THE IMPACT OF DIGITAL GAMES ON HIGH SCHOOL STUDENTS' ACADEMIC ACHIEVEMENT IN MATHEMATICS EDUCATION: A META-ANALYTIC INVESTIGATION

Godwin Nnaemeka Okeke

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APPROVED:

Tandra Tyler-Wood, Major Professor
J. Michael Spector, Committee Member
Gerald A. Knezek, Committee Member
Cathleen Norris, Interim Chair of the
Department of Learning Technologies
Victor Prybutok, Interim Dean of the College
of Information and Vice Provost of
the Toulouse Graduate School

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The focus of this study was to conduct a meta-analytic investigation to combine the results obtained in independent studies aimed at determining the effectiveness of using digital games, as opposed to traditional methods, as a strategy for improving students' performance in high school mathematics. The major question of this study is: "Does the research on the use of games in high school mathematics support the use of games as a teaching strategy for improving student achievement?" To answer this question, meta-analysis was employed. Meta-analysis synthesizes and analyzes the quantitative data collected in independent and multiple empirical studies carried out on similar topics, situations, and hypotheses in order to reach a general judgment regarding the results of these studies. To determine which studies to use, specific criteria including articles published in refereed journals, thesis, and dissertation studies with experimental and control groups, research with effect size, sample size, standard deviation, and means. Based on these criteria, it was decided to include six experimental studies in the meta-analysis. The result showed that there was no significant differences between the use of digital games and traditional methods to teach mathematics in high school. The weighting factor of the two variables, standard deviation and number of participants, may account for the lack of support for gaming over traditional method of instruction.

By

Godwin Nnaemeka Okeke

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INTRODUCTION

1.1 Context of the Problem—Defining Games

In Reality is Broken, Jane McGonigal said, “If you are a gamer, it is time to get over any regret you might feel about spending too much time playing games. You have not been wasting your time. You have been building up a wealth of virtual experiences that can teach you about your true self; what your core strengths are, what really motivates you and what makes you happiest” (McGonigal, 2011, p.12).

A digital game is defined herein as a digital experience in which participants strive to achieve a set of non-trivial, fictive goals within the constraints of a set of rules that are enforced by software; the participants receive feedback toward the completion of these goals (e.g., progress, advancement, win condition) and the participants are intended to find some recreational value in the game. Digital games appear in various forms such as symbols, objects, pictures, and icons. There are more than 500 million gamers worldwide and a cohort of extreme gamers (defined as those playing for more than 45 hours a week) has developed in America (McGonigal, 2011). Digital games are played by teenagers with 60% of these teenagers playing more than half an hour per day (Corbett, 2012). The digital game industry is growing rapidly with reported revenue of $25 million in 2011 according to the Entertainment Software Association (Geuter, 2012).

According to (Gee, 2003), approximately 90% cell phones owned by students connect not only to social media networks but, more importantly to games. For example, 65% of the 2 billion apps downloaded are games at a cost of over $175,000 per day. Furthermore, about 97% of youths between the ages of 12 and 17 enjoy playing games on their computers, and the average player has been doing so for half of their lives. The United States boasts over 183 million gamers and China has well over 200 million gamers (Brooke-de-Bock, 2012). The average American gamer spends 13 hours a week on digital games and those in the forefront spend a lot more time–up to 45 hours each week (McGonigal, 2011).

The generation born in the 1990s may be called the game generation. High school students born between 1980 and 2004 are called the millennial generation (Prensky, 2001). According to Beloit College, the class of 2016 entering college freshmen has always lived in cyberspace, and some can be considered electronic narcotics (Beloit College, 2012). Consequently, teachers of these students need a paradigm shift to catch up with the learning styles of this new-age crop of students; if current technology has changed our lives as adults, it has also influenced youth and how they think about learning and education.

Since 2000, there has been increasing interest in the use of digital games in pursuit of educational goals. Digital games are highly engaging and motivating, and seasoned educators have suggested taking advantage of this enormous tool to facilitate learning (Gee, 2007; Kafai, 1995; Squire, 2003). Instructors find a gap between what they experienced in school in the 20th century versus the experience of students in the 21st century. Little wonder, then, that the present generation of students interacts differently than prior generations of students (Prensky, 2001). Past research work indicates that digital games have the potential to draw students into the learning process and to encourage them to participate through a more interactive environment (Weber, 2007). According to Kim (1995), not all learning needs to be serious in the sense of being focused tightly on specific concepts, principles, and procedures without enhancements that might add a sense of excitement. Having fun does not mean that learning is not taking place. Kim suggested that it is possible to learn math while enjoying oneself at the same time and that one of the best ways of learning math is through games. Research supports the idea that games can stimulate students' interests and motivation (Grimes & Feenberg, 2009), and that may be the reason why hundreds of studies have been conducted on the impact of digital games in education. This researcher intends to focus specifically on the impact of digital games on mathematics in high school.

1.2 Statement of the Problem

Digital games can be used as learning tools. This idea is clearly amplified by (Jonassen 1989) in his work entitled *Computers as Cognitive Tools*. Digital technology is simple yet powerful. Digital games use technology pedagogy that is a tool used by a teacher to describe and understand effective pedagogical practice in a technology-enhanced learning environment. To facilitate students' development of various higher-order thinking skills, skill development can be achieved by aligning the cognitive processes required to use a given technology with the intended student learning outcomes. Further, mapping the cognitive characteristics of the technology and the learning process in a given instructional situation operationalizes digital games (Klein, 2003). Teachers who were more accepting of constructivist principles were more likely to use instructional software based on a student-centered concept of teaching and learning. Examples are open-ended applications that enable students to construct a more complex understanding of the learning material (Maloy, Edwards, & Anderson, 2010).

1.3 Purpose of the Study

The purpose of this investigation was to explore the effectiveness of digital games on math achievement in high school. A meta-analysis was conducted with six empirical studies out of an initial number of 101 studies on traditional high school methods of mathematics instruction versus mathematics instruction via digital games. These six studies involved two groups—one group received traditional lessons and the second group received game-based lessons. A single meta-analysis was used for the two groups, borrowed from the works of Chen-Lin, Kulik, and Kulik (1991) who conducted a meta-analysis with only 32 out of 254 studies.

The dearth of empirical studies on the effect of digital games on math ability, the questionable results when digital games are used in math education, and above all, the rampant methodological flaws in existing empirical studies presupposes a clear need for a meta-analytic approach of the kind just described.

1.4 Overview of Meta-Analysis

Meta-analysis connotes a rigorous alternative to the causal narrative discussions of research studies that are rapidly expanding our research literature (Hunter, Schmidt, & Jackson, 1982). It is the analysis of analyses (Glass, 1976). It is a compendium of methods, significant levels, effect-size estimation, and analysis of variance (Rosenthal, 1984). A meta-analysis is linked to a systematic review that answers a research question by collecting and summarizing all empirical evidence that fits pre-specified eligibility criteria. A single meta-analysis was used for the two groups—a treatment group who received a game-based treatment and a control group that did not. (Chen-Lin, Kulik, and Kulik 1991) conducted a meta-analysis with a small sample size. Their results support the view that computer or digital-based instruction enhances student achievement and raises final examination scores. A systematic review identifies all studies that would meet the eligibility criteria and assesses the validity of the findings through the assessment of risk of bias called the file drawer effect. The file drawer effect refers to the practice of researchers filing away studies with negative outcomes. Negative outcomes refer to finding nothing of statistical significance and so the research is sometimes not published. Systematic review in a meta-analysis establishes synthesis and presentation of the characteristics of the included studies. A meta-analysis is a single document that summarizes findings from a collection of relevant studies and provides a more accurate estimate of information effectiveness in comparison to a single study. Meta-analysis aggregates all relevant studies on a particular topic and synthesizes the studies into one numerical answer, usually depicted on a forest plot. A funnel plot is a simple scatter plot of the intervention effect estimates from individual studies against some measure of each study's sample size. It is used primarily as a visual aid for detecting bias or heterogeneity. A symmetric, inverted funnel shape arises from a 'well-behaved' data set in which publication bias is unlikely. The greatest strengths of digital games as a medium involve their affordances for supporting higher-order cognitive, intrapersonal, and interpersonal outcomes in order to shift the emphasis and increase the value of future research (Gee, 2007; Squire, 2011).

1.5 Relevance of the study

Students and educators today are witnessing unprecedented pressure to achieve state proficiency standards on K-12 math achievement measures (Trends in International Mathematics and Science Study, 2003). As a result, stakeholders in education have embarked upon instructional strategies to improve math achievement (Fasset & Morella, 2008). In a typical classroom setting, a teacher's explanation of concepts through narratives or examples can be confusing to students using only typical classroom instructional practices. With the use of digital games, many abstract concepts (e.g., replacing formulas with concrete objects like cones, boxes, shapes; connecting content to learners' daily life experiences with practical examples and making learning true to life; and providing visual, tangible aids that learners can touch and use in the process of solving a mathematics problem) are broken down into simple chunks that the learner is comfortable with and can handle effectively. All these activities can augment computer designs and these computer-generated, virtual representations can help learners generate their own mental models of the mathematical concepts (Brandt, 1997). Digital games also offer students a familiar format to experience active learning through visualization, authentic problem-solving tasks, and instant feedback (Gee, 2003; Ke, 2009; Laurel, 1991).

Proficiency in math is critical if a student wants to succeed in a college preparatory math course in high school and establishes the basis for a solid foundation in the future (Gillispie, Martin, & Parker, 2009). There are studies that suggest proficiency in math increases the chances of college and career success and provides employment opportunities to potential candidates (U.S. Department of Education, 1977; Vogel, 2008). The use of Scholastic Aptitude Test (SAT) scores to identify mathematics talent has increased substantially over the past decade. The SAT is used to screen more than 150,000 students every year as a part of an assessment of mathematical talent. However, ill preparation in high school math is detrimental for high-poverty and minority students, especially African American, Hispanic, and English learners because of shaky and unstable foundations in early mathematics development (Albrecht, 2012).

Today's students and instructors experience unprecedented pressure to achieve state proficiency standards on K-12 mathematics achievement. Instructors endeavor to bring in computer games that integrate technology into mathematics classroom teaching and learning to enhance understanding and mastery of content by learners. In using computer games to teach mathematics, the question of effectiveness of the games used becomes very critical. The possibility of effectively using games as an instructional strategy is buttressed by empirical studies that showed the effectiveness and motivation of games when used by learners (Bahr & Rieth, 1989; Conati & Zhao, 2004; Ke & Grabowski, 2007).

Teachers and administrators often have challenges trying to determine how a particular game is aligned with the required curriculum, how to support its use in a math lesson, and how to set aside the time required for proper understanding of the game in a regular school setting (Van Eck, 2006). Further, not all schools have up-to-date computers, infrastructure, resources, and the technical know-how to support gaming. In addition, the No Child Left Behind (NCLB) act's emphasis on the use of rigorous, scientifically-based research interventions demands that teachers evaluate the efficacy of specific games on achievement and determine if the content of the game addresses tested content (U.S. Department of Education, 2002).

Although it is apparent that digital games facilitate learning and understanding of mathematics, there was lack of empirical evidence to support this assertion in K-12 educational settings (Tarng & Tsu, 2010). Publications of digital games have increased since 2006 (Chorney, 2012). In addition, the articles that empirically tested the impact of math on academic achievement seldom had positive findings and findings were not replicated (Dede, 2011).Research shows that many studies have missing demographics and did not have sufficient depth to be used in a meta-analysis. Moreover, several studies with small sample sizes tended to have larger effect sizes on average than studies with larger sample sizes, thus misleading meta-analysis findings (Cheung & Slavin, 2013). The first step in meta-analysis is to search the literature to find relevant articles and authors on studies that have addressed the same research question. The search is conducted using electronic databases such as the PsycINFO, ESBCO, and ERIC. Cheung and Slavin (2013) made it clear that one of the major challenges of a meta-analysis is that significant findings are more likely to be published than non-significant findings because researchers seldom submit non-significant findings (Dickey, 2007). This phenomenon is known as publication bias or the file-drawer problem (Rosenthal, 1979). This issue is not trivial.

Significant findings are estimated to be eight times more likely to be published than non-significant results (Wood & Fasset, 2003).

To address the problem of publication bias, researchers can extend their search from papers to relevant conference proceedings, and also by contacting experts via direct mailing (DM) to inquire about possible unpublished data relevant to researches that are not in the public domain.

Gaming and simulation have a lot in common. Simulation can facilitate the effectiveness of a game used in teaching mathematics (Fletcher & Tobias, 2006). A game is a system in which players engage in artificial conflict, defined by rules, where a player's action results in quantifiable outcomes (Bloom, 2009). Players compete against the opposing team based on rules that structure their actions to meet objectives determined by the game (Corbett, 2012). (Garns, Ahlers, and Drishall 2002) defined simulation as a model, a system, a reality, and a learning process. Educational simulation offers the opportunity for learners to experiment with aspects of reality that would otherwise be impossible to study outside of real-life situations (Hung, 2011). Once a goal is achieved through stimulation of the basic concept, the player can modify or change the variables several times to examine their effects on outcomes (Kiili, 2005).

1.6 Theoretical Framework

The theoretical framework for this study is drawn from theorists in the field of psychology, education, mathematics applications, and mathematical principles and standards. John Dewey, a pioneer in educational philosophy, has made, arguably, significant contributions to the development of educational thinking in the twentieth century. Dewey posited that students gain understanding through their individual experiences, interaction, and reflection (Eckerdal, 2009). Further, students make connections between what they have learned in the present to their prior knowledge of the subject matter. Dewey also believed in creating student-centered learning experiences that were not only valuable and relevant but also flexible to fit students' needs (Pieratt, 2010; Tzuo, 2007). Student-centered learning can be used to encourage students toward more active and participatory roles in their learning in school as a means of innovation and change (Ornsterns & Lavine, 2003; Pieratt, 2010; Vartuli & Rohs, 2007). Students who are supposed to be the beneficiaries of learning accomplish little or nothing in teacher-dominated classrooms. According to (Bransford, 1999), learners must learn by doing, as in the theory of constructivism in which "learning by doing" means some form of hands-on, external, and practical activity. Consequently, when students do not produce a particular pattern of thought, they will not be prepared to learn the relevant target concept during a mathematics class. Again, there is the issue of knowledge assembly where the learner puts forth the effort and attention to assemble their ideas with meaningful connection—not just finding solutions to problems, but knowing how to do so.

Digital annotation is a tool that can enhance comprehension, especially now when the current state-mandated tests in mathematics contain comprehension passages that must be interpreted and analyzed before solving the problem. Digital annotation is a note-taking technology that adds an extra layer of representation (e.g., highlights, bookmarks, meta-data, and linkages between sources) to digitally-retrieved sources. Further, digital annotation serves as a memory aid to retain information externally (Grimes & Feenberg, 2009).

According to the National Council of Teachers of Mathematics (NCTM, 2000), students learn mathematics by actively building new knowledge from experience and prior knowledge; i.e., students actively construct meaning and do not passively absorb experiences. This belief is contrary to the conventional or traditional approach of learning where students memorize and regurgitate as needed (Beal, Qu, & Lee, 2008). There is also the need for alignment of factual knowledge and procedural efficiency coupled with conceptual knowledge for students to be effective mathematical learners (NCTM, 2000). Thus, connected and conceptually-grounded ideas enable students to master and recall information and use such knowledge to tackle new and unfamiliar problems (Hiebet & Carpenter, 1992).

One of the principles of learning is recognizing previous knowledge in order to connect to present knowledge; i.e., the learner moves from what they already know (previous knowledge) to what they are yet-to-know (Christensen & Geber, 1990). This principle of learning is emphasized by the NCTM when they suggest that effective mathematics teaching requires the understanding of what students already know and need to learn, and then challenges and supports students to learn existing knowledge well (NCTM, 2000). This principle implies that the knowledge students have is not enough; the teacher must also have an understanding of what the learner needs and be able to accommodate or modify content if necessary.

The present generation of 21st century students need skills for success in their endeavors after graduating from high school. Perhaps the reason students are struggling so much in mathematics is because instruction is communicated to them in a language or with a method that they do not fully understand. It is a problem when the bulk of students are taught in a conventional or traditional method without the use of technology applications that they are familiar with because the technology foundation is not laid early enough (e.g., beginning in pre-K). It has always been 'drill and practice' with some digital tools as a source of fun and recreation for the learner (Ahmad, Shafie, & Latif, 2010; Gillispie, Martin, & Parker, 2009). In spite of the fact that research has shown advantages of using digital games to enhance learning in the classroom, very few studies have been conducted to show the benefits to high school students, especially in mathematics classrooms (Li & Ma, 2010).

1.7 Research Questions

RQ1: What empirical evidence exists to show that the use of games in high school mathematics can improve learning?

RQ2: What conclusion, if any, can be drawn from findings related to the first question about any potential advantages of game-based mathematics learning in high school versus traditional methods?

1.8 Definition of Terms

Digital game – A digital game is an interactive program for one or more players, meant to provide entertainment. A game is an adaptation of ‘traditional’ game systems, with rules, player representation, and environment managed through electronic means.

Constructivism – Constructivist theory stands on the premise that we construct or build knowledge of our world from our perceptions and experiences that come about through our previous knowledge (Simon, 1995, p. 115).

Edutainment – A term similar to infotainment that expresses the marriage of education and entertainment in a work such as presentation or a website. The one-time, most educationally-effective children's program Sesame Street and the Jeopardy! mathematics game are examples of edutainment.

Effect size – A quantitative measure of the difference between the average score of participants in the treatment group and the average score of participants in the control group.

Extrinsic motivation – The performance of an action in order to earn a merit, avoid criticism, or please other people for some reason that may have little to do with genuine and lasting understanding. The learner is not really interested in the activity for its own sake, but only about the gain emanating from the activity.

Intrinsic motivation – The natural tendency to seek out and conquer challenges as we pursue personal interests and exercise capabilities (Deci & Ryan, 1985; Reeve, 1996).

Jeopardy! –A classic game show with questions and contestants who vie for supremacy. Rewards are given at the end of the activity to winners of the game. The Jeopardy! game is credited to Merv Griffin who was the founder.

Millennial generation – The demographic cohort following Generation X that is Generation Y. Most researchers and commentators use birth years between 1980 and 2004.

Publication bias – The tendency of researchers, reviewers, and editors to screen reports for publication on the basis of size and statistical significance of effects, rather than on the basis of study quality.

Traditional math teaching – A traditional, conventional, or teacher-centered approach to learning is still used in our classrooms today. Traditional classrooms use a sequence of memorizing, internalizing, and regurgitating undigested facts and procedures (Okeke, 2014). Instruction follows the same routine every single day and includes note taking, guided practice, and independent practice (Battista, 1999).

1.9 Limitations of the Study

This study is limited to digital games in high school mathematics classes. The researcher did not investigate digital games in elementary, junior high, or college classes. The criterion for this study was exclusively for high school students. The meta-analysis study analyzed traditional and game learning strategies in a high school. The participants range in age from 15 to 19 years old. The studies used are only those that met the criteria set forth for this research project and addressed game/traditional methods and studies that have mean scores, standard deviation, effect size, and mean effect size.

Meta-analysis cannot be conducted in an experimental fashion and therefore exposes the researcher’s inability to control sample sizes and missing data. Small samples led to the decreased sensitivity to a certain extent. Secondly, it was not possible to evaluate (code) the design quality of the research used in the primary studies. Further research is sought to consider the impact of digital games on gender (male versus female) in elementary or middle school or with special needs.

CHAPTER 2

REVIEW OF RELATED LITERATURE

2.1 Transforming Tradition via Technology

As a secondary school educator, I realized that students take their mobile devices wherever they go, including school. Students of this generation have become so used to having technology at their disposal that they cannot go anywhere without it. They use technology such as cell phones, iPods, or iPhones to play games, to communicate with friends and family, for entertainment and informational purposes. Smart phones are used to send text messages, take pictures, and log onto the Internet. Google is a common term used not only to identify an Internet search engine but also as a verb referring to finding answers to a specific question. Facebook is a common Internet website for communicating with others. It is truly a different world that we are living in today. If students are so proficient with the use of these mobile devices, why can they not transmit the same knowledge and skill set to accomplish their set goals in their academic endeavors? This is part of the reason why I embarked on this project.

The use of edutainment—a blend of education and entertainment that also educates and enlightens the learner—and games are resulting in a creative output that foreshadows a new Renaissance in learning to afford new options for human creativity and global social interaction in various fields of life. These technologies—as well as those emerging within a new, cyber-enabled landscape of social networking and advancing neural computer technology in an emerging global, technological workforce—are disrupting traditional education practices; producing new learning processes, environments, and tools; and expanding scientific discovery by exponential proportions (Psotka, 2013). Why is game-based learning so glacially slow at a time when our world is in dire need of a highly creative, innovative, and technologically sophisticated workforce to manage its complexities on a global scale? Many computer visionaries have foretold the coming transformation of education by computing (Feurzeig & Papert, 2011); yet, in retrospect, these prognostications sound alarmingly redundant year after year. An earlier respected pioneer, Seymour Papert, whose MIT Logo lab spawned many innovations, believed that digital games would not have much of an impact until education changed fundamentally (1996). What kind of changes could facilitate the implementation of new technology? Collins and Halverson suggested that the problem is not better simulations, games, and intelligent tutors but rather, a radical restructuring of the curriculum (2009). We need smaller curriculum modules than entire schools of four- or five-year course sequences. These courses need nationwide certification based on formerly monitored assessments. With these smaller modules, technology could be focused on improving instruction or radically altering its form in a completely disruptive way.

When mainframe computer manufacturers ignored the encroachment of personal computers, they held back the development and innovation surrounding their use; by doing so, they ensured their own demise. Instead of seeing the enormous popular advances that PCs held, they adamantly refused to use their skill and expertise to promote and accelerate this marvelous new technology development; this lack of foresight cost them their pre-eminence (Dede, 2005).

Simulations and games are burgeoning in many commercial and military enterprises but have made less impact on education (Khan & Christhi, 2011). The touch-sensitive, easy-to-use, direct manipulation interfaces on cell phones were unthinkable for those using early machines. At the time, these affordances fit well with teachers' competences and were relatively easy to integrate into classroom activities and remediation. These simple educational activities were not sufficiently important then to justify the purchase of expensive machines; one or two machines often sat frequently unused in classrooms or computer rooms with locked access. New processes demanded new workforce skills; therefore, a market developed around teaching these targeted skills, but educators safely ignored the main issues by relegating computers to teaching tasks like keyboarding (Dede, 2011).

In 1978, the National Science Foundation (NSF) funded a ground-breaking effort to build computer technology for education. Out of this enterprise came research and development including the successful and dominant games: Rocky's, Carmen Sandiego, and Oregon Trail. The use of these games became popular in mathematics, English, and history classes and their use was supported, theoretically and practically, by new insights into motivation and emotion in learning. From these earlier efforts, theoretical frameworks emerged that focused on learning toward a theory of intrinsically motivating instruction.

The first viable commercial game that led the foundation for the entertainment industry was the 1971 game Computer Space. The gaming industry experienced commercial ups and downs until ultimately, console gaming crashed in 1977. Rising again in the 80s with low publishing costs, game development expanded with different genres, such as adventure, fighting, and interactive movies, maze, platform-adventure, racing, and role-playing games. Video games became widespread and deeply established in the 1990s when they became mainstream entertainment and consolidated with publishers. Increasing computer power and lower costs afforded the integrated use of 3-D graphics, multimedia capabilities, and the production of newer genres, such as MUD (Multi-User Dungeons), multiplayer, real-time virtual worlds; first-person shooter games; and the massively multiplayer online role-playing games (MMORPGs) or "Persistent Worlds".

Although the gaming industry spawned scores of multibillion-dollar companies, most current commercial games have had little education content for mathematics, chemistry, or physics, and have not been designed with embedded pedagogical strategies that would make them appealing to teachers or parents (Kafai, 2006). Commercial games, however, have been shown to develop physical and cognitive skills in learners (Lin, Linn, Varma, & Liu, 2010). Many teachers and administrators are waiting for definitive proof that games are more effective than traditional instruction; although, from numerable studies, students are not learning well using traditional and text-based instructional methods (Okeke, 2014).

2.2 Games and Learning

Most games emphasize strategies that focus on participants' internal motivation to perform a task (Utman, 1997). Research on intrinsic motivation has found greater success when students engage in creative or complex tasks. However, this is not to say that extrinsic motivation has no role in effective game design. Intrinsic and extrinsic objectives are sometimes entwined. Immersive experiences in digital games can be pleasurable as well as disturbing/frightening (Lee & Hammer, 2011). Being immersed in a virtual environment provides a very specific set of affordances—both internal and external—to the environment. In *Why Virtual Worlds Can Matter*, Becker advocates that some things that occur in and around virtual worlds "may in fact point us in the direction of new forms of knowledge and acting in virtual spaces and give us insight into what new technologically mediated worlds may look like in the coming decades" (2007).

New technologies often have the potential for disrupting existing, established practices and this is prominent in education and training today. However, education has been slow to adopt these changes on a large scale; innovations appear to be adopted more by students within their changing social lifestyles than policy (Ladley, 2011). Education needs to become more modular and move out of the classroom into informal settings, e.g., homes and especially the Internet. Nationwide certifications based on these modules would permit technology to enter education more rapidly.

2.3 Digital Games and Mathematical Education

Games intrinsically represent fun, especially for young learners. It is possible that the combination of games and mathematics can lead to absence of fear and can enhance interest for learning mathematics (Cheng & Su, 2012; Mayer et al., 2002). Games can be interesting, interactive, lively, motivating, and can instill confidence in the minds of learners (Cheng & Su, 2012; Druckman, 1995). During the learning process, learners can challenge themselves and become deeply involved in goal-driven activities (Kiili, 2005). The development of digital technology has allowed digital learning activities to gradually infiltrate into our classrooms (Prensky, 2009). Digital technology has provided high-level simulations of authentic learning situations by offering user-friendly media activities for learners in the classroom (Hwang & Chang, 2011). Digital games can promote the breadth, depth, and variability of learning. Through appropriate learning design, it is possible to create an interactive, collaborative, and realistic simulated learning situation in the digital setting (Rasmusen, 2007). When learners learn in a life-like learning situation, they can increase their cognitive structure and stimulate their thinking and problem-solving capabilities (Brown, Collins, & Duguid, 1989). Some of the characteristics of games which are synonymous with the ideal conditions for learning are that games are active, system rule-based, contextually situated, and engaging. Game-based learning is more engaging and motivating than a traditional learning environment (Amory & Meyer, 1999).

Children and adults enjoy playing games. (Prensky, 2005) posited that “experience tells us that games can be very productive learning activities.”

Based on this information about digital games for learners, one wonders why games are not used more widely in classrooms. There are several reasons for this: inconsistent empirical evidence, time constraints, limited resources, and methodological flaws in empirical studies on games within the classroom (Kebritch, 2010).What is pertinent is that teachers need assistance in developing the technological, pedagogical, and content knowledge needed to effectively use games for learning. Thus, without this knowledge, teachers will not attempt to implement digital, game-based learning until they are confident in their ability to use games effectively to enhance learning (Erhel & Jamet, 2013).

Mathematics is a universal language and a fundamental discipline. It constitutes a significant area because most people participate in financial transactions every day. Math is said to be the foundation of other scientific fields (Becker, 2007). A solid foundation of mathematics in early childhood development will enhance and stabilize mastery on primary, secondary, and college levels (Stubblefield, 2006). However, there are militating factors against laying a solid foundation in early childhood education including anxiety, emotion, and intelligence, as attested to by educational psychologists (Cheng & Su, 2012). Many young learners are frustrated with mathematics at elementary and secondary levels; the failure rate is alarming. The fact that learners are not intelligent is not the problem; however, because some fundamental issues are not addressed, learners become low achievers (Kiili, 2005). Anxiety is caused by an intense classroom environment (Gibert, 2010). To help students avoid math anxiety and unnecessary emotions, it is imperative that the environment is interactive and lively, where every learner is a stakeholder with ownership of their learning.

As a teacher with over three decades of experience, my students generally believe that learning math equates to struggling with abstract concepts. However, according to research findings (Bai, Pan, Hirumi, & Kebritchi, 2012; Rhyne, 2000), digital games can help with math learning in the sense that games present abstract concepts in a visual manner that students enjoy. Within the limited time that students have in classrooms, students can easily be lost or become confused through narratives. With the use of computer technology, many abstract concepts can be visualized through computer designs. By so doing, virtual representations can help learners generate mental models of the math concepts (Brandt, 1997; Lopez-Morteo & Lopez, 2007). In addition, digital games give students the opportunity to choose from a variety of options to experience active learning through stimulated visualization, authentic problem solving, and instant feedback (Gee, 2003; Ke, 2009; Laurel, 1991). The process of building game activities into a math lesson develops students' problem-solving skills by enabling them to understand the concepts logically through the use of a visualized environment (Razak, Connolly, Baxter, Hainey, & Wilson, 2012).

A relationship exists between student engagement and student achievement (Kerr, 2005). To be successful in school, students must be engaged in their learning (Appleton, Christenson, Kim, & Reschly, 2006). Engagement implies regular class attendance, class participation, rigor in learning, and understanding and support from peers, adults, and teachers (Glanville & Wildhagen, 2007). Student learning environments are relevant and meaningful and allow for the needs of individual students to be fully engaged and focused in their learning (Klein, 2003). SCORE is an acronym that describes the index needed to meet the demand of student engagement (Strong, Silver, & Robinson, 1995) and stands for the following:

“S” represents Success—the need for mastery

“C” represents Curiosity—the need for understanding

“O” represents Originality—the need for self-expression

“R” represents Relationships—the need for involving others

“E” represents Energy—the necessity for a complete and productive life.

2.4 Digital Games as Instructional Tools

Learning refers to the active construction of an individual’s own knowledge by integrating new information with previous experience (Zeynel, Beyda, & Burak, 2013). From the student’s perspective, there are many advantages to using digital games in the classroom. The digital Jeopardy! was developed by Merv Griffin in 2004 and was adapted for the classroom to teach mathematics by Story, a math professor at Akron University. The classroom version allows students to engage in an interesting experience while deviating from classroom norms of passivity (Sugarman & Leach, 2005). The fundamentals of this game are shown in Figure 1.

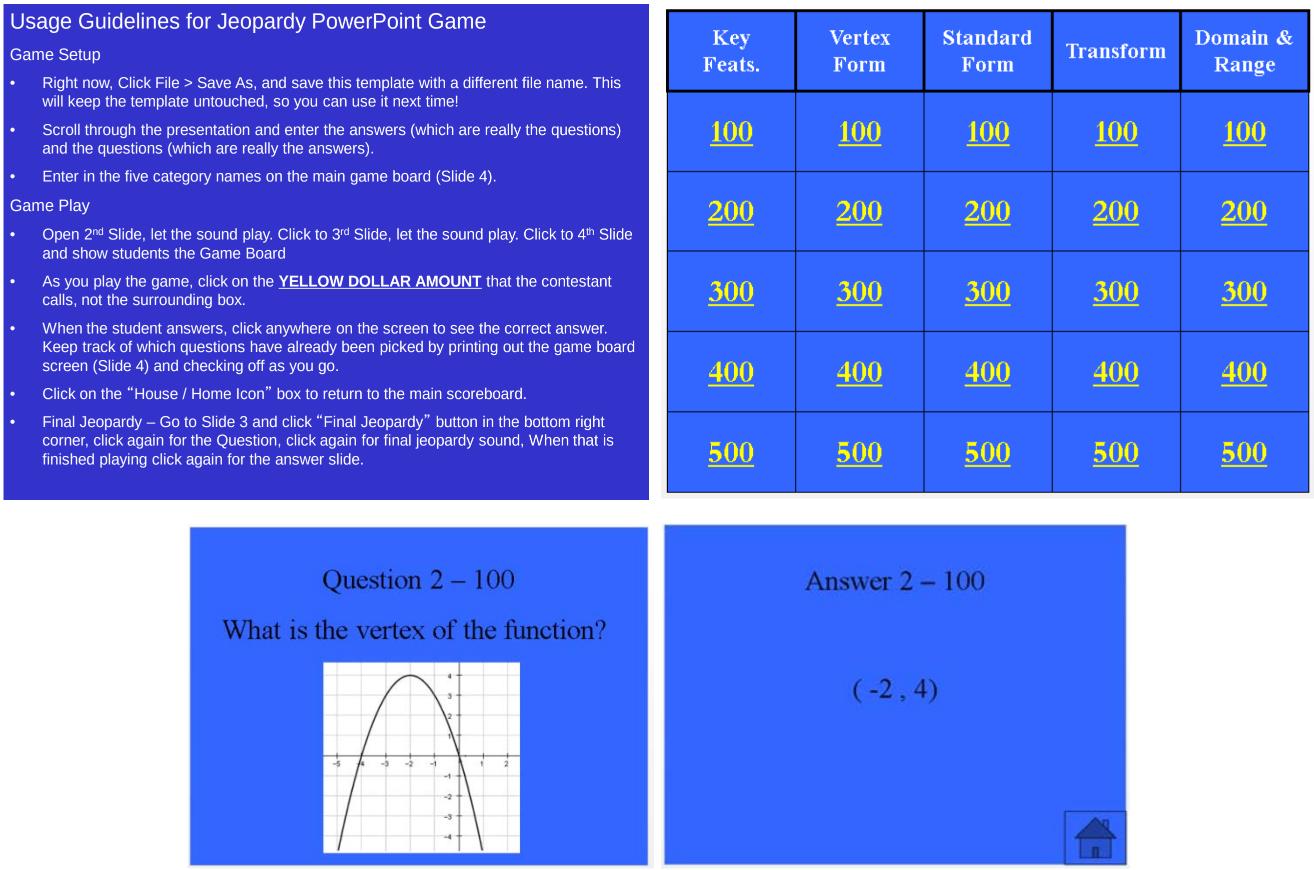


Figure 1. Jeopardy! Game Power Point Game.

Fast-paced competition such as the game of Jeopardy! motivates most modern-day learners to remain alert in their respective groups and encourages student participation to ensure their group emerges victorious. The questions cover a wide variety of math content and there are rewards and prizes for correct answers. Teachers and students benefit from this quiz game as the teacher presents topics on past and present concepts; students refresh their memories on past topics and answer questions on current topics.

Most schools are characterized by the traditional medium of print, which is too limiting to meet the challenges of diverse learners’ needs. For example, print materials present information for typical learners using one mode of representation (picture or text) without making provisions for individuals who learn best through audio or video. Digital games with text, pictures, video, animation/simulation, and audio can provide various levels of difficulty for learning tasks and several levels of support to students in addition to appealing to their abilities, interests, and needs (Rose, Meyer, & Hitchcock, 2005). The experiential learning theory of Martin & Wu (2010) in which learning occurs as a result of conducting tasks and reflecting on such experiences is still relevant in our classrooms today. According to Tracy and Meyer (2004), instructional games are effective learning tools because of immersion effects of games, where learners submerge themselves into the game environment and activities, thereby increasing their attention levels of the tasks at hand. Consequently, learners optimize performance as exemplified by the flow theory of Csikszentmihalyi (1990), which states that students are engaged when:

- They are completely involved and focused
- They have a sense of joy
- They know what needs to be done and how well they are doing as they progress
- They are capable of doing the activity
- They do not realize that time is passing.

Further, instructional games provide opportunities for learning by interacting with simulated environments and conducting tasks (Egenfeldt-Nielson, 2005). A good example is illustrated by Tarng and Tsu (2010) who theorized that digital games motivate students, make them active participants in their learning, simulate real-life situations, aid current teaching practices, and promote problem solving. The diagram in Table 1 portrays a cyclic process geared toward enhancing learning output or product.

Table 1

Game-Based Model of Learning Output (Adapted from W. Tarng and W. Tsai, 2010, World Academy of Science, Engineering and Technology, 61, p. 338.)

Input (Variables)	Process (Cyclic in Nature)	Output/Product
Learning Contents: Math	System Feedback	Learning Achievement
	User Judgment	Goal application
Digital Game Elements	User Behavior	Goal accomplishment
	System Feedback	Goal evaluation

This model is an illustration of how the learning process occurs in a typical classroom. Input spells out the content laced with corresponding digital game elements. User judgment leads to goal application, user behavior is a result of goal accomplishment, and system feedback tells the learner whether or not the set goal has been accomplished. The process is cyclical and ultimately increases learning achievement because of student engagement, interests, and commitment to the task at hand. According to (Trybus, 2009), digital games, apart from being highly engaging, have a learning pace attuned to the needs of individual students and give immediate feedback that enable students to know their mistakes. Digital games are student-centered which promotes challenge and cooperation, and engages students in the process of accomplishing given tasks. In addition, digital games give learners the opportunity to process mentally, use interpersonal skills, and develop spatial ability and physical coordination. Learners are provided the opportunities to improve learning accuracy, memory retention, critical thinking, information assembling, and new and current knowledge, discover new ideas and concepts, simulate and solve real-life experiences and problems, and test hypotheses (Huang, Wu, & Chen, 2012). Digital games give learners the opportunity to maintain self-confidence, effectively use learning tools, and encourage them to work with peers (Ke, 2008). Further, digital games enhance learning by doing, and strengthen multi-tasking abilities, strategic thinking, collaboration, and leadership abilities (Kickmeier-Rust & Albert, 2010).

Digital games have positive effects on learning by enhancing learners' memories and extending their cognitive capabilities. In addition, digital games reinforce, accelerate, and support higher-order thinking skills (Huang, 2011). (Mitchell and Savill-Smith 2004) identified some educational benefits derived from using games in our classrooms. They suggested that digital games:

- Are valuable tools that accelerate learning
- Encourage learners who lack interest or confidence in themselves
- Can reduce training time and the load of the instructor
- Enhance knowledge acquisition and retention
- Allow for manipulation of objects, supporting development towards levels of proficiency
- Are most effective when they are designed to address a specific problem or to teach a certain skill
- Are relevant to specific learning activities and goals
- Can be used to facilitate tasks appropriate to the learner's level
- Are designed to support specific learning outcomes, such as recall of factual content or as the basis for active involvement and discussion
- Are good vehicles for embedding curriculum content, such as math and science concepts that may be hard to visualize with concrete materials
- Enhance creativity and other forms of critical thought
- Have the potential to support cognitive processing and the development of strategic skills and encourage greater academic, social, and computer literacy skills among learners.

In a quantitative, quasi-experimental study with a pre- and post-test design to analyze student learning with digital games, (Tarng & Tsu 2010) discovered that the experimental group used in the study used digital math games at home, while the control group did not use digital games. This study showed that there was a significant difference in learning with the experimental group who used digital math games. The researchers also discovered that most students were satisfied with the use of digital games for learning and the context in which the games were used to support their learning.

A meta-analysis study was carried out by (Li and Ma 2010) that involved the learning of math with digital games for grades K-12. The researchers used a three-step approach that involves formulating the problem, finding solutions, and making sure that past errors are not repeated. In addition, there was a 100% interpreter agreement to code criteria to determine the articles and dissertations to be used in the meta-analysis. The result of this study showed a positive effect on the use of digital games on math achievement and the result was further enhanced when digital games were used: (a) with special needs students, (b) in elementary math classroom, and (c) where a constructivist approach to teaching was practiced. A short intervention of six months with digital games was better than interventions of six to twelve months.

A quantitative, experimental study was conducted by (Camli and Bintas 2009) with a pre- and post-test design to determine the academic achievement of students using digital games. The researchers used computer software designed to assist students in math problem solving. The results of the study showed that the experimental group who used digital games for mathematics performed significantly higher on the post-test than the control group, which had no access to digital games.

A mixed-methods study was conducted by (Brom, Sisler, and Slavik 2010) to determine the effectiveness on student learning of a digital game. The researchers used pre-tests, videos, field notes, post-tests, and teacher and student interviews. Participants included 220 students aged 16-18 from eight secondary schools. The result of the study showed that digital games were easy for learners to use, they enjoyed role-playing with the game, and they appreciated the real-life data and story-telling features.

In a quantitative study conducted by (Kanthan & Senger 2011) to determine the effect of digital games on student learning, the researchers discovered that games are effective for teaching and learning, even for adults. Games support multiple intelligences and are motivating and engaging. These authors continued by positing that digital games effortlessly and seamlessly integrate vital concepts necessary for learning within safe, virtual, and mystical worlds.

Over the years, researchers have shown that one effective strategy of engaging students is to establish subject matter authenticity (Cheng & Su, 2012). Problem solving should not be done only within the four walls of the classroom; students need to know how to apply the knowledge they learn in real-life situations. Students understand the whole concept of application through digital games where they have the opportunity to explore, experiment, discover solutions to problems, and acknowledge their mistakes and shortcomings. Students often ask about relevance of what they study in the classroom to practical life. When course materials are linked to actual events in a student's past or present, the student is more likely to be motivated to embrace the given task. Student interest and enthusiasm could skyrocket if subject matter that builds on past and present experiences was presented (Hung, 2011).

The traditional method of teaching is still common in our classrooms today, even when most students are fully immersed in technology applications in other areas of their lives. Students prefer the use of tools to facilitate learning but most teachers prefer to teach the way they were taught (traditional method). Changing pedagogy to eliminate the achievement gap is a strategy that most researchers believe have some merit. A clear element of the new reform models is to change classroom instruction from teacher-centered to student-centered (Cline, 2007). Creating a student-centered classroom is the heart of reaching students with poor basic skills through problem-based digital games (Gros, 2007).

Researchers in the 1990s such as (Kafai & Kulik 2007) demonstrated the effectiveness of using digital games to increase learning and motivate learners, especially in math lessons where many students either shy away or are intimidated by numbers (Cognition & Technology Group, 1990).

2.5 Math Instruction in the United States

Mathematics is an ancient discipline. Mathematics ability has long been regarded as a basic skill—one of the three skills to be learned in primary and secondary schools: reading, writing, and arithmetic. In the 21st century, there has been particular emphasis placed on STEM (science, technology, engineering, and mathematics) education at all levels. As a consequence, math abilities beyond simple arithmetic skills are now considered basic skills. As it becomes increasingly apparent that having mathematics knowledge will be a critical component of success in the jobs of the future, educators are reworking teaching strategies to ensure that learners develop these skills. Mathematics is no longer simply a solitary subject in and of itself. Rather, its integration into multiple aspects of everyday life in the 21st century—from the use of technology to paying bills—makes it necessary to show students how mathematics can be integrated into other subjects. Mathematics teachers can help students build their critical thinking and problem-solving skills by asking them to look for a logical structure when solving mathematical problems and back up their answers with verifiable evidence. Assistant superintendent Kimberly Beck of the Ridgefield school district commented in The Ridgefield

Press (December 11, 2012) about the new trend for learners: “It is no longer what the students know, it is about what they can do with what they know.” Intelligent, adaptive learning is defined as digital learning that immerges students in modular learning environments where every decision a student makes is captured, considered in the context of sound learning theory, and then used to guide the student’s learning experiences to adjust to the student’s path and pace within and between lessons, and provide formative and summative data to the student’s teacher (Woolley-Wilson, 2013). However, students often perceive math as a difficult subject (Comadera, Hunt, & Simonds, 2007). One of the factors that make students see math as very challenging is a low level of confidence in their mathematical abilities. Such a negative feeling may consequently lead students to give up learning math (Camli & Bintas, 2009).

Teachers at all levels risk losing the interest of students when the curriculum is not perceived by students as relevant to their needs and interests. Therefore, educators must start looking at how students learn and when and why learning occurs or fails to occur (Cohen, 2011). The goal of an educational game is to increase a student’s motivation and learning (Kulik & Kulik, 1991). Moreover, educational games increase motivation and achievement in math classrooms (William, 2006). Students who engage in educational games can master skills, concepts, tasks, and resolve conflicts without unpleasant consequences, i.e., not feeling bad about their inability to successfully complete a given task. Educational games do a better job of teaching than decontextualized, skill-drill instruction (Renaud 2011, p. 59).

Motivating learners to engage in learning tasks is a constant challenge. It is imperative to teachers, particularly mathematics teachers, as motivation enables students to make learning-related decisions. Without motivation, a purposeful learning process is difficult to sustain (Keller, 2008). Extrinsic motivation alone, as in making high grades, is not enough.

Learners may still experience obstacles to pursuing their academic goals, particularly in mathematics. Thus, there can be motivational problems with regard to an intrinsic desire to study mathematics, and volitional problems associated with the willingness and ability to remain focused and on task in their mathematical studies (Kim & Keller, 2008). However, self-confidence plays an important role in learning math because self-confidence is a predictor of learning behavior, such as the amount of effort made and the expectation of outcomes. Students with a high level of self-confidence may attain better performance in math tasks and engage in target tasks more actively than those who are less confident about those tasks (Kebritchi, 2008). Therefore, embedding digital games into math learning may be a possible solution to enhance student confidence, motivation, and learning achievement (Ke & Grabowski, 2007).

There have been ongoing “mathematics wars” regarding the best approach to deliver math instruction to students. There are two main approaches to how math is taught in American classrooms—the constructivist approach and the skills approach. The constructivist approach is based on the principle that students should be taught how to think, not only to figure or guess the correct answer, but more importantly, to be able to explain the process of arriving at a solution. Furthermore, the constructivist method implies that students should be able to reason, be held accountable for their choices, and communicate effectively to peers, adults, and teachers. The curriculum for the constructivist teacher is meant to help math students understand math vocabulary, develop content knowledge, and learn the ability to define and solve problems using different tools and techniques. The constructivist approach involves math investigation, connections to previous knowledge, teaching for understanding, and above all, reasoning. At the end of every unit of the math curriculum, there is a reflection section. This section is reserved for students to articulate their understanding of skills in that unit. The role of teachers in a constructivist teaching method is to lead and offer suggestions but not give out answers to questions (Kim & Chang, 2010). The goal of the constructivist method of teaching is to connect mathematics to the lives of students through the problems they solve outside the classroom on a daily basis.

Alternatively, the skills (or cognitive) approach to learning math is using previous knowledge to determine what the learner pays attention to, perceives, learns, remembers, and forgets. According to (Alexander, 1996), what we already know—our knowledge—"is the scaffold that supports the construction of all future learning" (p. 89). Some researchers have argued that when learning new concepts in math, continuous practice is required to ensure that knowledge is retained. Further, (Hong, Cheng, Hwang, Le, and Chang 2009) have argued that providing various learning strategies and accurate and meaningful prompts based on an individual student's ability can be an effective approach to learning math.

Neither the constructivist approach nor the skills method has proven to be successful in boosting student achievement in math on a consistent level. While there have been increases in student achievement since 1900, the 2007 National Assessment of Educational Progress (NAEP) report card shows only 32% of students were proficient in math compared to 30% in 2005 and 29% in 2003, respectively (Middleton & Spanias, 1999). According to (*Trends in International Mathematics and Science Study* 2003), students who studied at home using computers recorded higher achievement than students who did not use computers at all or only used them at places other than home or school, and the report concluded that students with a positive attitude had higher average math achievement than those with a negative attitude. That attitude was worse the longer students were in school because they questioned the rationale of math to real-life situations (English, 1997). Further, students who did not have access to computers at home to practice math had negative perceptions of math (Trends in International Mathematics and Science Study, 2003).

2.6 Learning Strategies Enhance Student Achievement

According to the National Mathematical Advisory Panel (2008), American secondary school students have not been succeeding in math, especially in Algebra. Although high school students struggle with math across the board, student understanding of algebraic concepts is of major concern. American students seem to enjoy math at the early elementary grades but begin to dislike math in Grade 4 when abstract or symbolic concepts are introduced in algebraic thinking (Chorney, 2012). The NCTM has endorsed algebra as a K-12 enterprise and set up goals that all students learn “algebra or excel in high level mathematics” (2009). Further, the National Research Council (2000) proposed the introduction of basic algebraic concepts in early grades to lay a solid foundation for later years (p. 102-104).

Students often encounter challenges dealing with math word problems when information about the problem is presented as text rather than in mathematical notation. Algebra is generally a systematic way of expressing generality and abstraction and the focus is on expression or representation of relations. Algebraic thinking involves translating verbal information into symbolic expressions and equations, and generating equations that represent quantitative problem situations where one or more of the quantities is unknown (Bazemore, Van Dyk, Kramer, Yelton, & Brown, 2006). Mathematical word problems involve higher-order, cognitive skills that require steps or processes “between the posing of the task and the solution to the problem” (Cheng & Su, 2012).

Concrete, manipulative, pictorial diagramming or schema-based mapping instruction, computer-aided instruction, and direct instruction are very effective methods to teach math and promote student learning and achievement (Huizarga, Admial, & Akherman, 2009). Another important strategy is modelling. Modelling implies translating authentic problems into mathematic expressions that include real objects, formulas, and algebraic expressions. Mathematical models are essential and must be introduced to all age groups including elementary school children (Bai, 2010). Model problem structures facilitate solution planning and accurate problem solving. For example, to arrive at a product, two factors have to be multiplied. This is a general concept in multiplication and division and is similar to the conceptual, model-based, problem-solving (COMPS) approach.

Many high school students express concern about the way and manner in which teachers impart instruction. Some complain that the teacher goes too fast, causing students to lose track of the explanation. They are ashamed to ask questions for fear of being labeled as dumb and would rather pretend to understand the lesson when they actually have no idea of how to solve the problem.

Trust is a very important concept in the teaching and learning process. If students have no trust or confidence in their teachers, they are likely to develop apathy and resistance to the teacher's instruction (Chesebro & Martin, 2010). There has to be a stimulus-response approach to teaching and learning. The teacher motivates students by fully involving them in the learning process, and students follow instructions and guidelines as directed by the teacher. Clear and precise instruction should have the learning objective clearly spelled out. The teacher and students first practice in an interactive fashion, students then practice independently, followed by an evaluation of learning content commonly referred to as demonstration of learning (Comadena et al., 2009). Certain behaviors among teachers increase their credibility. In the same vein, some behaviors from teachers tend to undermine the instructor's ability to impact the desired knowledge to their students. (Dornisch, 2013) opined that:

> Instructors that are argumentative without being verbally aggressive, who communicate in ways that generate understanding in the minds of their students, who use appropriate humor, manage compulsive communicators with pro-social management strategies, and who are immediate are generally perceived as more competent, trustworthy, and caring in the classroom (pp. 353-358).

The more teachers are able to prove their competence, trustworthiness, and credibility before their students, the better the positive learning climate becomes in the classroom. It is the responsibility of teachers to convince their students that they have full knowledge of the instructional content and have the ability and capability to deliver same to students in a way that they can understand.

Over the years, researchers have created strategies such as cognitive, constructivist, and affective learning. The ultimate goal is to motivate and empower the learner to grasp novel concepts with relative ease. Other researchers adopt different techniques like differentiated instruction, station learning, and modelling to enhance understanding and engage the student in the learning process (Kim & Chang, 2010). The focus should be on the student and instruction should be student-centered; this can be achieved if the teacher plays the role of a guide and facilitator and not as a reservoir of knowledge (Wei & Wang, 2010). Nevertheless, teachers need to be creative and, to some extent, critical and collaborative. "Teachers need organizational skills and modest techniques to keep their instruction lively throughout the duration of the class" (Freire, 2000, pp. 52-54). Strategies for increasing motivation and interests include student autonomy, brainstorming, provoking curiosity through discussion and evaluation, and highlighting the functionality of information (Weber, 2007). When all the strategies and techniques of learning are deployed correctly to engage students in the classroom, teachers and students experience success.

The cognitive approach suggests that the learner brings some information to the learning table. What the learner already knows determines to a great extent what to pay attention to, perceive, learn, remember, and even forget (Alexander & Martray, 1989). Thus, knowledge is more than an end product as it also guides new learning. A study carried out by (Ahmad & Lalif 2010) demonstrated the importance of knowledge in understanding and remembering. The researchers tested students on their knowledge of baseball and found that knowledge of baseball was not related to reading ability. Based on this research, the researchers were able to identify four groups of students: good readers/high baseball knowledge, good readers/low baseball knowledge, poor readers/high baseball knowledge, and poor readers/low baseball knowledge. The students were allowed to read a passage describing a baseball game and were tested after reading. The result showed that poor readers who knew baseball remembered more than good readers with little baseball knowledge and were almost as much as good readers who knew baseball. Poor readers who knew little about baseball remembered the least of what they had read. Thus, a good basis of knowledge can be more important than good learning strategies in understanding and remembering, but extensive knowledge and good strategies are even better. Cognitive learning implies that the concepts learned in the classrooms are intended to apply to life beyond school (Ahlfeldt, 2009). According to (Comadena, Hunt, and Simonds 2007), cognitive learning is positively influenced when students report satisfaction with the course or instructor.

2.7 The Relevance of Digital Games in Learning

Digital games have been popular—especially among secondary school students—since the turn of the 20th century. By 2004, a popular version of a digital game known as World of Warcraft (WoW) swept the world off its feet. It is estimated that over 12 million people subscribe to it. WoW encourages and implements role-playing, involving the player in the learning process and making players take ownership of their learning. This idea is of immense importance in our math classrooms today because most veteran teachers do all the teaching while students sit back passively and copy completed mathematical problems; however, instructors want learners to be fully involved, proactively participate in the teaching/learning process, and to be successful. World of Warcraft connects people both physically and virtually, and have specific purposes and functions to fully engage students who might be shy or laid back in their approach to embrace math concepts. Table 2 shows the relevance of WoW in real life situations.

Table 2

The Relevance of World of Warcraft in Real-Life Situations

World of Warcraft (WoW)	Classroom
Anyone with Internet access can play	Available around the world
A social place to digitally gather and play the game with others	Provides an education to those who are given permission to enter
Brings together both virtual worlds and connects them to our physical world	Brings together subjects into one physical or virtual space
Time functions differently in WoW; completion is valued rather than hours played	Hours spent in class is valued more than work completed.
Available to any who do not opt out by choice or circumstance	Limited by funding per institutions
Achievement is easily measured and risk of failure is low	Participants are groomed and practice for careers in the “outside” world

Digital games are a kind of intervention because they create opportunity for the shy and struggling learners to become involved and can engage them in activities they were not previously willing to do. According to (Codding, 2011), intervention intensity can be useful and was operationalized by factors such as time, school personnel effort, and available resources. Further, to increase intervention effectiveness, the intervention has to match the student's need. This approach is a behavioral model of learning and instruction that hypothesizes stages of skills progression and correspondingly differentiated intervention formats. For example, students who are first acquiring skills are considered to have different instructional needs than students who have already acquired a skill but are working on becoming better. Practice is a key ingredient in building interventions (Comadena, et al., 2007).

In a follow-up study, (Chin, Chang, and Wang 2008) conducted a meta-analysis across 17 studies of basic mathematics intervention using percent of all non-overlapping data to estimate the size of the effect. The researchers found that 30 or more intervention sessions produced large effects. Moreover, multiple baseline and alternating treatment designs produced more robust effects than other, less rigorous designs. This study is consistent with policy recommendations for the need to enhance and evaluate experimental vigor when seeking to establish evidence-based practices.

The standards-based movement is a predominant challenge that public schools face. This challenge calls for clear, measurable standards for all students and also calls for evidence-based interventions to facilitate students to meet the standards. According to the NCLB, public schools that receive federal Title 1 funding but fail to meet the criteria of adequate yearly progress (AYP) for two consecutive years must provide supplementary services, measured by standardized tests (2002). Self-developed probes are not as reliable and valid as standardized tests (Kuncel &

Hexlett, 2007). Therefore, it is important to question the effectiveness of such interventions on student performance on standardized, high-stakes assessments.

Research by (Frymier & Shulman 1994) demonstrated that treatment packages designed to improve automatic fact retrieval that included direct practice, timed practice with corrective feedback, and strategic counting surpassed treatment packages that omitted these features. Interventions that target students' conceptual understanding have been shown to be effective in correcting student's misconceptions of fundamental mathematical principles and establishing an understanding of underlying mathematics concepts for problem solving (Hatti, Rogers, & Swaminathan, 2014). Computational fluency is a necessary component for learning higher-level mathematics skills; students who have not mastered basic computational fluency by the end of elementary school are at risk for future difficulties with mathematics and problem solving. Instruction on procedure for executing number operations and repeated practice are essential for the development of computational proficiency.

A digital-based mathematics intervention called Mathematics Facts in a Flash (MFF) Renaissance Learning is a proprietary, computer-based mathematics intervention software designed to increase computational fluency by providing practice with basic mathematical facts. The study found that MFF was effective in improving mathematics achievement and students who used MFF longer showed greater gains in mathematics achievement (Project Tomorrow, 2010).

The first step in a meta-analysis is to search the literature for studies that have addressed the same research question using electronic study bases such as EBSCO, ERIC, and PsychoINFO to find articles. This can identify authors in the field who might have unpublished data or cite papers in the field. One potential bias in meta-analysis arises from the fact that significant findings are more likely to be published than non-significant findings because researchers do not submit non-significant findings (Hattie, Rogers, & Swaminathan, 2014), and reviewers tend to reject manuscripts containing them. This is known as publication bias or the "file drawer" problem (Rosenthal, 1979). This bias is not trivial because significant findings are eight times more likely to be submitted than non-significant ones (Hedges & Vevea, 1998). The negative effect of bias is that meta-analytic reviews will over-estimate population effects if they have not included unpublished studies. This is because the effect sizes in unpublished studies of comparable methodological quality will be smaller (Dickey, 2007) and can be just half of comparable published research. Dealing with the effect of the file drawer problem can best be executed through direct messaging to authors in the field, posting a message to a topic-specific newsgroup, or by using LISTSERV.

> Involving a student/learner in a task should have to do with his/her interest. When a learner loses interest in the learning process, apathy, boredom, and off-task activities immediately sets in. To capture the interest of the learner, the curriculum must be designed in such a way that it arouses students' curiosity and interest. Thus, "…… we must work to listen to our students, to understand why they consider some topics inappropriate/irrelevant, so that we and our students might more fully understand each other (Fassett & Warren, 2007, p. 43).

2.8 Summary

Students use games to explore and ultimately construct concepts and relationships in authentic contexts. The concept of learning-by-doing comprises core constructivist principles that underlie game-based learning. Educational games have immersion effects in the sense that learners submerge themselves into the game environments and activities and increase their attention levels for the tasks at hand. Digital games can provide effective and motivating learning environments and improve learning effectiveness of students. Research has shown that students acquire new knowledge and complex skills from games (Foreman, 2004).

This study examines the impact of digital games on high school mathematics achievement through a systematic review of existing literature. A meta-analysis of 101 studies was investigated. Out of this number, six studies were shortlisted based on specific criteria. This study focused on two teaching methods only—games, and the traditional method. Because meta-analysis cannot be conducted in an experimental fashion, it is not possible for the researcher to control sample sizes, means, standard deviation, and effect sizes.

Student learners in the 21st century play to learn. They prefer to be fully engaged in the learning process—hands-on, interactive, and using appropriate tools to accomplish given tasks. However, most of their teachers were trained to teach by the conventional or traditional method, which makes the teacher very active while students are passive listeners. The millennial generation—also known as Generation Y, which differs from Generation X—are the demographic cohort following Generation X. There are no precise dates when the generation starts and ends but it is estimated to be between 1980 and 2004. Students born within this age bracket have been playing digital games for their entire lives and expect to be equally engaged in the classroom (Prensky, 2001, p. 1). Games are no longer regarded as a waste of valuable time. Pairing fun with learning may help improve student engagement and achievement in schools. Digital games have the capacity to provide powerful learning environments, where actions within the gaming system have the capacity to produce meaningful outcomes for the learner (Gee, 2003). The exploration and interaction learners experience within video game environments can facilitate acquisition of skills in problem solving, pattern recognition, spatial orientation, and the ability to manage resources and information, interpret graphs, and navigate effectively (Fassett & Warren, 2007). This chapter has outlined the current literature on educational theories, learning paradigms, strategies that enhance student achievement, math instruction in the U.S., and digital games as veritable tools for math instruction.

CHAPTER 3

DESIGN METHODOLOGY

3.1 Introduction

The purpose of this study is to investigate the impact of digital games on high school students' academic achievement in mathematical education. Searches were limited to published, peer-reviewed articles. The meta-analysis synthesized research on digital games to systematically examine their efficacy for learning relative to traditional methods. In light of the dramatic evolution of digital games for learning over the past decade, this study focused on research published between 1980 and 2015.

- RQ1: What empirical evidence exists to show that the use of games in high school mathematics can improve learning?
- RQ2: What conclusions, if any, can be drawn from findings related to the first question about any potential advantages of game-based mathematics learning in high school versus traditional methods?

3.2 Method

The meta-analysis method combined several research findings using quantitative techniques. Meta-analysis was employed to establish statistical significance out of an aggregate of studies because this technique develops a better estimate of effect magnitude. Meta-analysis statistically combines the results of several studies that address shared research hypotheses. This study combined statistical information from different studies on a specific topic and identified patterns among student results.

3.3 Data Collection

Data that investigated the impact of digital games on high school mathematics achievement was collected from studies spanning 13 years from 2002 to 2015. Data were collected from sources such as ProQuest, Digital Dissertations, EBSCO, ERIC, and Google Scholar databases.

3.4 Selection Criteria

A total of 101 articles were identified for potential inclusion. Based on the selection criteria (Burns et al., 2010), only six met the requirement to execute this research project. The criteria were:

- Articles published in refereed journals and thesis and dissertation studies
- Studies used experimental and control groups
- Studies with effect size (ES), sample size, standard deviation, and mean
- Research was conducted with high school students
- Participants were between the ages of 15 and 19
- Studies compared gaming in mathematics instruction and traditional methods

3.5 Published Research Studies

There were 101 studies out of which six were carefully selected based on specific criteria. Table 3 illustrates each of the six studies, the treatment, the control, and the mean difference. The year behind the name is the date the study was published.

Table 3

The Six Studies on Digital Games Versus Control Method, Experiment Mean, Control Mean, Experiment Standard Deviation, Control Standard Deviation, Experiment Sample Size, Control Sample Size, and Gains from Standard Deviation Difference in Pre- and Post-Test Data.

Studies	ExpM	ExpSD	ExpN	ContM	Cont-SD	ContN	SMD	Total N
1.Amanda 2015	156.96	10.22	140	155.32	8.64	140	1.58	280
2. Yueh 2014	87.45	11.39	36	83.35	6.87	40	4.52	76
3. F. Ke 2008	58	11.8	115	53	9.37	113	2.43	228
4.Chen 2012	15	3.56	181	13	3.07	171	0.49	352
5.Ramadan 2003	42.43	15.01	89	36.13	12.77	87	2.24	176
6.Ugyen 2002	14.43	3.83	69	13.42	3.33	60	0.50	129

Notes: Adapted from "The Use of Computer and Video Games for Learning: A Review of the Literature," by A. Mitchell and Savill-Smith, 2004. p. 18, London, England: *Learning and Skills Development Agency*. Reprinted with permission. ExpM = experimental mean; ExpSD = experimental standard deviation; ExpN = total experimental sample; ContM = control mean; ContSD = control standard deviation; SMD = standardized mean difference; ContN = total control sample; TotalN = experiment and control total. The date is the year of publication.

Six studies were used to conduct the meta-analysis on the impact of digital games on students' achievement in mathematical education in high school. The experimental group showed gains in all the six studies in the standard deviation mean difference.

Amanda 2015

This study examined treatment effects by race, sex, socioeconomic status, and achievement risk status and did not indicate differences in intervention effects on year end state test scores by subgroup. The experiment group has a sample size of 140 participant and the control group has 140 participants. Experimental assignments predicted differences in gains over time, favoring the intervention group for two of the three measures. Overall, the data suggested stronger intervention effects for students who began the intervention at greater risk, including students of minority ethnicity.

Yueh 2014

This study centered on supporting mathematics learning through gaming activities. Digital games provide promising possibilities to motivate and engage students in learning. The sample size for the experimental group was 36 and that of the control group was 40. According to this study, most students have relatively lower positive attitude towards mathematics learning, even though their mathematics performance is great. A quasi-experiment was conducted to examine the influence of game enjoyment versus mathematics learning. The result revealed that games enhance learning mathematics.

F. Ke 2008

This article reports findings on computer games used within various classroom situations. The study examined whether digital games, in comparison to traditional paper-and-pencil drills would be more effective in facilitating mathematics learning outcomes. The experimental group had a sample size of 115 while the control group sample size was 113. The findings indicated that digital games in comparison to paper-and-pencil drills, were significantly more effective in promoting learning mathematics. In addition, cooperative goal structure, as opposed to competitive and individualistic structures, significantly enhanced the effects of digital games on attitude towards mathematics learning.

Chen 2012

This study examines the impact of digital games on mathematics education in high school. There were two groups – the experimental and control groups. The sample size of the experiment group was 181 while the control group had a sample size of 171. In a period of 18 weeks the experimental group used technology-based games in mathematics instruction while the control group received instruction via traditional method. Results from the two groups showed that using digital-based games to study mathematics was beneficial to students' achievement than the traditional method.

Ramadan 2003

This study adopts an Input-Process-Outcome model to develop a digital game-based learning system in addition to exploring the impact of different learning methods on learning performance and anxiety about mathematics. The sample size for the experiment group was 89 and the control group had a sample size of 87. The diagnostic mechanism strategy demonstrate the advantages of digital games for mathematics learning. The findings of this study suggests that centering on the daily life experiences of learners, integrating a proper game model can effectively enhance interest in learning mathematics and reduce anxiety.

Ugyen 2002

This study attempted to apply digital games in teaching and learning strategies to promote students understanding of mathematics concepts. The sample size for the experimental group was 69 while the control group had a sample of 60. With the benefit of computer games in motivating students' learning, this study developed the enabling environment to ensure the success of using games in a mathematics classroom. The results showed that digital games improved students' learning achievement in mathematics.

There is a difference in the standard deviation between the experimental and control groups. For example, the first study, Amanda 2015, has 1.58 SD difference over the control group and its standard deviation of the experimental group was 10.22, compared to the control group with 8.64. The second study, Yueh 2014, has an SD difference = 4.52. The standard deviation for the experimental group was 11.39 compared to 6.87 for the control group. The third study, F. Ke 2008, had an SD = 2.43 and the experimental group had a standard deviation of 11.8

compared to 9.37. The fourth study, Chen 2012, had an SD = 0.49 and the experimental group had a standard deviation of 3.56 as compared to the control group with 3.07. The fifth study was Ramadan 2003 with SD difference = 2.24. The experimental group had a SD = 15.01 as compared to 12.77 in the control group. Finally, the sixth study, Ugyen 2002, had an SD difference = 0.50. The experimental group had a standard deviation of 3.83, compared to 3.33 standard deviation from the control group. In each of the six studies, the experimental group had a positive effect over the control group, indicating that digital games might successfully enhance mathematics instruction more than traditional methods.

Table 4 shows the six studies further broken down into the means of the experimental and control groups, and their mean difference.

Table 4

The Six Studies Broken Down By Means

Studies	Exp.Mean	Control Mean	Mean Difference
Amanda 2015	156.96	155.32	1.64
Yueh 2014	87.45	83.35	4.10
F. Ke 2008	58	53	5.0
Chen 2012	15	13	2.0
Ramadan 2003	42.43	36.13	6.3
Ugyen 2002	14.43	13.42	1.01

Table 4 shows the six studies with the experiment means, control means and their difference. On each of the six studies, the experiment mean had a gain over the control mean. This mean difference ranges from 1.01, Ugyen 2002, to 6.3 Ramadan 2003. Between 2003 and 2015, there was also an average mean difference of 3.19 for the rest of the four studies. It is therefore apparent that the use of digital game in teaching mathematics holds the potential for being significant.

3.6 Data Analysis

The instrument for this study was six research studies on the impact of digital games on math achievement. There was stringent criteria to eliminate any study that fell below the requirement. The second research question—which sought to investigate the empirical evidence that exists with regard to traditional methods and their impact on learning—was addressed by comparing the mean differences between the experiment/treatment group versus the control or traditional method group. The forest plot was used to compute the effect of digital, interactive games over traditional methods.

The null hypothesis is the sample distribution mean of the experimental group and is equal to the mean sample of the control group. This implies that if the means were equal, there would be no difference among the experimental and control groups. However, if the mean score for the experimental group was higher, this would indicate that digital games were a more effective method of providing instruction to students.

3.7 Procedures

Age, gender, race, SES, and and scores for the experimental and control groups were collected. Out of the six studies carefully and systematically selected, data from the experimental and control group were collected and computed. The sample size, mean, standard deviation, and effect size of the two groups were provided by the six studies. The statistical data from these studies enabled the researcher to run the meta-analysis using Excel, SPSS, and other relevant tools. The demographics of students, including their gender, socioeconomic status, and ethnicity were analyzed.

CHAPTER 4

FINDINGS

This chapter provides the results of the data collected and analysis of the study. This study was to test the impact of digital games on math achievement in high school students. Six studies included comparisons of digital games to traditional method instructional conditions. The results indicated that digital games were associated with a 0.082 relative to control conditions with 0.067. The index effect size (ES) provides a more exact picture of the degree of benefits from digital games in the studies. The average effect size in the six studies was 0.40; its standard error was 0.043. This average effect size means that in the typical study, the performance of digital games was 0.082 standard deviation higher than the performance of the control group. The research questions guiding this phase of the evaluation research were:

- RQ1: What empirical evidence exists to show that the use of games in high school mathematics can improve learning?
- RQ2: What conclusion, if any, can be drawn from findings related to the first question about any potential advantages of game-based mathematics learning in high school versus traditional methods?

4.1 Descriptive Analysis Results

The average ES on the six studies F (0.058) = 0.815; t (5.847); LL = 0.178; UL = 0.681; SE = 0.043 and experimental mean = 0.40; control mean = 0.159; experiment SD = 0.072; control SD = 0.057. A total of 101 studies were reviewed by the researcher. The researcher found six studies representing approximately a 6% sample of the population that met criteria for inclusion in the meta-analysis. One of the reasons for cutting down on the number was to eliminate studies that were not directly related to digital games and math achievement. Secondly, because resources available to the researcher were limited, there was the need to work on what was feasible relevant to time, finances, and deadlines.

Each of the selected six studies described below had two groups – a control group and an experimental group.

Table 5 Illustrates descriptive statistics for the demographics of the control group, experimental group, and total sample size. Also included in this table are the ratios of gender, race, socioeconomic status, and free and reduced lunches offered to students used for this meta-analysis. The studies targeted Title 1 schools where the majority of students were entitled to free or reduced lunch.

Table 5

Descriptive Statistics for Sample Demographic Characteristics as a Function of Group (N=6)

Variable	Control Group N = 3 Percent = 50%	Experimental Group N = 3 Percent = 50%	Total Sample N = 6 Percent = 100%
Gender			
Male = 6 (55%)	3 (50%)	3 (50%)	6
Female = 6 (50%)	3 (50%)	3 (50%)	6
Race			
African American	1 (34%)	1 (34%)	2
Hispanic	1 (33%)	1 (33%)	2
Others	1 (33%)	1 (33%)	2
Socioeconomic status (S.E.S.)			
Reduced Lunch	1 (33%)	1 (33%)	2
Free Lunch	2 (67%)	2 (67%)	4

The two groups had a population of 101 out of which six were selected based on specific criteria. Six studies directly related to high school mathematical games and traditional methods were used to compute the effect size of the investigation. To be included in the meta-analysis, the study had to have mean, standard deviation, effect size, and mean effect size. The description of the process used in the design and structure of the study was followed by statistics for all the variables and an explanation of the effect of digital games on math achievement. Finally, the researcher made a summary of the procedures listed above.

4.2 Analysis of Study

The purpose of this study was to investigate the degree of math achievement by students when digital games are used as the instructional focus. Prior to this research, it was not feasible to determine which of the two instructional systems— traditional method or digital games—as the more effective method. The researcher compared the six studies in this research to synthesize and analyze the results based on mean, standard deviation, mean differences, and effect size as shown in Table 6. The alpha level was set at .05, which represented a significant difference in the achievement results of the six studies and showed differences between the use of games and traditional methods to teach mathematics in high school.

Table 6

Computed Data for Experiment and Control Groups with Mean, Standard Deviation, Sample Size, Sample Total, Effect Size and Weight for Each Study

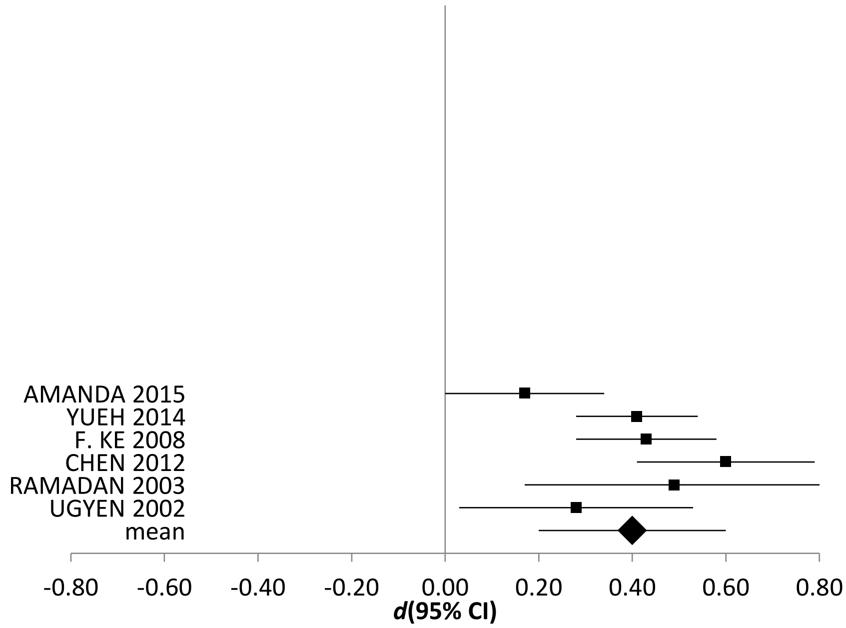
	STUDY NAME	EXP MEAN	EXP SD	MEAN CONT	CONT SD	EXP SIZE	CONT SIZE	TOTAL SIZE	EFFECT	WEIGHT
1	AMANDA(2015)	156.96	10.22	155.32	8.64	140.00	140.00	280.00	0.17	47.60
2	YUEH (2014)	87.45	11.39	83.35	6.87	36.00	40.00	76.00	*0.44	33.24
3	F. KE (2008)	58.00	11.80	53.00	9.37	115.00	113.00	228.00	*0.47	107.16
4	CHEN (2012)	15.00	3.56	13.00	3.07	181.00	171.00	352.00	*0.60	211.20
5	RAMADAN (2003)	42.43	15.01	36.13	12.77	89.00	87.00	176.00	*0.45	79.20
6	UGYEN (2002)	14.43	3.83	13.42	3.33	60.00	69.00	129.00	*0.28	36.12

Notes: Adapted from “Research Design-Qualitative, Quantitative and Mixed Methods Approaches” by John W. Creswell, 2009. EXPMEAN= Experimental mean. EXP SD= Experimental standard deviation. MEAN CONT= Control mean. CONT SD = Control standard deviation. EXPSIZE= Experiment size. CONT SIZE= Control size.

The mean and standard deviations for the experimental groups in the six studies are listed in the first and second columns of Table 6. The mean and standard deviation for the control group are contained in the third and fourth columns. The sample size for the experimental group is in the fifth column and, for the control group, in the sixth column. The effect size for both the experimental and control groups is listed in the seventh column and the weight of each study is contained in the last column. All of the six studies have effects ranging from 0.17 to 0.60. The asterisks indicate a large effect size, and suggest that teaching with digital games have an edge over the traditional method; however, these effects are not statistically significant to conclude that digital game instruction is better than the traditional method. The weight is determined by multiplying the effect size by the sample size. A high effect size and a large sample size equals a high weight. Conversely, a small effect size combined with a small sample size equals low weight. Thus, the highest weight of 211.20 was recorded by Chen (2012) as that study had a fairly high sample size of 352 participants and a large effect size of 0.60

Six studies were used to compute the meta-analysis statistics via the forest plot as shown in Figure 2.

Figure 2. Forest plot of the six studies



Based on the data in Figure 2, the researcher used a forest plot to conduct a meta-analysis. A forest plot is a graphic representation of a meta-analysis, usually accompanied by a table listing references, author, and date. This graphical display is designed to illustrate the relative strength of treatment effect (ES). Meta-analysis uses tables that list the mean scores, standard deviation, confidence interval, and mean difference. Each line on the plot represents a study (name and date) according to standardized mean difference (SMD). The mean score for all the studies is plotted between -0.80 to 0.80. The vertical line is the line of no effect. The closer a mean is to the vertical line, the less impact it has on the study. Conversely, the further away a mean is from zero, the more effect the mean has on the study. Based on this logical assertion (Ugyen, 2002), a mean of 0.52 has the highest effect size. The diamond shape at the bottom of the plot represents the average mean of 0.42 for the six studies. The plot has a confidence interval of 95% with an alpha value of 0.05.

The six studies, their means, and standard deviations were as follows: Amanda 2015 (156.96) (1022); Yueh 2014 (87.45) (11.39); F. Ke 2008 (58) (11.8); Chen 2012 (15) (3.56); Ramadan 2003 (42.43) (15.01) and Ugyen 2002 (14.43) (3.83). The effect size is the degree or magnitude to which the treatment or phenomenon is present in the population or the degree to which the null hypothesis is false. The effect sizes are: Amanda = 0.17; Yueh = 0.44; F. Ke = 0.47; Chen = 0.60; Ramadan = 0.45, and Ugyen = 0.28. The effect sizes indicate that digital games can enhance math achievement in high schools. However, when entered into a meta-analysis the overall gains of the treatment (game groups) do not indicate that curricula including games provide greater achievement gains for students when compared to traditional methods.

The six studies used to address Research Question 1 investigated the empirical evidence of using games in high school mathematics to improve learning. The effect size, lower limits, upper limits, and confidence interval of these six studies are computed in Table 7.

Table 7

Studies from the Experimental Group with Effect Size, Lower Limits, Upper Limits, and Confidence Interval

Study	Cohen’s d	LL 95%	UL 95%	LL CI for figs	UL CI for figs
Amanda 2015	0.17	-0.067	0.401	0.24	0.24
Yueh 2014	*0.44	-0.014	0.897	0.45	0.45
F. Ke 2008	*0.47	0.205	0.732	0.27	0.27
Chen 2012	*0.60	0.386	0.814	0.22	0.22
Ramadan 2003	*0.45	-0.223	0.386	0.67	0.67
Ugyen 2002	0.28	-0.072	0.875	0.11	0.11

Notes: LL = lower limits; UL = upper limits; CI = Confidence Interval

4.3 Test of Heterogeneity

The researcher used the fixed-effect model for this study rather than the random-effect model because all six studies used in this research were drawn from a single population, i.e., similar subjects and methods. The studies report a common effect size (ES) and so the effect size is fixed or constant and the goal of this model is to estimate the impact of these parameters.

Hypothesis: There is no statistically significant difference in mathematics achievement between digital game instruction and the traditional methods.

4.4 Data Analysis

The studies investigated in this research are divided between experimental and control groups. The mean, standard deviation, and the effect size of each group are shown Table 6. The weight of each study was also computed because the scales of every study are different. The effect size is a standardized difference between a pair of means of the experimental and control groups. It is the strength of a relationship between the treatment and the outcome variable, i.e., the magnitude of the treatment effect. Cohen's d is an effect size used to indicate the standardized difference between two means.

The hypothesis was tested by comparing the mean of the control group with the mean of the experimental group. The yardstick for this measurement is that equal means indicate no difference; a higher mean score for the control group compared to the experimental/treatment group indicates that traditional instruction is more effective. A higher mean score for the experimental group shows that blending digital interactive games with conventional methods is the more effective instructional strategy.

4.5 Direction of the Effect

Research Question 1: What empirical evidence exists to show that the use of games in high school mathematics can improve learning?

The six studies and their effect sizes used for this meta-analysis were:

- Amanda 2015 (ES 0.17)
- Yueh 2014 (ES *0.44)
- F Ke 2008 (ES *0.47)
- Chen 2012 (ES *0.60)
- Ramadan 2003 (ES *0.45)
- Ugyen 2002 (ES 0.28)

These six studies included a comparison of digital games to traditional method instructional conditions. The effect size for the six studies were significant with Ugyen having the highest and Amanda with the least. The index effect size (ES) provides a more exact picture of the degree of benefits from digital games in the studies. The average ES = 0.43, and mean SE = 0.031. This average effect size indicates that in the typical study, the performance of digital games was 0.082 standard deviation higher than the performance of the control group.

The objective of this systematic review was to examine the impact of digital games on mathematics achievement in high school. Based on six independent findings extracted from 1,041 learners that were part of the meta-analysis, the researcher did not find a positive effect on the use of digital games on mathematics instruction.

Any tool, technology, or game by itself cannot replace good teaching. Technology flows with good teaching. According to Fletcher and Tobias (2006), we are in an information era where digital games have become essential in teaching and learning. However, based on the effect size of combining all six studies in a meta-analysis to compare the effect of teaching with digital games against teaching using the traditional method, no difference was noted. The meta-analysis has a proabilty level of greater than .05. In research, that is not considered a statistically significant result. However, overall the game group had a higher mean, indicating that digital games may have an edge over traditional methods if a greater number of studies were available to include in the meta-analysis. That fact notwithstanding, the null hypothesis that there is no statistically significant difference in mathematics achievement between teaching using digital games and teaching using the traditional method is not rejected.

Research Question 2: What conclusions, if any, can be drawn from findings related to the question about any potential advantages of game-based mathematics learning in high school versus traditional methods?

The game-based method has been described as providing a modular learning environment that can enable learners to be fully engaged and take control and responsibility of their own learning versus teacher-dominated instruction witnessed in the traditional method. Hong et al. (2009) strongly outlined the potential advantages of game-based mathematics learning:

- Can use game-based learning as a valuable tool to accelerate learning
- Can encourage learners who lack interest and confidence in themselves
- Can reduce training time and load of the instructor
- Can enhance knowledge acquisition and retention
- Can allow for manipulation of objects and support development towards levels of proficiency
- Are most effective when they are designed to address a specific problem or to teach a certain skill
- Are relevant to specific learning activities and games

- Are designed to support specific learning outcomes such as recall of factual content or as the basis for active involvement and discussion
- Are good vehicles for embedding curriculum content such as mathematics and science concepts that may be hard to visualize with concrete materials
- Can enhance creativity and other aspects of critical thought
- Have the potential to support cognitive processing and the development of strategic skills
- Can encourage greater academic, social, and computer literacy skills among learners

Learning is transitioning from paper and pencil, drill and practice, and memorization and regurgitation to using tools like calculators, computers, iPads, and other electronic devices to solve problems. The emphasis with the 21st century learner is now on speed, accuracy in learning, knowing what was learned, and being able to apply knowledge in a similar situation outside the classroom. Digital games offer students the opportunity to participate in the learning process—as opposed to a classroom where the learner is often unengaged, easily bored, tired, and wants to quit because they are not fully integrated into the learning process. The literature supports the use of digital games but the meta-analysis found no significant difference in achievement between the students that used games and the students who used more traditional methods of instruction.

4.6 Effect Size Measures (ESM)

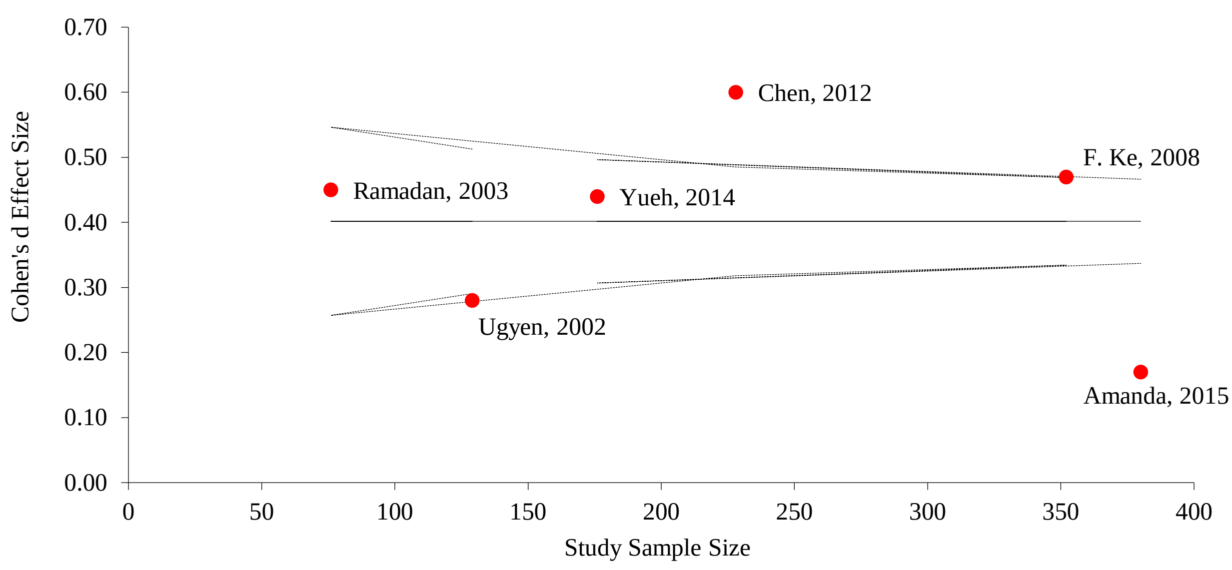
Effect size measures (ESM) transform reported sizes to a common measure. Examples of standard measures include spread/variance, confidence interval, standard deviation, and sampling error. These standard measures are displayed in a forest plot (Figure 2). A forest plot is a graphical display of estimated results from a number of scientific studies addressing the same questions. It is a graphical display used in meta-analysis to illustrate the relative strength of treatment effect. On the plot, each line represents a study in the meta-analysis plotted according to the standardized mean difference. In order to check publication bias, a funnel plot is integrated into the study.

4.6.1 Funnel Plot

A funnel plot is a scatter plot of treatment effect against a measure of study size. It is used as a visual aid to detect bias. When a funnel plot is in the form of a symmetric, inverted funnel-shape, it is a sign of a "well behaved" dataset in which publication bias is unlikely.

Figure 3 demonstrates the spread of the studies of the effect size and year. The effect represents the magnitute of treatment and the year is when the research was investigated. These studies range in distribution over 13 years from 2002 to 2015 and cover the era of the millenial generation. The effect is between 0 and .60, as depicted by the funnel plot in Figure 3.

Figure 3. Funnel plot of the relationship between Cohen's d effect size and study sample size



Notes: The funnel plot is a funnel-like figure with two diagonal lines that represent the 95% confidence interval, and a vertical central line. The x-axis represents the study sample size and the y-axis represents the effect size. The average effect size for this study was 0.40; the Amanda effect size = 0.17; Yueh = 0.44; F. Ke = 0.47; Chen = 0.60; Ramadan = 0.45; and Ugyen = 0.28.

The four studies with large effect size of 0.44, 0.45, 0.47, and 0.60 fall around the two horizontal lines or confidence interval of 95%. The other two studies with less effect size of 0.17 and 0.28 respectively fall outside the the funnel plot, indicating that these studies were not as significant as the perviously mentioned four. The four studies with large effect size that fell within the 95% confidence interval representing the two horizontal lines indicated less probability of publication bias.

These six studies were used to address Research Question 1 which investigates the empirical evidence that the use of games in high school mathematics can improve learning.

4.6.2 Scatter Plot

Figure 4. A scatter plot of the studies.

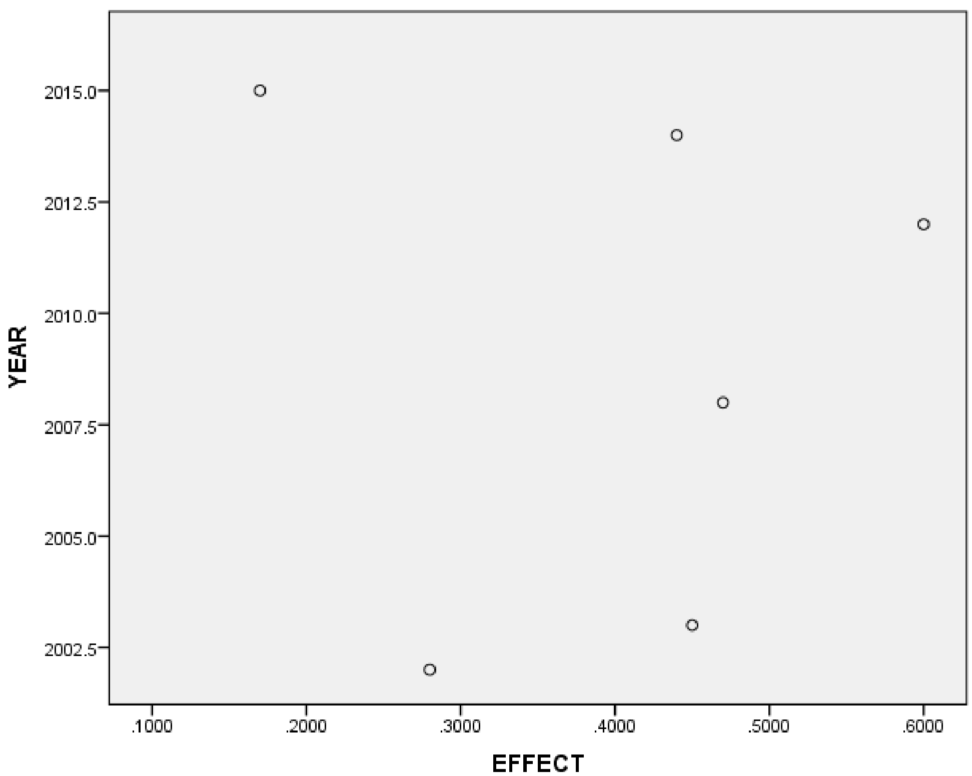


Figure 4 is a scatter plot that further demonstrates how the studies are spread out. The horizontal axis represents the effect size and the vertical axis is the year the study was conducted.

Except for one study, all fell between the years 2000 and 2015 with an effect ranging from 0.17 to 0.60. Based on the scatter plot, it seems that there is no correlation between year of study and effect size. For example, Chen's study in 2012 had a large effect size of 0.60, but in 2015, Amanda's study's effect size was 0.17. It does appear that effect size did not increase with time. Further, F. Ke's study in 2008 had a large effect size of 0.47, but in 2014, six years later, Yueh's effect size dropped to 0.44. Effect changes were not determined by increase or decrease in time. Therefore, it cannot be argued based on this study that older studies have higher effect sizes while newer studies have lower effect sizes. The studies are scattered all over. There is no defined pattern.

CHAPTER 5

DISCUSSION, IMPLICATION, AND CONCLUSION

5.1 Discussion

This meta-analysis examined results of six studies that compared the impact of digital games on mathematics achievement in high school. Findings indicate that digital games have no significant gains over traditional methods or control conditions. These results do not support the findings in previous studies (Papastergiou, 2000) that demonstrated the effectiveness of using digital games, calculators, and other digital tools for learning mathematics. The findings are not consistent with the results of another study conducted by (Kebritch et al. 2010) who found that digital games had a positive effect on student mathematics achievement at the high school level. The small number of studies and the small effect sizes most likely impacted the findings in the current study. According to the literature, it is of vital importance to design digital games to align content and learning strategies with the structure of the game (Li & Ma, 2010). Further, when using digital games, there is need for feedback that will enable the learner to monitor their own learning and to identify their weaknesses in each of the learning units. The combination of formal (traditional methods) and informal (digital, interactive games) learning environments has been proposed and argued by researchers as an empowering approach to providing quality education (Toh, So, Seow, Chen, & Looi, 2013).

For children who grew up in the sixties, games represented a great pleasure. The situation has not changed in the 21st century when our youth's infatuation with digital games is considered. If mathematics learning in the classroom can be combined with games, this learning experience can alleviate the fear students have whenever mathematics is mentioned (Cheng & Su, 2012). Moreover, games can be interesting, interactive (where the teacher does not dominate instruction), and lively. Using games as part of instruction could lead to student motivation, vested interests, learning enthusiasm, more confidence, and significant fun (Kiili, 2005). Because of the tendencies students have to experiment by way of doing their own thing, some studies have shown that games enhance learning math through doing (Cheng & Su, 2012).

Students of this generation have grown up with technology at their fingertips. They have mastered technology skills in games, entertainment, and learning. The use of and rapid change in technology has led students to constantly adjust to new ways of thinking and learning (Prensky, 2001). Students of the 21st century are in need of the most current tools that will help them navigate through high school, college, or the workforce. The challenge, however, is that students are taught in the traditional method rather than the digital approach (Ahmad & Lalif, 2010). Much research has been conducted about the great benefits of using digital games (Li & Ma, 2010) but very little has been conducted to show the impact of digital games on mathematics achievement with high school students. This study raises the issue that using digital games as a way to deliver instruction "would not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition" (Chesebro & Martin, 2010). Our nutrition – learning — can be damaged by a bad choice in delivery methods (e.g., food may decay if not delivered in refrigerated trucks). As learners become familiar with technology, novelty effects tend to decrease, which often results in diminished motivation for using digital games for learning (Fletcher & Tobias, 2006). There exists a consensus among researchers (Chen-Lin, Kulik & Kulik, 1991) that digital games offer a range of advantages:

- They support student learning and engagement in various ways
- They offer unique and contemporary learning opportunities
- They offer opportunities for hands-on activities

- Story-lines provide opportunities for role-playing
- They offer opportunities for teaching with informal learning environments
- They promote collaboration and interaction
- They offer opportunities for understanding the relationship between science and technology
- They offer opportunities for developing various skills such as constructing arguments and debating skills.

Playing a dynamic, interactive, digital game followed by short class discussions about the game can stimulate mathematical reasoning. Furthermore, home computing is a sine qua non to creating an effective learning environment to support and extend school learning.

5.2 Limitations of the Study

One limitation for any systematic review in a meta-analysis study is the "file drawer problem" when studies with no significant results are not published. The researcher tried to address this problem by including unpublished dissertations, but this was only a partial solution. The researcher had a design issue in the sample size—6 out of 101. This may have led to the lack of statistically significant effects of digital games on mathematics achievement. The fact that meta-analysis cannot be conducted in an experimental fashion exposes the researcher's inability to control sample sizes and missing data. Small samples led to decreased sensitivity of data analysis. Further, it is impossible for any meta-analysis to evaluate the design quality of the programs used in primary studies.

5.3 Implications

The results of this study are significant to educational researchers who are considering the use of digital games to boost mathematics achievement in high school. Technology, with all its visual and hands-on approaches and attractions, is in total alignment with what youths of the 21st century are craving. Not much can be accomplished without first capturing the interests and desire of learners. The results indicate that, overall, digital games did impact the learning of mathematics in the current meta-analysis. However, the results from the individual studies highlights the need to further investigate the blending of direct instruction with interactive games to engage and motivate learners for better outcomes.

5.4 Recommendations for Future Study

A future study might explore the cognitive processes students employ for the duration of the digital games. Research could also be conducted on whether or not learners are able to transfer gaming processes to non-game situations such as real-world mathematics problems. A further study could conduct an investigation into the relationship between the amount of time learners spend to complete a given game and the amount of student engagement in their course. A future or follow-up effort could examine additional, high-quality, empirical studies as they become available.

Finally, a study could address the impact that digital games have on the affective domain of identifying, understanding, and addressing how people learn.

5.5 Conclusion

Researchers have conducted many studies to determine if digital game programs can, in fact, produce beneficial effects. They have divided classes of students into experimental and control groups and have taught the experimental group with new innovations while teaching control students with conventional methods only. No outcome from individual studies can definitely show whether digital games are generally effective. To reach a conclusion, reviewers must take into account the results from many studies carried out in different places, at different times, and under different conditions.

Students come into the classroom environment excited about learning only to be restrained by traditional instructional methods with fixed mindsets—in other words, a one-way application of mathematical concepts. Memorization without understanding characterize traditional classrooms, but students today are interested in relevance and practice.

Digital games can be interesting, interactive, lively, down to earth, motivating, and can instill confidence in the minds of learners (Cheng & Su, 2012). Learners can challenge themselves and become deeply involved in goal-driven activities. Research conducted by Woolley-Wilson (2013) has proven that students do not excel when they are compelled to learn in an unfamiliar learning style provided by the instructor instead of finding what works best for the learner—which is involving interactive games in the learning process. When students are determined to learn because they are interested, learners tend to put in more effort. Learners strive to rise to the challenge even when content appears to be challenging (Huang, 2011).

It has been argued by researchers in the studies included in the meta-analysis that digital games have been an empowering approach to provide quality education. When teachers are not confident about the use of technology, they are reluctant to use it. Mobile devices allow students to use motor skills and movement, which some traditional classroom environments lack. Some researchers have suggested that professional development enhances the effectiveness of traditional methods by equipping teachers with the right technology tools to address their students' needs (Easton, 2011). However, professional development is often not job-embedded and shows no evidence of instructional alignment. Further, most students in the 21st century tend

Digital games empower students to be proactive, adventurous, inquisitive, and explorative in their quest for knowledge and to use digital technology in the classroom to learn mathematics.

Finally, the first caveat was that although meta-analysis can increase statistical power to detect effects by pooling findings across multiple studies, analysis involving small numbers of studies should be interpreted in light of the limitations of their statistical power. Secondly, the findings should not be interpreted as suggesting that game-based instruction is superior or inferior to traditional methods. Both methods, game and tradition, have particular affordances and constraints that must be considered in the design of high-quality instruction. Therefore, this research argues against the simplistic position that games can play no critical role in mathematics instruction. Mathematics instruction is complex and should be acknowledged as such.

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