 2: Control Group (Group 1)**

1. Administrator distributes the envelopes of student treatment procedure and the BPNS questionnaire to each computer lab prior to the experiment session.
2. All students go to their assigned computer labs.
3. Proctor distributes the BPNS questionnaire to each student, and announces, “Attention, all students. Please truthfully answer all questions on this questionnaire. You have 15 minutes to complete it. Is there any question? If not, let’s begin.”
4. When the time reaches 15 minutes, proctor announces, “Attention, all students. Time is up and I will collect your questionnaire. Please stay quiet while I collect your questionnaire.” Proctor collects the questionnaire.
5. Proctor distributes Group 1 treatment procedure to each participant. Proctor announces, “Attention, all students. This assignment is the same as what you worked on in last session. Please continue on what you have been working on. When you work on your assignment, you are allowed to communicate with other students. Our session will end when the bell rings for this period. Do you have any question? If not, let’s start.” If a student has a question that proctor cannot answer, administrator will give the answer.
6. Proctor monitors the treatment and solves any issue that students may have. If there is an issue that proctor is not certain, administrator offers the solution.

7. When the bell rings, proctor announces, “Attention, all students. This session of experiment is over. Please save your work, log off your computer and go to your next class. Thanks for your participation.”

### **Session 2: Three Treatment Groups**

1. Administrator distributes the envelopes of student treatment procedure of each group and the BPNS questionnaire (and game play questionnaire to Group 3 and 4) to each computer lab prior to the experiment session.
2. All students go to their assigned computer labs.
3. Proctor distributes treatment procedure to each participant. Proctor announces, “Attention, all students. All treatment is the same as what you have been working on in last session. Please continue. When you work on your assignment, you are allowed to communicate with other students. We will stop the treatment at around 20 minutes before the bell rings. Do you have any question? If not, let’s start.” If a student has a question that proctor cannot answer, administrator will give the answer.
4. Proctor monitors the treatment and solves any issue that students may have. If there is an issue that proctor is not certain, administrator offers the solution.
5. When time reaches 20 minutes before the bell rings, proctor distributes the BPNS questionnaire (and game play questionnaire to Group 3 and 4) to each student, and announces, “Attention, all students. Please truthfully answer all questions on this questionnaire. You have 15 minutes to complete it. Is there any question? If not, let’s begin.”

6. When the time reaches 15 minutes, proctor announces, “Attention, all students. Time is up and I will collect your questionnaire. Please stay quiet while I collect your questionnaire.” Proctor collects the questionnaire.
7. When the bell rings, proctor announces, “Attention, all students. This session of experiment is over. Please log off your computer and go to your next class. Thanks for your participation.”

### **Session 3: Control Group (Group 1)**

1. Administrator distributes the envelopes of posttest, student treatment procedure, and the BPNS questionnaire to each computer lab prior to the experiment session.
2. All students go to their assigned computer labs.
3. Proctor distributes the BPNS questionnaire to each student, and announces, “Attention, all students. Please truthfully answer all questions on this questionnaire. You have 15 minutes to complete it. Is there any question? If not, let’s begin.”
4. When the time reaches 15 minutes, proctor announces, “Attention, all students. Time is up and I will collect your questionnaire. Please stay quiet while I collect your questionnaire.” Proctor collects the questionnaire.
5. Proctor distributes Group 1 treatment procedure to each participant. Proctor announces, “Attention, all students. All treatments are different in this experiment, but you will have the opportunity to experience all other treatments after the last session. When you work on your assignment, you are allowed to communicate with other students. I will stop the treatment and give you a posttest at 40 minutes before the end of this period. Do you have any question? If not, let’s start.” If a student has a question that proctor cannot answer, administrator will give the answer.

6. Proctor monitors the treatment and solves any issue that students may have. If there is an issue that proctor is not certain, administrator offers the solution.
7. When it is 40 minutes before the end of the class period, proctor in each computer lab distributes the mathematics posttest. Proctor announces, "Attention, all students. Please complete the posttest truthfully and I will collect them in 35 minutes. This posttest will not be recorded as your academic assessment. Is there any question? If not, let's begin."
8. When the time reaches 35 minutes, proctor announces, "Attention, all students. Time is up and I will collect your posttest. Please stay quiet while I collect your test." Proctor collects the posttest.
9. When the bell rings, proctor announces, "Attention, all students. This experiment is over. Please save your work, log off your computer and go to your next class. Thanks for your participation."

### **Session 3: Three Treatment Groups**

1. Administrator distributes the envelopes of posttest, student treatment procedure, and the BPNS questionnaire (and game play questionnaire to Group 3 and 4) to each computer lab prior to the experiment session.
2. All students go to their assigned computer labs.
3. Proctor distributes treatment procedure to each participant. Proctor announces, "Attention, all students. All treatments are different in this experiment, but you will have the opportunity to experience all other treatments after the last session. When you work on your assignment, you are allowed to communicate with other students. I will stop the treatment and give you a questionnaire and posttest at 55 minutes before

- the end of this period. Do you have any question? If not, let's start." If a student has a question that proctor cannot answer, administrator will give the answer.
4. Proctor monitors the treatment and solves any issue that students may have. If there is an issue that proctor is not certain, administrator offers the solution.
  5. When it reaches 55 minutes before the bell rings, proctor announces, "Attention, all students. Please stop what you are doing. We will take the questionnaire, now."
  6. Proctor distributes the BPNS questionnaire to each student, and announces, "Attention, all students. Please truthfully answer all questions on this questionnaire. You have 15 minutes to complete it. Is there any question? If not, let's begin."
  7. When the time reaches 15 minutes, proctor announces, "Attention, all students. Time is up and I will collect your questionnaire. Please stay quiet while I collect your questionnaire." Proctor collects the questionnaire.
  8. Proctor in each computer lab distributes the mathematics posttest. Proctor announces, "Attention, all students. Please complete the posttest truthfully and I will collect them in 35 minutes. This posttest will not be recorded as your academic assessment. Is there any question? If not, let's begin."
  9. When the time reaches 35 minutes, proctor announces, "Attention, all students. Time is up and I will collect your posttest. Please stay quiet while I collect your test." Proctor collects the posttest.
  10. When the bell rings, proctor announces, "Attention, all students. This experiment is over. Please log off your computer and go to your next class. Thanks for your participation."

APPENDIX B  
FIDELITY CHECKLIST

## Fidelity Checklist

Major steps	Fidelity criteria	Rating				
		Ideal	Highly Acceptable	Acceptable	Minimal	Unacceptable
Treatment design	What is the level that administrator provide the following information?					
	Rational of treatment	5	4	3	2	1
	Theories and variables	5	4	3	2	1
	Target population	5	4	3	2	1
	Goal and procedures of treatment	5	4	3	2	1
	Treatment manual	5	4	3	2	1
Training	What is the level that proctors' credentials and researcher-proctor relationship has been emphasized?	5	4	3	2	1
	What is the level that the training process has been implemented?	5	4	3	2	1
	What is the level that training procedure has been standardized?	5	4	3	2	1
	What is the level that proctor's knowledge and skills have been measured after training?	5	4	3	2	1
	What is the level that supportive personnel have been informed about their role and responsibility in the experiment?	5	4	3	2	1
Delivery of treatment	What is the level of the proctor's effort to treatment manual precisely?	5	4	3	2	1



	What is the level that the proctor provides sufficient time on tasks?	5	4	3	2	1
	What is the level that the proctor follows treatment procedures on randomization?	5	4	3	2	1
	What is the level that the proctor avoids threats to validity by following treatment manual?	5	4	3	2	1
Receipt of Treatment	What is the level that all participants understand the rationale and goal of the treatment?	5	4	3	2	1
	What is the level that all participants have the ability to perform the task?	5	4	3	2	1
Enactment of treatment	What is the level that all participants perform the task appropriately?	5	4	3	2	1
Proctor comments on treatment delivery and participants' behavior						

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*Note.* Rating scales: 1=unacceptable, 2=minimal, 3=acceptable, 4=highly acceptable, 5=ideal.

### **Definition of Rating Scales**

- Ideal: Performance consistently far exceeds the requirements needed to fulfill the objectives, expectations, and tasks in this item.
- High Acceptable: Performance is often above the requirements needed to fulfill the objectives, expectations, and tasks in this item.
- Acceptable: Performance meets the requirements needed to fulfill the objectives, expectations, and tasks in this item.
- Minimal: Performance normally meets the requirements needed to fulfill the objectives, expectations, and tasks in this item but occasionally fails to meet all requirements.
- Unacceptable: Performance fails to meet the requirements needed to fulfill the objectives, expectations, and tasks in this item.

APPENDIX C  
QUESTIONNAIRES

## CONFIDENTIALITY AND LIMITED USE AGREEMENT

September 20, 2011

Gary Liu  
University of Georgia  
240A Riverbend Road  
Athens, GA 30602-8001

Attention: GARY LIU

Dear Gary:

You have expressed an interest in using Metrics and/or Methodologies developed by us for the testing of video games, interactive products, simulations, and virtual environments. While we intend to make this information available free of charge for purely academic uses (i.e. not directly or indirectly related to any commercial application or for-profit use), the information you have requested is of a confidential and proprietary nature that we believe is of substantial value to us. You agree that any information disclosed to you by us shall be deemed confidential and proprietary information. You acknowledge that any disclosure of such confidential and proprietary information by you to third parties will prejudice our ability to conduct our business successfully. The confidential and proprietary information that you have requested may include, without limitation, among other things, technical and functional characteristics of our business; our trade secrets; ideas, products, services, and content; object, source and other computer code, data and techniques; databases, product designs, plans, samples, models and prototypes; schemes and schemas; know-how; metrics and methodologies, sales, customer and supplier information, and other marketing and technical information ("Confidential Information"). For purposes of this Confidentiality and Limited Use Agreement (the "Agreement"), the term "Confidential Information" does not include any information which (i) at the time of disclosure or thereafter is generally available to and known to the public (other than as a result of disclosure directly or indirectly by you), (ii) was available to you on a non-confidential basis from a source other than us or our representatives and advisors, provided that such source is not in breach of any obligations of confidentiality to us, or (iii) has been independently acquired or developed by you without violating any of your obligations pursuant to this Agreement.

Accordingly, whether or not any relationship is hereafter established between us, except as otherwise specified herein, you will hold all such Confidential Information in confidence and not disclose such information to others, and you will not use such information commercially or for any purpose other than to conduct discussions between us or for those purposes explicitly granted under Exhibit A, attached hereto. You agree to limit dissemination of and access to the information so disclosed only to those of your employees, representatives and advisors who have a need for such access and who agree to treat such information as confidential pursuant to the terms hereof.

Notwithstanding the foregoing, you may disclose Confidential Information only (i) in accordance with certain limited use rights granted to you, all more particularly described in Exhibit A, or (ii) in the event that you are required or become legally compelled (by oral questions, interrogatories, requests for information or documents, subpoena, civil investigative demand or similar process) to disclose such Confidential Information; provided, however, that you shall promptly advise us of such request or legal compulsion and to the extent that we secure a legally enforceable protective order, you shall comply with such protective order. You understand that we make no representations or warranties as to the accuracy or completeness of any such Confidential Information. Upon our request, you will immediately return to us or destroy all Confidential Information and certify in writing to us that all such Confidential Information has been returned or destroyed. Except as otherwise set forth in Exhibit A, nothing contained in this Agreement shall be construed as granting or conferring any rights to you by license or otherwise in any Confidential Information disclosed, or under any trademark, patent, copyright or other intellectual property

Confidentiality and Limited Use Agreement\_Gary\_liu

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right. In addition, you will not reverse engineer, decompile, disassemble or create derivative works based upon the Confidential Information.

This Agreement will be construed according to the laws of the State of Delaware and any suit brought hereon must be brought in the state or federal courts sitting in Florida, the parties hereby waiving any claims or defenses that such forum is not convenient. This Agreement supersedes all prior communications, agreements, and understandings related to the subject matter herein. Amendment or waiver of the provisions of this Agreement must be in writing and executed by both parties. No failure or delay by us in exercising any right, power or privilege hereunder shall operate as a waiver, nor shall any single or partial exercise of a right, power or privilege preclude any other or further exercise thereof, or the exercise of any other right, power or privilege under this Agreement. This Agreement may not be assigned by you without the prior written consent by us. This Agreement shall be binding on and inure to the benefit of our respective directors, officers, representatives, agents, successors and permitted assigns. In the event you, your representatives or advisors breach or threaten to commit a breach of this Agreement, you agree that monetary damages may not be a sufficient remedy for any such breach, and that we will, in addition to any other remedies available to us, be entitled to injunctive relief. You also agree that in the event of any litigation between us to enforce any rights hereunder, the unsuccessful party to such litigation will pay to the prevailing party therein all costs and expenses including, but not limited to, reasonable attorneys' fees and costs, actually incurred by the prevailing party.

Please confirm your agreement to and acceptance of the foregoing by signing in the appropriate space below.

AGREED AND ACCEPTED:  
GARY LIU

By: Gary Liu  
Title: Doctor student

**EXHIBIT A****Limited Use License****RIGHTS**

**Grant of Rights.** Subject to all of the terms and conditions of this Agreement (including, without limitation, the restrictions and limitations set forth herein), we hereby grant to you a limited, revocable, nonexclusive, nontransferable, nonsublicensable right to access and use the Metrics and Methodologies all solely for your internal, non-commercial, academic research purposes. In connection with such purpose, you may publish the results of your research using the Metrics and/or Methodologies (the "Results") solely in academic publications, but you will not disclose any specific Metrics and/or Methodologies or any portion thereof. In consideration for this limited right to use the Metrics and/or Methodologies, whenever you publish the Results in any format, you will reference that the Metrics and/or Methodologies used by you to generate the Results were provided to you by us.

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**No Additional Rights.** Except as expressly provided in this Agreement, nothing in this Agreement shall operate to assign, license, or otherwise transfer any intellectual property rights or any other rights or interests from us to you or vice versa. We hereby reserve all rights owned or licensable by us that are not expressly granted herein to you. There are no licenses by implication under this Agreement.

**LICENSE RESTRICTIONS**

**Use.** You may use the Metrics and/or Methodologies (or any portion thereof) only for the purposes contemplated by this Agreement. Without limiting the generality of the foregoing, you shall not: (a) market, sell or distribute the Metrics and/or Methodologies; (b) make the Metrics and/or Methodologies available to any individuals other than your Authorized Users; (c) download, use, modify, archive, publish, transmit, translate, reverse engineer, decompile, disassemble or create derivative works based upon the Metrics and/or Methodologies, except as otherwise expressly permitted herein; (d) copy the Metrics and/or Methodologies, except as otherwise expressly permitted herein; (e) rent, lease, grant a security interest in, or otherwise transfer or attempt to transfer any rights in or to the Metrics and/or Methodologies; or (f) remove or deface any legends, restrictions, product identification, copyright, trademark or other proprietary notices from the Metrics and/or Methodologies and/or any related documentation.

**Audit Right.** We shall have the right, upon reasonable notice, during normal business hours, to inspect your computer system(s) and documentation and manuals to insure compliance by you use with the use restrictions contained herein.

**DEFINITIONS**

**Authorized Users.** "Authorized Users" means students, faculty and/or employees of your academic institution who agree to be bound by the terms and conditions of this Agreement.

**Metrics and/or Methodologies.** "Metrics and/or Methodologies" means metrics, methods, correlations, variables, surveys, measures, questionnaires, scales, scoring guides, and all information related to the foregoing and any portion thereof, including without limitation all PENS variables.

**Parties.** "We", "us", "our", etc. means Immersyve, Inc. "You", "your", etc. means Gary Liu, University of Georgia, etc.

GARY LIU

By:

Name:

Title:

*Gary Liu*  
*Gary Liu*  
*Doctoral Student*

### Questionnaire for All Groups

Student Number: \_\_\_\_\_ Group Number: \_\_\_\_\_

Please fill out the questionnaire *based on your experience in this session.*

1=Very Strongly Disagree

2=Strongly Disagree

3=Disagree

4=Neutral

5=Agree

6=Strongly Agree

7=Very Strongly Agree

- |  |   |   |   |   |   |   |   |
|--|---|---|---|---|---|---|---|
| 1. I feel like I am free to decide for myself.                           | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 2. I really like the people I interact with.                             | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 3. I do not feel very competent.   | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 4. I feel pressured.   | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 5. People I know tell me I am good at what I do.                         | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 6. I get along with people I come into contact with.                     | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 7. I pretty much keep to myself and don't have a lot of social contacts. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8. I generally feel free to express my ideas and opinions.               | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 9. I consider the people I regularly interact with to be my friends.     | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 10. I have been able to learn interesting new skills recently.           | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 11. I frequently have to do what I am told.                              | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 12. People around me care about me.                                      | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

13. I feel a sense of accomplishment from what I do.	1	2	3	4	5	6	7
14. People I interact with tend to take my feelings into consideration.	1	2	3	4	5	6	7
15. I do not get much of a chance to show how capable I am.	1	2	3	4	5	6	7
16. There are not many people that I am close to.	1	2	3	4	5	6	7
17. I feel like I can pretty much be myself.	1	2	3	4	5	6	7
18. The people I interact with regularly do not seem to like me much.	1	2	3	4	5	6	7
19. I often do not feel very capable.	1	2	3	4	5	6	7
20. There is not much opportunity for me to decide for myself how to do things.	1	2	3	4	5	6	7
21. People are generally pretty friendly towards me.	1	2	3	4	5	6	7

### Questionnaire for Games Groups

Student Number: \_\_\_\_\_ Group Number: \_\_\_\_\_

Please fill out the questionnaire *based on your experience in this session.*

1=Very Strongly Disagree

2=Strongly Disagree

3=Disagree

4=Neutral

5=Agree

6=Strongly Agree

7=Very Strongly Agree

- |  |   |   |   |   |   |   |   |
|--|---|---|---|---|---|---|---|
| 1. I feel like I am free to decide for myself.                           | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 2. I really like the people I interact with.                             | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 3. I do not feel very competent.   | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 4. I feel pressured.   | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 5. People I know tell me I am good at what I do.                         | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 6. I get along with people I come into contact with.                     | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 7. I pretty much keep to myself and don't have a lot of social contacts. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8. I generally feel free to express my ideas and opinions.               | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 9. I consider the people I regularly interact with to be my friends.     | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 10. I have been able to learn interesting new skills recently.           | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 11. I frequently have to do what I am told.                              | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 12. People around me care about me.                                      | 1 | 2 | 3 | 4 | 5 | 6 | 7 |



13. I feel a sense of accomplishment from what I do.	1	2	3	4	5	6	7
14. People I interact with tend to take my feelings into consideration.	1	2	3	4	5	6	7
15. I do not get much of a chance to show how capable I am.	1	2	3	4	5	6	7
16. There are not many people that I am close to.	1	2	3	4	5	6	7
17. I feel like I can pretty much be myself.	1	2	3	4	5	6	7
18. The people I interact with regularly do not seem to like me much.	1	2	3	4	5	6	7
19. I often do not feel very capable.	1	2	3	4	5	6	7
20. There is not much opportunity for me to decide for myself how to do things.	1	2	3	4	5	6	7
21. People are generally pretty friendly towards me.	1	2	3	4	5	6	7

### Game Enjoyment

1. I enjoyed playing the game very much.	1	2	3	4	5	6	7
2. I thought the game was boring.	1	2	3	4	5	6	7
3. I think this game is fun to play.	1	2	3	4	5	6	7
4. The game does not hold my attention.	1	2	3	4	5	6	7

APPENDIX D  
MATHEMATICS ASSESSMENT

**MM1G1.a**

Determine the distance between two points.

1. Find the distance between the points  $(-6, 3)$  and  $(-6, -2)$ .

(A) 25                      (C) 5  
(B) 145                    (D)  $\sqrt{145}$

2. What is the distance between the two points  $(-5, 7)$ ,  $(9, -3)$ ?

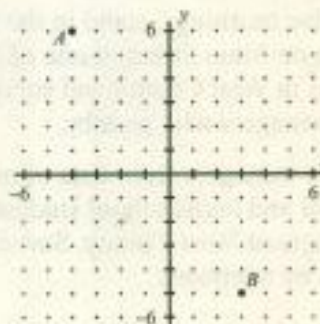
(A)  $2\sqrt{74}$   
(B)  $\sqrt{74}$   
(C)  $\sqrt{2}$   
(D) 74

3. What is the distance between the points  $(-2, -7)$  and  $(10, -12)$ ?

(A) 10 units  
(B) 13 units  
(C) 17 units  
(D) 23 units

4. What is the distance between points A and B?

(A)  $\sqrt{12}$   
(B)  $3\sqrt{45}$   
(C)  $\sqrt{170}$   
(D) 89



5. The positions of two airplanes approaching an airport are plotted on a graph grid with the airport located at  $(0, 0)$ . The locations of the planes are given by the coordinates  $(-7, 3)$  and  $(4, 0)$ . Each grid square is 1 mile wide. How far apart are the approaching airplanes?

(A) 9.7 miles  
(B) 11.4 miles  
(C) 34.2 miles  
(D) 150 miles

**MM1G1.b**

Determine the distance between a point and a line.

1. A vertical line is drawn at  $x = 3$ . What is the distance between that line and point A with coordinates  $(-2, 1)$ ?

(A) 2  
(B) 3  
(C) 5  
(D) 8

2. A horizontal line is drawn at  $y = -4$ . What is the distance between that line and point B with coordinates  $(1, 0)$ ?

(A) -4  
(B) 1  
(C) 2  
(D) 4

3. A vertical line is drawn at  $x = 3$ . What is the distance between that line and point C with coordinates  $(4, 5)$ ?

(A) 1  
(B) 2  
(C) 3  
(D) 4

4. A horizontal line is drawn at  $y = -5$ . What is the distance between that line and point D with coordinates  $(5, 5)$ ?

(A) 0  
(B) 1  
(C) 5  
(D) 10

5. A horizontal line is drawn at  $y = 4$ . What is the distance between that line and point E which lies at the origin?

(A) 0  
(B) 2  
(C) 4  
(D) 6

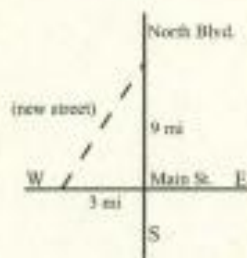
**MM1G1.d**

Understand the distance formula as an application of the Pythagorean theorem.

1. A radio station is going to construct a 12-foot tower on top of a building. The tower will be supported by three cables, each attached to the top of the tower and to points on the roof of the building that are 16 feet from the base of the tower. Find the total length of the three cables.

(A) 20 ft                      (C) 100 ft  
(B) 60 ft                      (D) 80 ft

2. The city commission wants to construct a new street that connects Main Street and North Boulevard as shown in the diagram below. The construction cost has been estimated at \$90 per linear foot. Find the estimated cost for constructing the street. (1 mile = 5280 ft)



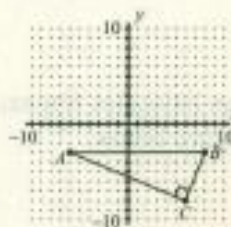
(A) \$4,552,587              (C) \$475,200  
(B) \$50,090                (D) \$4,508,143

3. Find the length of the leg of this right triangle. Give an approximation to 3 decimal places.



(A) 22.804                      (C) 5.657  
(B) 10.863                      (D) 11.314

4. Triangle ABC is a right triangle, with  $A = (-6, -3)$ ,  $C = (6, -8)$ ,  $AC = 13$  and  $CB = 5\frac{5}{12}$ .



Which of the following are the coordinates of B? Round to the nearest hundredth if needed.

(A) (8.31, -3)                (C) (7.9, 8.08)  
(B) (7.08, -3)                (D) (8.08, -3)

5. How long is a string reaching from the top of a 13-ft pole to a point on the ground that is 8 ft from the bottom of the pole?

(A)  $\sqrt{124}$                       (C)  $\sqrt{233}$   
(B) 12                              (D) 16

APPENDIX E

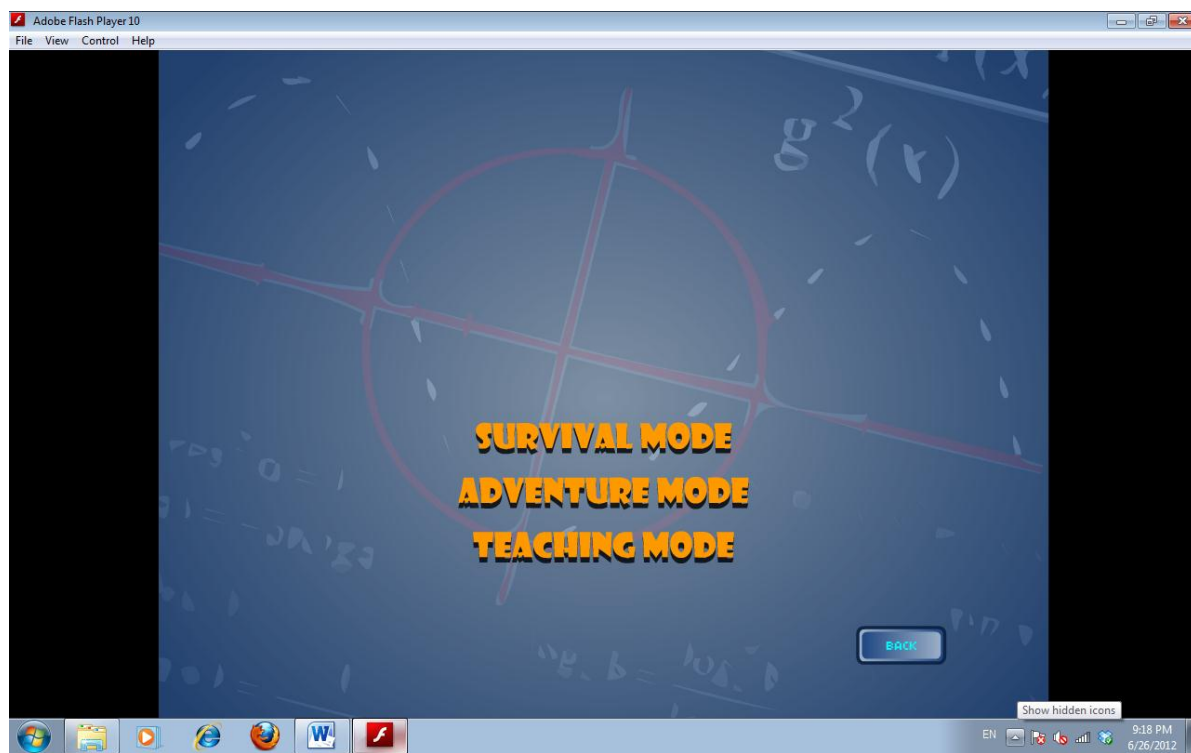
STORYBOARD OF MATHFIGHTER



Enter the game.



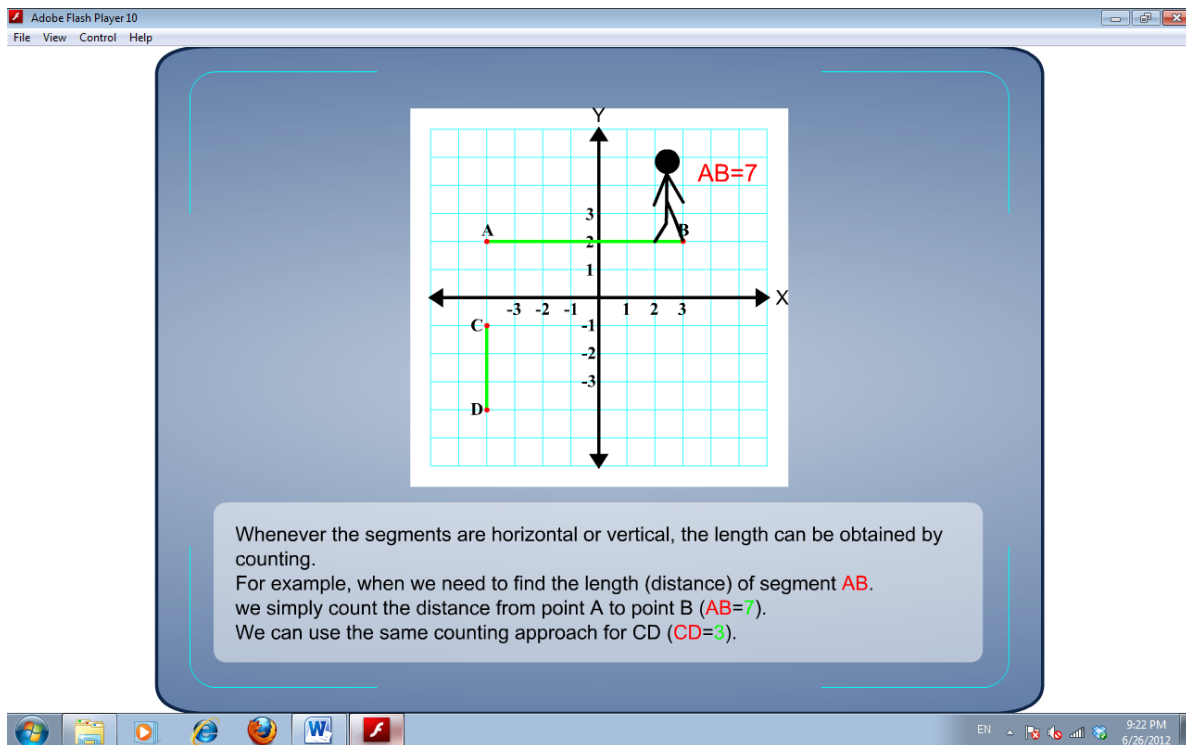
Game has three modes: survival, adventure, and teaching.



In survival mode, a game story is introduced that the virtual figure enters a math world.



A math world introduces how to calculate the distance of two points in a coordinate.





The virtual figure moves forward/backward when clicking on left/right arrow key.



The virtual figure shoots monsters when clicking on mouse.



When reaching the castle, calculate the distance of two bombs by using coordinate tool.



Enter the distance in the gun setting and press the button to shoot.



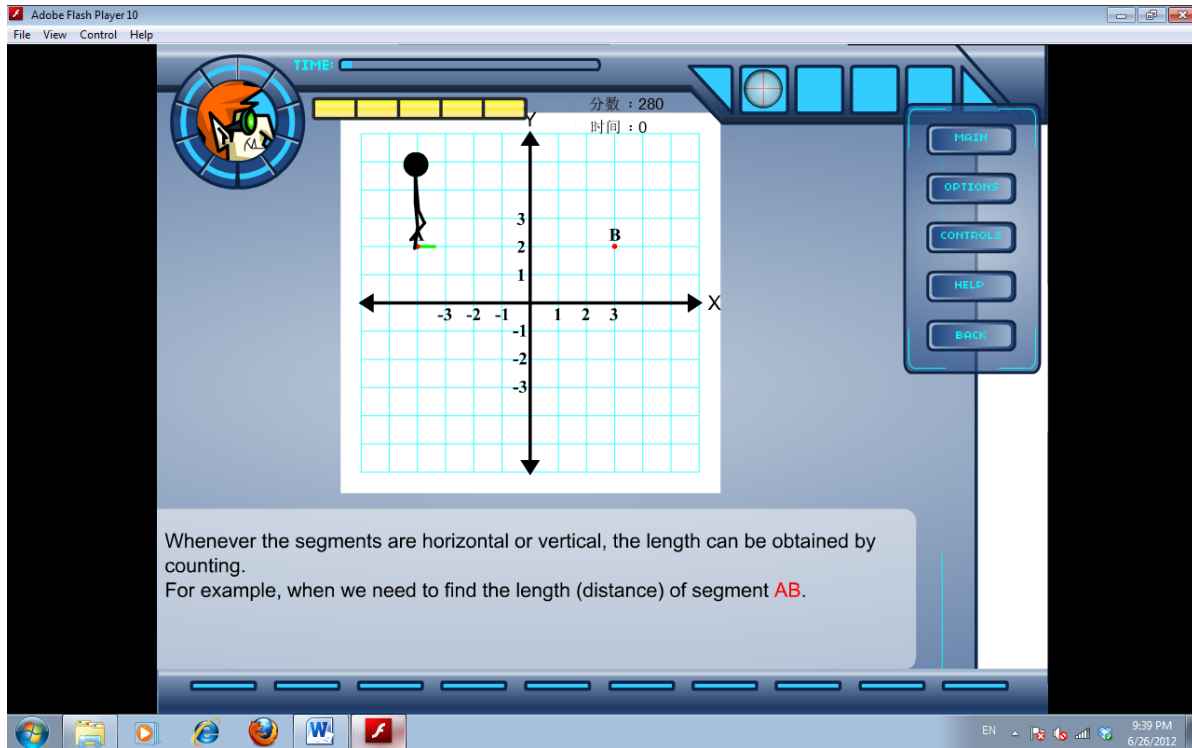
If the answer is right, castle is destroyed, and players win this level.



Move to next castle and repeat the same process to destroy the castle.



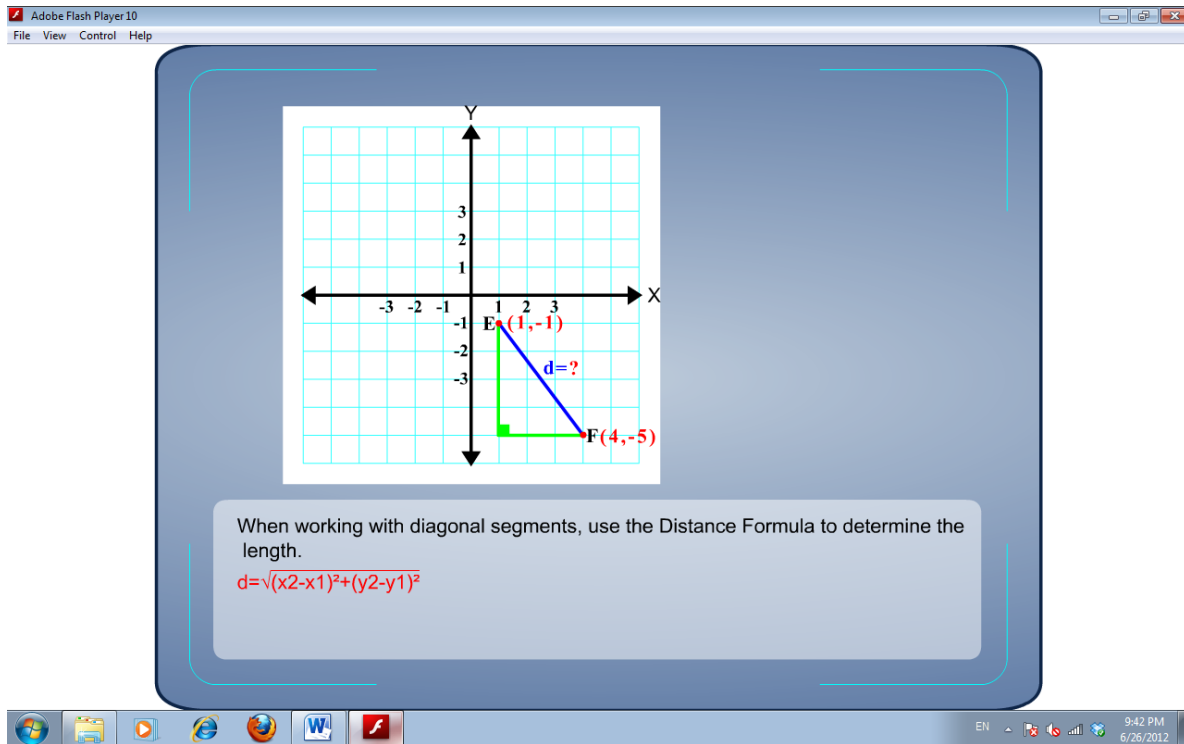
If the number is wrong, the mathematics instruction is displayed again.



Play on the same castle again after instruction, and move to next castle with the design of same mathematics concept.



Move to the instructional of next mathematics concepts after all castles in the same level are destroyed.



Shoot monsters at the next level.





Use the new mathematics concepts to calculate the distance of two bombs.



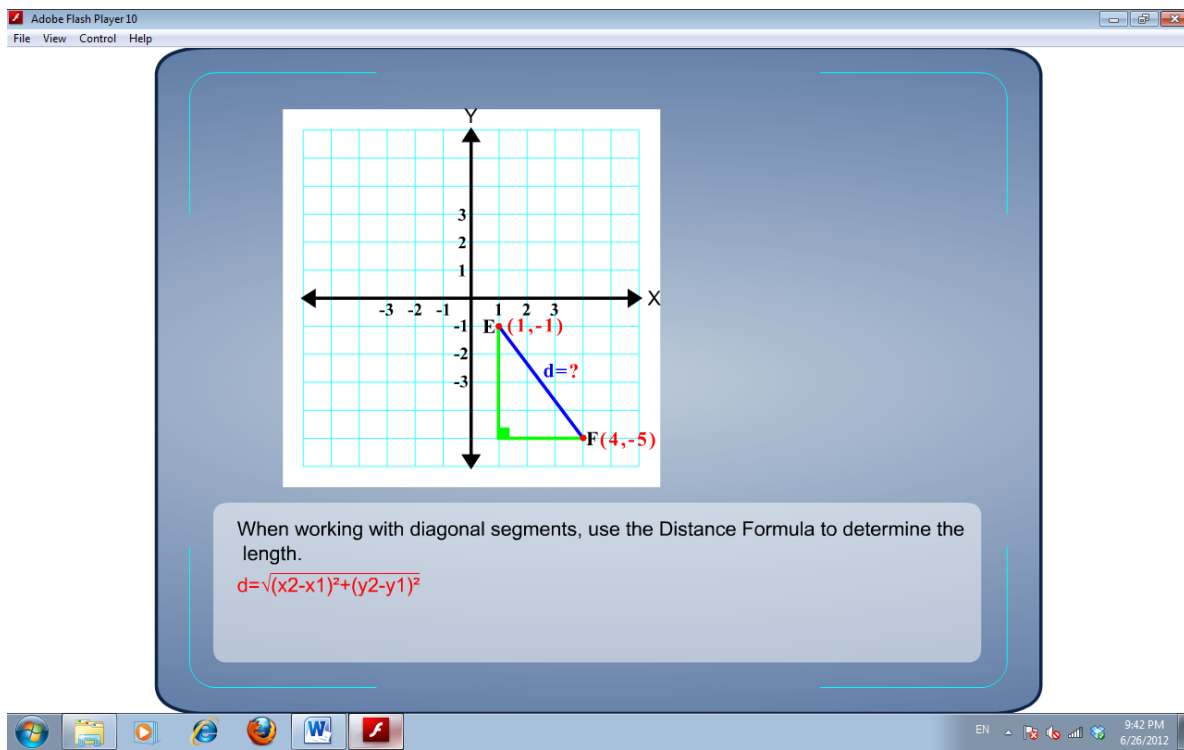
Enter the correct distance and press the button to shoot.



Win if the distance is correct.



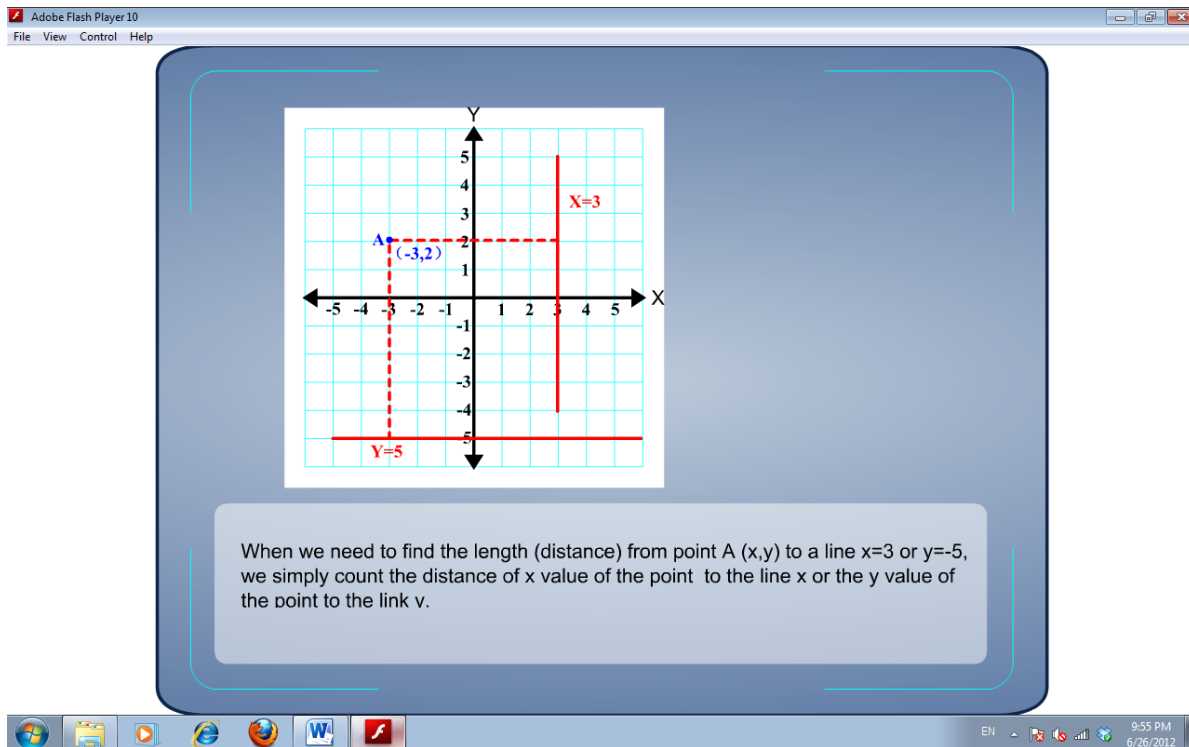
If the answer is wrong, same instruction will be displayed.



Move to the same castle after instruction.



Enter instruction of new mathematics concept if all castles on the same level are destroyed.





When reaching the castle, use new mathematics concept to calculate the distance.

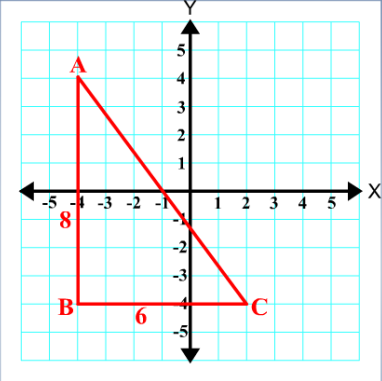


Follow the same process as before till all castles on the same level are destroyed.



Move to the mathematics instruction of next level.

Adobe Flash Player 10  
File View Control Help



$$AB^2 + BC^2 = AC^2$$

$$8^2 + 6^2 = AC^2$$

$$64 + 36 = AC^2$$

$$100 = AC^2$$

$$AC = 10$$

When working with diagonal segments, the Pythagorean Theorem can be used to determine the length.  
Notice how a right triangle was formed with AC as the hypotenuse.  
The legs of right triangle are on the graph and the length can be counted.  
Using the Pythagorean Theorem ( $a^2 + b^2 = c^2$ ).

EN 10:02 PM 6/26/2012

Calculate the distance with new mathematics tool and destroy the castle.

Adobe Flash Player 10  
File View Control Help

TIME:  分数 : 0 时间 : 88



Input the correct distance and press the button to attack.

EN 10:04 PM 6/26/2012

Follow the same process till all castles on the same level are destroyed.



Win this level and win the game.



No instruction is provided in adventure mode.



Users figure out how to calculate the distance on their own.



APPENDIX F  
STUDENT TREATMENTS PROCEDURES

## **Student Treatment Procedures**

**Group 1: learning mathematics without game or instructional support.** Students worked on a research assignment about what mathematics skills are required for pursuing a specific career.

**Group 2: learning mathematics with instructional support in non-gaming environment.** Students worked on web-based mathematics problems. At the beginning of the assignment, an instruction of how to solve the mathematics problems was provided. When working on the mathematics problems, students were provided with guided practice based on the result. Explanatory feedback was provided.

**Group 3: game-based learning with instructional support.** Students played the version of *MathFighter* with instructional support. An instruction of how to solve the mathematics problems was provided at the beginning of the game. When playing the game, players were provided with guided practice based on the game result. Explanatory feedback was provided when players did not give the right solution. Players continued to next level after completing the current level.

**Group 4: game-based learning without instructional support.** Students played the version of *MathFighter* without instructional support. Players entered the game directly without instruction, and guided practice or explanatory feedback was not provided. Players continued to next level after completing the current level.





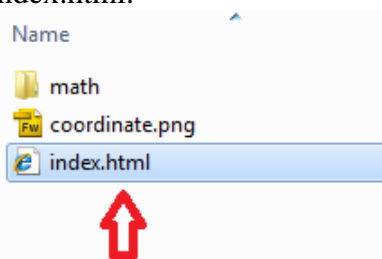
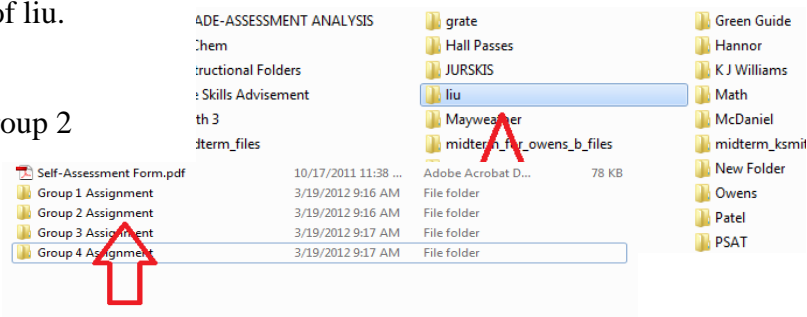
## Group 2 Treatment Procedure

Please follow the instructions to complete your assignment.

**Step 1:** Turn on your computer and click on Computer on your desktop. Choose J drive on your screen and browse to the folder of liu.

**Step 2:** Click on the folder of Group 2 Assignment.

**Step 3:** Click on the file of index.html.



**Step 4:** Follow the pages to complete the assignment. You have 3 sessions to complete the assignment.

Math and Learning	
<p><b>Welcome To Work On This Math Assignment!</b></p> <p>You will practice on some math problems with instructional support, such as guided practice and feedback. Enjoy your learning experience.</p> <p><a href="#">Please click here to go to the exercise.</a></p>	<p><b>Questions and answers</b></p>



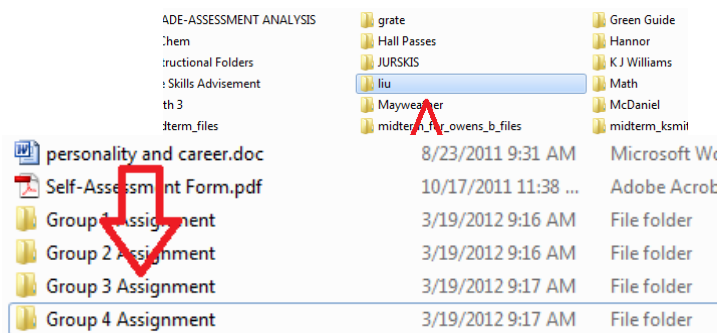
## Group 3 Treatment Procedure

Please follow the instructions to complete your assignment.

**Step 1:** Turn on your computer and click on Computer on your desktop. Choose J drive on your screen and browse to the folder of liu.

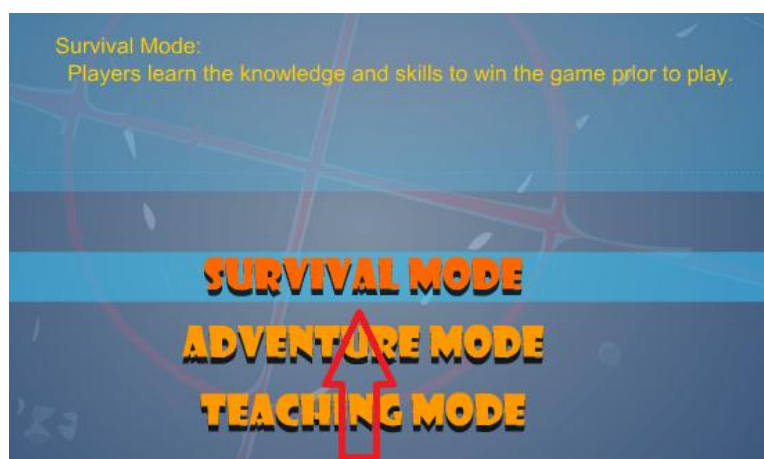
**Step 2:** Click on the folder of Group 3 Assignment. Click on GAME folder.

**Step 3:** Click on the file of index.swf.



Name	Date modified	Type	Size
18.swf	3/13/2012 11:55 PM	SWF Movie	712 KB
19.swf	3/13/2012 11:55 PM	SWF Movie	701 KB
20.swf	3/13/2012 11:55 PM	SWF Movie	719 KB
21.swf	3/13/2012 11:55 PM	SWF Movie	706 KB
fourpei.swf	3/13/2012 11:21 PM	SWF Movie	60 KB
index.swf	3/13/2012 11:55 PM	SWF Movie	377 KB
onepei.swf	3/13/2012 11:21 PM	SWF Movie	69 KB
trepei.swf	3/13/2012 11:21 PM	SWF Movie	76 KB
tyopei.swf	3/13/2012 11:21 PM	SWF Movie	56 KB
剧情动画1.swf	3/13/2012 11:21 PM	SWF Movie	15 KB
剧情动画2.swf	3/13/2012 11:21 PM	SWF Movie	15 KB
剧情动画3.swf	3/13/2012 11:21 PM	SWF Movie	15 KB
剧情动画4.swf	3/13/2012 11:21 PM	SWF Movie	15 KB

**Step 4:** When you start playing, choose Survival Mode and start on level 1. Enjoy the game experience.



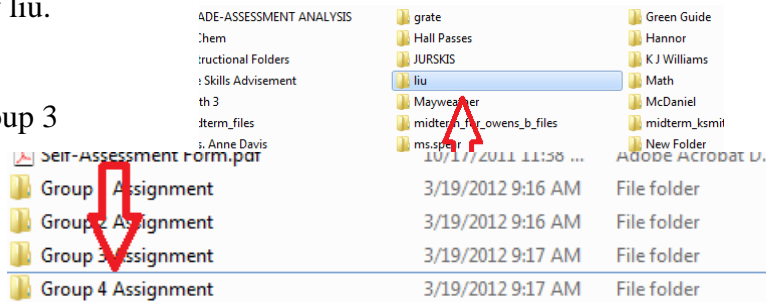
## Group 4 Treatment Procedure

Please follow the instructions to complete your assignment.

**Step 1:** Turn on your computer and click on Computer on your desktop. Choose J drive on your screen and browse to the folder of liu.

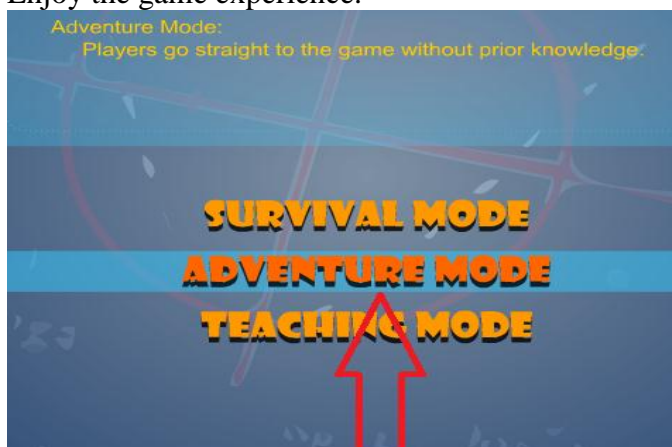
**Step 2:** Click on the folder of Group 3 Assignment. Click on GAME folder.

**Step 3:** Click on the file of index.swf.



Name	Date modified
18.swf	3/13/2012 11:5
19.swf	3/13/2012 11:5
20.swf	3/13/2012 11:5
21.swf	3/13/2012 11:5
fourpei.swf	3/13/2012 11:2
index.swf	3/13/2012 11:5
onepei.swf	3/13/2012 11:2
trepei.swf	3/13/2012 11:2
tyopei.swf	3/13/2012 11:2
剧情动画1.swf	3/13/2012 11:2
剧情动画2.swf	3/13/2012 11:2
剧情动画3.swf	3/13/2012 11:2
剧情动画4.swf	3/13/2012 11:2

**Step 4:** When you start playing, choose Adventure Mode and choose any level you want to play. Enjoy the game experience.



## APPENDIX G

### APPROVAL AND PERMISSION DOCUMENTATION

Mar. 15, 2012

### Minor Assent Form

Dear Participant,

You are invited to participate in my research project titled, “Motivational Effects of Instructional Support Provided by Game-based Learning of High School Mathematics.” Through this project I am learning about how student motivation can be impacted by instructional support elements inside a computer game.

If you decide to be part of this, you will allow me to work with you on your motivation toward mathematics. You will take instructional support assignment either with or without gaming environment. You will take assessment on the academic performance of mathematics and motivation questionnaire. Your participation in this project will not affect your grades in school. I will not use your name on any papers that I write about this project. However, because of your participation you may improve your motivation toward mathematics and your academic performance on mathematics. I hope to learn something about motivation that will help other children in the future.

If you want to stop participating in this project, you are free to do so at any time. You can also choose not to answer questions that you don't want to answer.

If you have any questions or concerns you can always ask me or call my teacher, Dr. Rojewski at the following number: 706-542-4461.

Sincerely,

Yu Liu  
Workforce Education, Leadership and Social Foundations Department  
University of Georgia  
Contact Information  
Tel: 678-677-7796                      Email: yuliu@uga.edu

---

I understand the project described above. My questions have been answered and I agree to participate in this project. I have received a copy of this form.

---

Signature of the Participant/Date

**Please sign both copies, keep one and return one to the researcher.**

Additional questions or problems regarding your rights as a research participant should be addressed to The Chairperson, Institutional Review Board, University of Georgia, 629 Boyd Graduate Studies Research Center, Athens, Georgia 30602; Telephone (706) 542-3199; E-Mail Address IRB@uga.edu

Gary Liu  
2575 Harris Street  
East Point, GA 30344  
March 15, 2012

Dear Student Parents/Guardians:

I am writing to inform you that your child is invited by Mr. Liu to participate in his research about motivation on mathematics through different instructional support conditions. The reason for the study is to find out how instructional support of mathematics in computer games such as explanation and feedback can impact student motivation.

Participants will experience one of the four conditions: (a) learning without instructional support or game, (b) learning with instructional support but without game, (c) game-based learning with instructional support, or (d) game-based learning without instructional support. The research is under the supervision of regular classroom teachers. Students will take a questionnaire after the exposure to the conditions. Participants will take pre-and post-test on mathematics. The research will be administered in three days and 90 minutes each day in regular class period. No discomforts or stresses are expected.

No risks are expected in this research. No potential loss of instructional time will occur in this research because the content of research is compatible with required mathematics integration in career and technical education curriculum. The research is an alternative of the weekly assignment on college411 mathematics portion in career and technical education classes. Students have the option to work on regular college411 assignment and their grades will not be affected by the decision to participant or not to participate in the research.

No personally identifiable information will be gathered on student participants (e.g., name, social security number, or birth date). Each student will be assigned with a unique numeric identifier when the permission form is returned to the teacher. The identifier cannot be linked to students' identifiable information. All data will be kept in a secured location.

Further information will be provided if your child agrees to participate in the research. Your official permission will be needed prior to the research.

Sincerely,

Gary Liu  
Information Technology Teacher

- The reason for the study is to find out how instructional support of mathematics in computer games such as explanation and feedback can impact student motivation.
- The direct benefits to participants that I may expect from it are (1) participants' increased motivation toward mathematics, and (2) participants' better academic performance of high school geometry. The increased motivation toward mathematics could impact students' education during secondary schools, and may impact their post-secondary options for higher education or career, leading to potential societal benefits.
- Participants will experience one of the four conditions: (a) learning without instructional support or game, (b) learning with instructional support but without game, (c) game-based learning with instructional support, or (d) game-based learning without instructional support. The research is under the supervision of regular classroom teachers. Students will take a questionnaire after the exposure to the conditions. Participants will take pre-and post-test on mathematics. The research will be administered in three days and 90 minutes each day in regular class period. No discomforts or stresses are expected. No risks are expected.
- No potential loss of instructional time will occur in this research because the content of research is compatible with required mathematics integration in career and technical education curriculum. The research is an alternative of the weekly assignment on college411 mathematics portion in career and technical education classes. Students have the option to work on regular college411 assignment and their grades will not be affected by the decision to participant or not to participate in the research.
- No personally identifiable information will be gathered on student participants (e.g., name, social security number, or birth date). Each student will be assigned with a unique numeric identifier when the permission form is returned to the teacher. The identifier cannot be linked to students' identifiable information. All data will be kept in a secured location.
- The researcher will answer any further questions about the research, now or during the course of the project, and can be reached by email at: yuliu@uga.edu. I may also contact the professor supervising the research, Dr. Jay Rojewski, Workforce Education, Leadership and Social Foundations Department, at 706-542-4461.
- I understand the study procedures described above. My questions have been answered to my satisfaction, and I agree to allow my child to take part in this study. I have been given a copy of this form to keep.

678-677-7796  
**Telephone**

Date \_\_\_\_\_

## INFORMED CONSENT FORM (For Individuals over 18)

I, \_\_\_\_\_, agree to take part in a research study titled, “*Motivational Effects Of Instructional Support Provided By Game-Based Learning Of High School Mathematics*”, which is being conducted by Mr. Gary Liu, from the Workforce Education, Leadership, and Social Foundations Department at the University of Georgia under the direction of Dr. Jay Rojewski, Workforce Education, Leadership and Social Foundations Department (706-542-4461). I understand that participation in this research study is voluntary. I can refuse to participate or stop taking part at any time without giving any reason, and without penalty or loss of benefits to which I otherwise entitled.

- The reason for the study is to find out how instructional support of mathematics in computer games such as explanation and feedback can impact student motivation.
- The direct benefits to participants that I may expect from it are (1) participants' increased motivation toward mathematics, and (2) participants' better academic performance of high school geometry. The increased motivation toward mathematics could impact students' education during secondary schools, and may impact their post-secondary options for higher education or career, leading to potential societal benefits.
- Participants will experience one of the four conditions: (a) learning without instructional support or game, (b) learning with instructional support but without game, (c) game-based learning with instructional support, or (d) game-based learning without instructional support. The research is under the supervision of regular classroom teachers. Students will take a questionnaire after the exposure to the conditions. Participants will take pre-and post-test on mathematics. The research will be administered in three days and 90 minutes each day in regular class period. No discomforts or stresses are expected.
- No risks are expected. No potential loss of instructional time will occur in this research because the content of research is compatible with required mathematics integration in career and technical education curriculum. The research is an alternative of the weekly assignment on college411 mathematics portion in career and technical education classes. Students have the option to work on regular college411 assignment and their grades will not be affected by the decision to participant or not to participate in the research.
- No personally identifiable information will be gathered on student participants (e.g., name, social security number, or birth date). Each student will be assigned with a unique numeric identifier when the permission form is returned to the teacher. The identifier cannot be linked to students' identifiable information. All data will be kept in a secured location.
- The researcher will answer any further questions about the research, now or during the course of the project, and can be reached by email at: yuliu@uga.edu. I may also contact the professor supervising the research, Dr. Jay Rojewski, Workforce Education, Leadership and Social Foundations Department, at 706-542-4461.
- I understand the study procedures described above. My questions have been answered to my satisfaction, and I agree to take part in this study. I have been given a copy of this form to keep.

<u>Yu Liu</u>	<u>Mar. 15, 2011</u>	<u>yuliu@uga.edu</u>	<u>678-677-7796</u>
<b>Researcher</b>	<b>Signature</b>	<b>Date</b>	<b>Email</b>
			<b>Telephone</b>

Name of the Individual	Signature	Date
Please sign both copies, keep one and return one to the researcher.		

### Permission of School System

From: Sims, Dan A  
Sent: Monday, November 28, 2011 11:09 AM  
To: Liu, Gary  
Subject: RE: Request of Using Classroom for Research

Permission granted.

From: Liu, Gary  
Sent: Monday, November 14, 2011 9:39 AM  
To: Sims, Dan A  
Subject: A Question About Using Classroom for Research

Mr. Sims,

I am writing to request your permission to conduct an experimental research within our high school. I would like to conduct my research within the Business and Computer Science classes in our school. I have contacted the related department in the county, and Debbie Jaffe, the director of Data Integration and Utilization, replied that all I need is your permission if I conduct my research in our school. Her reply is attached below this request.

The experimental study is about student motivation in mathematics if instructional support is integrated in game-based learning. Students will play three versions of games with or without instructional support in mathematics, and their motivation will be evaluated with a questionnaire entitled Game Play Questionnaire. I would like to conduct the research within our schools during the month of January, 2012. The research will take place in a regular school day, during a regular class period, and under the supervision of regular classroom teachers. The parental permission slip will be distributed to the students prior to the experiment. No student will participate without returning a signed permission form. As the researcher, I will be administering the experiment within the classrooms. The data gathered will be kept confidential. No personally identifiable information will be collected. There will be no physical or psychological risk on participants in this experiment. The result will benefit our students who need to be motivated to learn mathematics.

Please let me know if you have any questions about the research study. Thank you in advance for your consideration of my request. I look forward to hearing from you soon.

Gary Liu  
Computer Science Teacher  
Doctoral Student at UGA



From: Jaffe, Debbie  
 Sent: Tuesday, September 27, 2011 1:10 PM  
 To: Liu, Gary  
 Subject: RE: A Question About Using Classroom for Research

Good afternoon, Mr. Liu! If you are only seeking to perform your research at Tri-Cities HS, since you are currently a teacher at the school, you will only need approval from the principal, Dan Sims. If, however, you are seeking to perform your research at multiple schools within the system, you will need to complete and submit a research application for district review. The review process usually takes six to eight weeks.

Information on the research application process, if you need to go that route, can be found on the FCS website via the link below:  
[http://portal.fultonschools.org/departments/Org\\_Advancement/Assessment\\_Accountability/Pages/ResearchRequests.aspx](http://portal.fultonschools.org/departments/Org_Advancement/Assessment_Accountability/Pages/ResearchRequests.aspx)

Good luck with your project! If you have any additional questions, please feel free to contact me,

Debbie Jaffe  
 Director, Data Integration and Utilization  
 Fulton County Schools  
[jaffe@fultonschools.org](mailto:jaffe@fultonschools.org)  
 404-763-5508 (office)

From: Liu, Gary  
 Sent: Monday, September 26, 2011 9:37 AM  
 To: Jaffe, Debbie  
 Subject: RE: A Question About Using Classroom for Research

Ms. Jaffe,

I am a technology teacher at Tri-Cities High School and I am taking my doctorate at UGA. Right now, I am working on my dissertation and I need to develop an experiment to study the effect of guidance in game-based learning. I would like to know whether I can develop such an experiment in regular classrooms at Fulton County.

My experiment will relates game-based learning and student motivation in math by using instructional support. I will develop a few small games with various learning elements and test the effect of those elements toward student motivation. To make it simple, students will play different computer games I designed and then will take a questionnaire about motivation after the experiment. Students' personal information will not be collected or released in the research. It would be helpful to let me know the possibility and the procedure to develop such an experiment in Fulton County schools. Your help is greatly appreciated. Have a nice day.

Gary Liu  
 Tri-Cities High School