USING ONLINE MATHEMATICS SKILLS GAMES TO PROMOTE AUTOMATICITY

LISA M. SUAREZ CARABALLO

Bachelor of Science in Mathematics
Cleveland State University
August 1992

Master of Education in Curriculum and Instruction
Cleveland State University
May 2002

submitted in partial fulfillment of requirements for the degree

DOCTOR OF PHILOSOPHY IN URBAN EDUCATION

at the

CLEVELAND STATE UNIVERSITY

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We hereby approve dissertation

of

Lisa M Suarez Caraballo

Candidate for the Doctor of Philosophy in Urban Education degree.

This dissertation has been approved

for the Department of

Urban Education

and

CLEVELAND STATE UNIVERSITY

College of Graduate Studies by

Joanne Goodell, Chairperson
Teacher Education, December 5, 2014

Karla Hamlen Mansour, Methodologist
Curriculum & Foundations, December 5, 2014

Jeremy Genovese
Curriculum & Foundations, December 5, 2014

Xiongyi Liu
Curriculum & Foundations, December 5, 2014

Barabara Margolius
Mathematics, December 5, 2014
DEDICATION

This dissertation is dedicated to my family. First, without the love, expectations and constant pushing of my mother I would not be where I am today. She has always been an example of how I should live my life and her high expectations of me have kept me trying to live up to them. Second, I would like to thank my husband. His unconditional love for me and our children has kept me going through this long and difficult process. All those nights cooking, eating dinner without me, taking care of and driving the kids to and from different events never went unnoticed or unappreciated. Lastly, my children, thank you for your patience putting up with me all those nights over the past four years having to stay up late waiting for me because you still had homework you needed help with or just wanted to talk. I could not have completed this dissertation without all of your love and never-ending support.
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ABSTRACT

The purpose of this study was to understand how the amount of time students spend playing math skills games online affects their engagement and automaticity with adding integers. This study sought to develop a deeper understanding of how playing online math skills games on the Internet against peers influenced the automatic recall of basic integer facts among high school students, how students’ prior knowledge of basic addition and subtraction facts influenced their automaticity adding basic integers, and how playing math skills games on the Internet influenced student engagement to practice.

Three Algebra 1 classes with 39 ninth grade students at an urban high school in the Midwest were assigned to one of two practice groups; traditional flashcard practice using the computer, and integer addition practice using an integer addition game on the Arcademics website against other students in the class. This study measured student engagement practicing basic integer addition facts with an eGameFlow survey. Achievement was measured using a gain score calculated from pre and posttests of student knowledge of basic integer addition facts. Student scores on basic addition and subtraction facts were compared in order to determine if student recall of basic integer facts was mediated by whether or not students previously mastered their basic addition and subtraction facts. Mann-Whitney U and linear regression were used to analyze the various research questions proposed in this study. Results demonstrate the rates of correct
responses and engagement increases with use of online skills games as compared to students using the skill building technique of flashcards on the computer.
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CHAPTER I

INTRODUCTION

Problem – Why are basic skills important?

In the world today there exists a global economy where it is believed that science, technology, engineering and mathematics (STEM) careers are at the forefront (Brown, Brown, Reardon, & Merrill, 2011). Yet many of our students in the United States (US) are not prepared to participate in this economy. Our students’ poor performance on state, national and international standardized tests demonstrates that they are failing to meet minimum standards in mathematics (Fleischman, Hopstock, Pelczar, & Shelley, 2010; Kilpatrick, Swafford, & Findell, 2001; Kuenzi, Matthews, & Mangan, 2006). These minimum standards are necessary for participation in today’s global economy and our future as a nation (Glenn, 2000). Although some standardized tests, like NAEP, have shown improvement in US pupils’ knowledge of math, the large majority of students still fail to reach adequate levels of proficiency when compared to other nations (Koretz, 2009; Kuenzi et al., 2006).
PISA is an international assessment of the reading, science and mathematical literacy of 15-year-old students. It is given in 3-year cycles, allowing for the monitoring of changes in student achievement. PISA defines mathematics literacy as: “An individual’s capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgments and to use and engage with mathematics in ways that meet the needs of that individual’s life as a constructive, concerned and reflective citizen” (OECD, 2010, p. 84). According to PISA, achievement in mathematics in the US is well below other member countries. 2009 results show that 15-year-olds in the US scored lower than average on the exam. This score was lower than students in 40 other countries out of a total of 97 that participated in the program.

Friedman (2007) in his book The World is Flat gave some chilling advice to his children:

“My advice (to my girls) in this flat world is very brief and very blunt: "Girls, when I was growing up, my parents used to say to me, 'Tom, finish your dinner- people in China and India are starving.' My advice to you (now) is: Girls, finish your homework-people in China and India are starving for your jobs.” (Friedman, 2007, p. 237)

As Friedman describes in the above quote, international competition for jobs is rising and students in the US need to perform well in school, especially in mathematics, to stay competitive.

In order to achieve success in high school mathematics and later, in their careers, students must have a strong foundation upon which to build. There are two basic constructs that form the foundation when students are learning mathematics: computation and application (NCTM, 2000; Rutherford-Becker & Vanderwood, 2009). Computation is the ability to perform math facts, while application is the ability to use knowledge and
math skills to find solutions to problems (Rutherford-Becker & Vanderwood, 2009). It is believed that these two constructs are distinct and highly related, where the skills in one area are necessary for success in the other (Thurber, Shinn, & Smolkowski, 2002). Some researchers believe that math computation is the best predictor of applied math performance, which means that the ability to perform basic math skills is important for mathematics achievement (Stickney, Sharp, & Kenyon, 2012), and the ability to effectively use those skills predicts performance on applied math tests (Rutherford-Becker & Vanderwood, 2009). The required foundation for success in mathematics involves fast, efficient recall of basic facts (Smith, Marchand-Martella, & Martella, 2011; Stickney et al., 2012).

Students in schools today, however, struggle to demonstrate proficiency in mathematics. Several researchers believe that the reason children struggle in mathematics is because they have deficits related to the mastery of procedures, or fast retrieval of arithmetic facts (Jordan, Hanich, & Kaplan, 2003; Stickney et al., 2012). The ability to perform mathematical procedures is important to mathematics achievement and therefore problems students have with procedural fluency needs to be addressed. Jordan et al. (2003) believe that the way to address problems with the efficient retrieval of math facts is to make sure the process becomes automatic for students.

The automatic process of skill acquisition has been defined by Bargh and Chartrand (1999) as an “intentional, goal-directed process that becomes more efficient over time and practice until they could operate without conscious guidance” (Bargh & Chartrand, 1999, p. 463). Researchers believe that once fluency is acquired one achieves automaticity, or intentional but effortless mental processes. Initially, conscious choice
and guidance are needed to perform the desired behavior or to generate accurate and useful answers. Through automaticity, conscious choice eventually drops out because it is no longer needed in the process. According to Bargh and Chartrand (1999) people are aware of the process of acquisition while they participate in considerable practice or frequent and consistent performances of a skill in order to develop that skill. When they finally acquire the skill, or achieve automaticity, the process involved in performing the skill moves into the subconscious. Conscious capacity then is freed up from having to direct and coordinate the lower level components of the skill and can then be used instead to engage in higher level thinking or strategy development during a game or performance (Bargh & Chartrand, 1999; Dehaene, 2010). Automaticity means that the process is unconscious, unintended, effortless, and very fast. When this happens many of these unconscious processes can operate at the same time. These processes develop out of repeated and consistent experience and automaticity takes tasks over from conscious choice (Bargh & Chartrand, 1999).

Achieving automaticity with basic facts will, in turn, allow students to focus on achieving a higher level of understanding in mathematics (Arroyo, Woolf, Royer, Tai, & English, 2010; Price, Mazzocco, & Ansari, 2013). Being able to recall facts without thinking about them allows students’ brains to focus on learning more complex mathematical ideas (Dehaene, 2010). A relationship between math skills fluency and cognitive ability has been found to exist in children and can affect their mathematical performance (Price et al., 2013; Ramos-Christian, Schleser, & Varn, 2008). Thus achieving automaticity with basic math skills can lead to a focus on higher level
mathematics which in turn can lead to higher achievement and greater participation in advanced mathematics (Price et al., 2013).

It is important then, if we are to increase the mathematics achievement of students in the US, improve our STEM workforce, and maintain our global competitiveness that students are motivated to practice and achieve automaticity with basic mathematics skills.

**Student Motivation to Practice**

Motivated students display a commitment to learning that is crucial for academic, social, and emotional development, which then leads to school and life success. Motivation is defined as the reasons people have for behaving in a certain way (Middleton & Spanias, 1999). Students who are motivated find schoolwork interesting and important, become absorbed in their studies, and put forth the effort necessary to achieve their goals (White-McNulty, Patrikakou, & Weissberg, 2005). When students are motivated they are inspired to spend the time necessary to acquire automaticity. In mathematics however, many students feel that success is out of their reach and their level of achievement, more often than not, falls well below their ability level (Middleton & Spanias, 1999). Therefore, in order for students to be motivated to learn they need to be challenged, feel comfortable with the mathematics they are learning and they must feel they have a chance to succeed (Middleton & Spanias, 1999).

**Method of Practice**

Emerging technologies, like games on the Internet, can help students gain the confidence necessary to engage in learning and give them the attitude that they can do mathematics. This confidence can increase student motivation to practice and consequently increase their automaticity with basic facts. Online math skills games are one way to motivate students to improve automaticity and achievement in mathematics.
education. Students can practice their arithmetic skills using traditional flashcards; however, the Internet with its ease of use, accessibility, graphics, speed and motivational appeal can provide remediation unlike any other medium.

Researchers argue that technology, specifically games on the computer, when aligned with sound learning theories, can greatly enhance student learning (Hong, Cheng, Hwang, Lee, & Chang, 2009; McDonald & Hannafin, 2003; Prensky, 2005). This technology, they believe, is a way to individualize learning for students, providing the appropriate level of challenge and increase their confidence and achievement (McDonald & Hannafin, 2003).

The National Council of Teachers of Mathematics (NCTM) also believes that electronic technologies are essential tools for teaching, learning, and doing mathematics. NCTM states that “technologies furnish visual images of mathematical ideas, they facilitate organizing and analyzing data, and they allow students to compute efficiently and accurately” (NCTM, 2000). In addition, NCTM (2000) believes that technology offers schools and teachers different options for adapting instruction to meet student needs. Students who are easily distracted may focus more intently on computer tasks.

NCTM is not alone in believing that technology can help students learn mathematics. A study by Habgood and Ainsworth (2011) found that playing a mathematical game on the computer led to increased motivation which then led to increased task persistence while Laughlin and Marchuk (2005) found that playing games promoted greater knowledge retention.
One website that offers engaging mathematics skills games is the Arcademics website (http://www.arcademicskillbuilders.com/about/). This website offers free online games that allow students to practice arithmetic skills. In addition to mere practice, their games have an added dimension to online skills games that other websites do not – multiplayer competition. Arcademics allows students to challenge their peers to compete against them in their games. The games are multiplayer but the students themselves can choose with whom they will compete. This added level of competition is a dimension that has not been studied previously and one which may lead to increased time practicing skills, recall, comprehension and achievement in mathematics.

Purpose
This study used quantitative and qualitative methods to explore whether or not basic math skills games from the Arcademics website motivated students to spend the time necessary to achieve automaticity in recalling basic operations with integers. The Arcademics website offers free games that allow students to practice basic skills in a highly competitive and multimedia rich environment.

A mixed methods design was used to describe student experiences while practicing integer math facts on the computer. The philosophical framework used in this study was the pragmatist paradigm. This paradigm was chosen because it offers an epistemological justification and logic for mixing both quantitative and qualitative research methods. The pragmatism paradigm has a high regard for human experience in action and constantly tries to improve upon past understandings using all forms of qualitative and quantitative analyses (Onwuegbuzie, Johnson, & Collins, 2009). The pragmatic research philosophy also results in more robust and interesting findings and therefore its findings are generally of greater value to practitioners (Sammons, 2010).
This study sought to use the results from the qualitative interviews and observations to inform and describe the quantitative findings therefore a convergent parallel mixed analysis was conducted to address the following research questions:

1. When given time to play integer addition games on the computer will students be engaged more than those students who practice adding integers using flashcards on the computer as demonstrated by self-reported ratings of engagement?

2. Does practicing integer facts using games on the computer increase student recall of integer math facts to a greater extent than those using flashcards on the computer?

3. Is there a relationship between participating students’ recall of integer mathematics facts and the extent to which those students have mastered their basic addition and subtraction facts?

4. Do multiplayer games with competition differ from single player games in:
   a. Student engagement as measured by eGameFlow survey score?
   b. Student achievement as measured by gain score on pre and posttests of integer addition facts?

5. Does gender play a role in the engagement and achievement of students playing multiplayer versus single player games as evidenced by eGameFlow survey score and gain score?
Definition of Key Terms
The following operational definitions will be utilized to carry out the current research study, and relate directly to the variables studied.

**automaticity** - “intentional, goal-directed process that becomes more efficient over time and practice until they could operate without conscious guidance” (Bargh & Chartrand, 1999, p. 463).

**competition** – two or more people or groups having directly opposing goals where they can either measure themselves against others or measure themselves against an ideal (Ciampa, 2014)

**computation** - the ability to calculate math facts (Rutherford-Becker & Vanderwood, 2009)

**confidence** – “one’s belief in one’s personal capabilities to coordinate and implement the actions necessary to complete a given task or goal” (Cordova, Sinatra, Jones, Taasoobshirazi, & Lombardi, 2014, p. 165)

**engagement** - feeling involved (Nkhoma, Sriratanaviriakul, Cong, & Lam, 2014)

**flow** - the state of mind of individuals when they are completely immersed in an activity (Csikszentmihalyi, 1990)

**fluency** – behavior that is flowing, effortless, well-practiced and accurate (Johnson & Layng, 1996)

**game** – “a contest of physical or mental skills and strengths, requiring the participant(s) to follow a specific set of rules in order to attain a goal” (Hogle, 1996)

**integers** – the set of numbers that includes zero, whole numbers and their opposites

**mathematics achievement** – the ability to perform mathematical procedures for manipulating representations to find mathematical solutions (Hatano, 1996)
**mathematical literacy** - “An individual’s capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgments and to use and engage with mathematics in ways that meet the needs of that individual’s life as a constructive, concerned and reflective citizen” (OECD, 2010, p. 84)

**math facts** – all of the combinations of 1-digit numbers and the corresponding arithmetic operation

**motivation** – “to be moved to do something” (Deci & Ryan, 2000)

**online games** – networked games played on the computer while on the WWW

**videogame** – a game which can be played using an audiovisual apparatus and which can be based on a story (Esposito, 2005)

**Organization and Overview of Dissertation**

This dissertation is organized into five chapters. Chapter One consists of the introduction, statement of the problem, purpose of the study, definition of key terms, chapter review, and organization of the study. Chapter Two includes the literature review, mathematics performance of students in the US and abroad, motivation for learning, flow theory, games including computer and online games, suggestion for research and summary. Chapter Three contains the research methodology used in the study, population of the study, pilot study, instruments used, student performance measures, research design, the data collection procedures, confidentiality and data analysis of research questions. Chapter Four provides the results of the study and Chapter Five discusses the results of the study.
Summary of Chapter I

This section reviewed the problem to be studied, the purpose of this study, definitions of key terms and the overall organization of the study.
The Glenn Commission (2000) which was convened to report on the state of mathematics and science instruction in the US concluded that the future well-being of the US depends not just on how well the US educates its children but on how well it educates them specifically in mathematics and science. From expertise in mathematics and science, the Glenn Commission stated, will come the products, services, standard of living, and economic and military security that will maintain the economy of the US in the future. The Commission concluded that today’s children must achieve at high levels in mathematics and science because they are the ones who will drive the technological creativity US companies will need to compete effectively in the global marketplace of the future (Glenn, 2000). When children cannot use mathematics effectively they are “cut off from whole realms of human endeavor” (Kilpatrick et al., 2001, p. 16).

**Mathematics Performance in US and abroad**

Studies over the past several decades have consistently found that American secondary school students perform less well in mathematics than their peers in many
other countries that might be considered either similar or competitors of the US (Greene & McGee, 2012; Koretz, 2009; Kuenzi et al., 2006; Schmidt, 2012). It is beyond dispute that the mathematics skills of students in the US are not where they need to be and their performance on mathematics assessments ranges from average to extremely poor, depending on the type of test and grade level at which the test is administered (Schmidt, 2012).

According to PISA, which describes the mathematics performance of 15-year-olds in the US as compared to other 15-year-olds internationally, achievement in mathematics is well below other member countries. Results of PISA in 2009 show that 15-year-olds in the US scored lower than the average on the exam. The average score was 496 and students in the US had an average score of 487. This score was lower than students in 40 other countries out of a total of 97 countries that participated in the program (Fleischman et al., 2010).

The US focused National Assessment of Educational Progress (NAEP), the internationally-oriented Trends in International Mathematics and Science Study (TIMSS), and PISA all demonstrate that most students educated in US schools lack the ability to understand and apply mathematical principles. These studies reveal large gaps among socioeconomic and ethnic subgroups and indicate that long-term trends have only shown slight improvement (Schmidt, 2012). About three fourths of US eighth graders enter high school without the preparation needed for higher level mathematics (Schmidt, 2012). This lack of preparation is thought to be the cause of many high school graduates lacking the skills necessary to enter college and take credit-bearing mathematics courses, or to apply for jobs that demand technical skills. If students are not proficient in
mathematics they will increasingly find it difficult to compete for jobs in a highly
technological economy that operates globally (Schmidt, 2012). Children in the US must
achieve at high levels in mathematics and science if they will eventually drive the
technological creativity of US companies expecting to compete effectively in the global
marketplace (Glenn, 2000; Kilpatrick et al., 2001).

**Automaticity and the Learning of Math Facts**

It is believed that the reason students do not achieve at high levels in mathematics
is because they lack a strong foundation. According to several researchers (Devlin, 2010;
Rutherford-Becker & Vanderwood, 2009; Wilson, Dehaene, Dubois, & Fayol, 2009) this
foundation has two parts – computation and application. Computation is the ability to
perform or recall math facts quickly and application is the ability to use knowledge and
math skills to answer word problems. Thurber et al. (2002) administered twelve different
mathematics assessments to 207 fourth graders and concluded that these two constructs
are distinct and highly related; the skills in one area are necessary for success in the other.

A balance between the two constructs of computation and application is seen as
critical for academic achievement (Moursund, 2004). Yet, Mind, Brain Education
researchers like D.A. Sousa (2011) explain that the human brain has serious problems
with one part of the foundation for learning mathematics, the act of calculating. Nothing
in the evolution of humans has prepared us for the act of memorizing dozens of
arithmetic facts (Devlin, 2010; D.A. Sousa, 2011). The brain’s preprogrammed function
is for approximating quantities, it is a pattern seeker (Devlin, 2010). The act of dealing
with exact calculations, or arithmetic, involves engaging the brain in something it was not
made to do. Devlin (2010) describes using the brain to perform arithmetic calculations as
using “the edge of a coin to turn a screw”, it is possible but it’s slow and inefficient
(Devlin, 2010, p. 171). In order for the human brain to learn how to compute it must be taught to create mental models of the basic facts and be given the opportunity to practice retrieval of those facts regularly until the process becomes automatic (David A Sousa, 2008).

Computation and understanding cannot exist without each other (Devlin, 2010). Education researchers continue to conclude that for students to be successful in mathematics, computation, or rote learning of arithmetic skills, and understanding must both be mastered by students (Ball et al., 2005; Devlin, 2010; Kim & Davidenko, 2006). Knowing how to compute arithmetic facts to the point of automaticity and understanding those facts enough in order to use them in novel situations is the key to future mathematics achievement (Ball et al., 2005; Moursund, 2004).

In order to explore the connection between computation, understanding and automaticity with math facts Mind, Brain Education researchers have used the relatively new technology of noninvasive functional magnetic resonance imaging (fMRI) to see what parts of the brain are involved with computation. fMRI’s capture pictures of the brain in action (Price et al., 2013). These pictures were analyzed and researchers used them to identify the circuits of the brain that were involved in the automatic retrieval of basic math facts. Using this information Price et al. (2013) hypothesized that if fluency with basic arithmetic was a scaffold for mathematical competence then researchers should be able to observe variations in brain activity in students who performed well on mathematical tasks with those who did not perform as well on those same tasks. In their research of twelfth grade high school mathematics students Price et al. (2013) found that students that activated areas of the brain that dealt with mental arithmetic, or the
automatic retrieval of facts, had higher PSAT scores than students who activated parts of their brains that used counting strategies (counting using their fingers or in their heads). The PSAT test is the Preliminary Scholastic Aptitude Test and is a test that is widely used in the US to predict college readiness (Price et al., 2013). Therefore, they concluded, that achieving automaticity when computing basic facts plays a key role in mathematics achievement and the learning of higher level mathematics while using inefficient counting strategies does not (Price et al., 2013).

Kilpatrick, Swafford and Findell (2001), editors of the National Research Council’s (NRC) Adding It Up studied the current state of mathematics education and made similar recommendations for improving student achievement. Adding It Up (2001) is the product of eighteen months of work completed by a committee sponsored by the National Science Foundation and the US Department of Education. This group was convened to review and synthesize research on mathematics learning from preschool through eighth grade. They concluded that proficiency with numerical procedures was an important foundation for the study of mathematics. In Adding It Up (2001) they described five “interwoven and interdependent” strands of proficiency seen as important for children to learn mathematics (p. 5). Two of these strands deal with procedures, or basic math facts. The first one is conceptual understanding of mathematical concepts, operations, and relations and the second one is procedural fluency. Kilpatrick et al. (2001) describe procedural fluency as the skill of carrying out procedures flexibly, accurately and efficiently. This fluency must come from the direct retrieval of the math facts from memory, automaticity, not from counting strategies (Woodward, 2004) as counting strategies have been found to be highly inefficient (Hecht, 2002).
Researchers have shown that in order for students to develop competence in mathematics students must have a deep foundation of factual knowledge and organize that knowledge in ways that facilitate procedural fluency (Kuenzi et al., 2006; Stickney et al., 2012). Factual knowledge and automaticity have been found to be much more important than many people originally thought in facilitating a successful student’s ability to plan a task, notice patterns, generate reasonable arguments and explanations, and transfer learning to other contexts (Bransford, 2000; Zentall & Ferkis, 1993).

NCTM in their *Principles and Standards for School Mathematics (PSSM)* agree that the alliance of these constructs, factual knowledge, procedural proficiency, and conceptual understanding are important and powerful (NCTM, 2000). Therefore, the ability to perform basic math skills is important for mathematics achievement (Ansari, 2010; Ball et al., 2005; Devlin, 2010; Moursund, 2004; Rutherford-Becker & Vanderwood, 2009; Stickney et al., 2012) and the ability to effectively use those skills predicts performance on applied math tests (Price et al., 2013; Rutherford-Becker & Vanderwood, 2009).

**Basic Skills and the Math Wars**

Performing well on math tests and being able to remember basic math skills is dependent on first learning those skills. However, in the mathematics education community a heated debate has raged for decades on how children should learn basic skills (Star, 2005). This debate has been dubbed the “Math Wars” (Marshall, 2003).

The ‘Math Wars’ came about in the 1990’s as a result of a push for social justice in mathematics education by social justice researchers and NCTM (Klein, 2007). Poor and urban students were not performing at expected levels in mathematics and the NCTM published several documents including, *An Agenda for Action* and the *PSSM*, that were
influential in attempting to change how mathematics was taught in the US for all children (Klein, 2007). The NCTM’s publications called for, among other things, decreased attention in rote practice of basic math facts and the teaching of paper and pencil computation while advocating for increased attention in the use of calculators, the use of manipulatives and deeper conceptual understanding (Klein, 2007).

During the 1990’s many states adopted the NCTM standards and purchased the subsequently developed ‘standards curricula’ but the lack of focus on basic skills in these texts infuriated many people (Klein, 2007). The disappointment and anger surrounding the standards curriculum arose because those that opposed the curriculum believed that its focus was ‘dumbing-down’ mathematics. The arguments that divided the mathematics education community during the math wars, and even today, are that the ‘traditional curriculum’ focused too much on basic skills leaving out understanding while the NCTM sponsored ‘standards-based’ curriculum was lacking in content and did not prepare children for college (Klein, 2007).

The existence of this debate provides evidence that math educators in the US do not agree on the respective roles of procedural knowledge and conceptual knowledge in student learning (Star, 2005). Regardless of the debate, however, the fact remains that children in the US struggle in mathematics and have failed to perform at high levels on national and international tests for decades (Reys, 2001).

Math Motivation and Flow

Even though students are struggling to attain proficiency in basic mathematics the amount of mathematics they are expected to learn continues to grow (Marshall, 2003). Graduation requirements in many states have increased becoming more rigorous with almost every student completing college preparatory course work (Allensworth, Nomi,
Montgomery, & Lee, 2009). In order to meet these growing demands children will need to be highly motivated to learn the ever increasing amount of material they are expected to know. They will also need to be motivated in order to help the US achieve success and stay competitive in a global economy.

One form of motivation that has been found to be effective in increasing time on task and learning is involving learners in activities where they are so involved in the activity that they lose track of time. This type of concentration has been defined as flow. Flow is the term used to describe the state of mind of individuals when they are completely immersed in an activity (Csikszentmihalyi, 1990). The study of flow came about in order to understand the phenomenon of autotelic or intrinsically motivated activities like rock climbing or dancing (Nakamura & Csikszentmihalyi, 2002). When a person is in a state of flow they are totally absorbed in an activity that they enjoy but it doesn’t have to be something easy. Nakamura and Csikszentmihalyi (2002) state that many times the activities people participate in when they achieve the state of flow require an enormous amount of physical or mental energy to complete. The person is so involved in the activity that their actions seem effortless and nothing around them matters.

There are two major conditions that need to be met to achieve a state of flow. The first is that the activity a person is participating in is challenging and stretches what that person knows or is able to do. Second, the activity must have clear goals and provide immediate feedback (Nakamura & Csikszentmihalyi, 2002). The challenge of the activity as well as the skill of the individual must be in balance, it can’t be too hard or too easy (Nakamura & Csikszentmihalyi, 2002). Nakamura and Csikszentmihalyi (2002) found that students in school, just like rock climbers or musicians, can also be in the state of
flow. They found that the state of flow is achieved when students are learning through a task where the difficulty of the task is one step above the student’s current skill level. Nakamura and Csikszentmihalyi (2002) compared this type of learning to Vygotsky’s zone of proximal development (ZPD). P. H. Miller (1993) described the ZPD as any activity a child completes that is just above his/her current level of understanding. Participating in a task that is at the correct level for a person has been found to be very important in order to promote academic achievement (Shernoff & Csikszentmihalyi, 2009). Shernoff et al. (2003) found in their study of high school students that activities that are academically challenging and provide students with a positive sense of self are the most enjoyable to students. Students were found to be more engaged when their skills and the perceived challenge of the activity were in balance (Shernoff et al., 2003).

**Games**

Games are a popular learning strategy that balances knowledge of skills and challenge, emphasizes experiential learning and also enhances both student engagement and flow (Games & Squire, 2011). Games, while popular, are very diverse in their nature and purpose leading to many definitions for games. A game in its simplest form is composed of three components: 1) players who are willing to play the game, 2) rules that define how the game is played and 3) goals that contribute to conflict and rivalry between the players of the game (Smed & Hakonen, 2003). Instructional games are games that include these features and are used in instructional contexts designed for training or educational purposes (Kebritchi, Hirumi, & Bai, 2010; Vandercruysse, Vandewaetere, Cornillie, & Clarebout, 2013).
Instructional games have been used in many educational contexts and some researchers have found them to be valuable tools for mathematics instruction increasing both motivation and student understanding (Hogle, 1996; Tobias, Fletcher, Dai, & Wind, 2011). Instructional games provide goals for students that help them focus on the task at hand before they can progress to the next level or learning target (Ciampa, 2014). Hogle (1996) found that with the focus provided by games students were more motivated to learn mathematics, retained more information, demonstrated improved reasoning skills and achieved a greater level of higher-order thinking. In order for instructional games to be effective however, several studies have found that educational games should be embedded in instruction that includes debriefing and feedback (Hays, 2005; Hogle, 1996). This type of communication has been found to be important because learners come to understand how what they did or what happened in the game supports the instructional objectives they learned in their classes. It also gives learners strategies to improve both their academic knowledge and their game play (Hays, 2005).

While there are studies that show games improve academic knowledge there also exist several literature reviews that suggest there are no clear learning advantages to using games for instruction (Hays, 2005; Ke, 2009; Kebritchi et al., 2010). The literature reviews suggest results are varied and fragmented, while some games can be effective in increasing student learning many others do not indicate a clear relationship between the game and increased student achievement (Ke, 2009; Kebritchi et al., 2010; Randel & Morris, 1992). Some newer research with games has found that the competition inherent in games can motivate students to actively participate in more challenging activities which in turn can increase their intrinsic motivation and achievement (Ciampa, 2014).
Games and Competition

Although competition in games has been found to help students focus on the instructional objectives increasing their motivation, there also exists much debate over the efficacy of using competition during instruction (Kohn, 1986). Competition exists whenever learners are able to compare their performance to some internal or external standard and contains two main ideas 1) individuals challenge one another and 2) there are clearly defined goals and enhanced motivation (Vandercruysse et al., 2013).

The negative aspects of competition that have been highlighted suggest that engaging in competition requires one person to fail in order for another person to succeed. This zero-sum attribute of competition creates anxiety that interferes with performance (Kohn, 1986). The possibility of failure causes stress and learning suffers. In this sense, competition is destructive because it forces students to compete against each other in a way that pits students against each other (Williams & Sheridan, 2010).

However, some researchers believe that competition is not always a bad thing. When competition and collaboration have been found to coexist as partners, constructive competition emerges (Williams & Sheridan, 2010). Constructive competition is defined as a “social and cultural phenomenon that enhances children’s abilities, develops their ambitions and encourages their learning” (Williams & Sheridan, 2010, p. 338). Students motivate and learn from each other while they are competing to achieve a common goal (Pareto, Haake, Lindström, Sjödén, & Gulz, 2012; Williams & Sheridan, 2010). In mathematics, the common goal can be complicated tasks involving problem solving or as simple as learning and practicing skills (Ricci, Salas, & Cannon-Bowers, 1996).
Computer Games
Constructive competition in educational computer games has increased student motivation and achievement while also increasing their popularity among students and teachers (Nejem & Muhanna, 2013). An educational computer game is defined as a game practiced on the computer for specific educational goals where the computer acts as both the opponent and the referee (Crawford, 1984; Nejem & Muhanna, 2013). Competition in computer games has captivated student interest to the point where students spend hours learning even when they are outside of school (Federation of American Scientists, 2005).

Several literature reviews have been conducted over the years detailing the influence of computer games on mathematics learning and motivation. Randel and Morris (1992) in their review of literature from 1984-1991 described several studies where using computer games for practicing mathematics skills improved achievement scores more than for students who received traditional instruction. Dempsey, Rasmussen, and Lucassen (1996) also reviewed the research literature over 12 years and found 99 sources that discussed instructional games. They reviewed 22 studies that discussed learning outcomes of problem solving where technology-based instructional games impacted learning. These studies reported that students using instructional games were more motivated to learn, retained more information, demonstrated improved reasoning skills and achieved a greater level of higher-order thinking when they played mathematics games (Dempsey et al., 1996). More recently, Vogel et al. (2006) conducted a meta-analysis and found that studies generally conclude that students achieved greater cognitive gains and had better attitudes when interactive games were used for instruction as compared to traditional methods.
Positive results have been found when researchers examine games that provide practice for learning specific skills as well. For example, Chang, Sung, Chen, and Huang (2008) used a quasi-experimental design to study the effects a computer-assisted learning (CAL) program had on second grade students’ learning of their multiplication facts. Students were given pre and post facts tests. The CAL activities were performed over a three-week period during three stages of instruction for 120 minutes. The CAL interactive activities allowed students to explore the meaning of multiplication interactively. All activities required students to practice repeated addition as well as answer traditional multiplication facts (Chang et al., 2008). The results of the study revealed that the CAL program significantly improved the comprehension of basic multiplication facts in students that began the program with relatively low test scores. However, the CAL program did not improve the scores of students with relatively high pretest scores. Researchers attribute these results to the relatively brief period of time students were involved in the program. These results were supported by Shirvani (2010) and D. J. Miller and Robertson (2010) who both found that although playing computer games increased student mathematical learning, higher performing students’ achievement results did not increase significantly.

Another study focusing on multiplication facts was conducted in an elementary school with third grade students using the free computer game, Timez-Attack. Researchers concluded first, that using the game as a supplementary activity in the classroom had a significant positive effect on students’ retention of multiplication facts (Faye, Hasan, Abdullah, Bakar, & Ali, 2012). Second, they concluded that there were no statistically significant differences between the retention of facts by gender. Lastly, they
found evidence to support previous studies that found no significant differences between the retention of multiplication facts between higher and lower performing students (Faye et al., 2012).

A study by Laffey, Espinosa, Moore, and Lodree (2003) used an experimental design to study how using mathematics computer programs affected the performance of pre-k through first grade, urban, African-American children from low socioeconomic status homes. Their study examined students that could not sit in their classrooms for more than 20 minutes without disrupting the class. They found in their research that games using interactive computer technology (ICT) had a positive effect on mathematics achievement. Students were randomly assigned to participate in the treatment or control group and both the groups received daily mathematics instruction by their teacher. The treatment group, however, received two 20-25 minute ICT sessions per week for eight weeks in a pull-out type program in a resource room. During this time they were allowed to engage with or not to engage with the computer, to walk around the room or to change computer programs based on their interests. The research assistants also rated all students’ behavior during the first and last 10 minutes of the treatment sessions. The students in the treatment group significantly outperformed the comparison group in their achievement of the mathematics objectives. This study also found that if the computer tasks were at the proper academic level (not too easy or too hard), in the students’ ZPD, children could be engaged in simple arithmetic as well as problem solving situations. The study also demonstrated that ICT experiences can help urban students with behavior problems improve their focus on learning tasks (Laffey et al., 2003).
A final study used the DimensionM game to study its effects on students’ speed and recall of mathematics facts, algebra skills and motivation (Kebrichti, Hirumi, & Bai, 2008). During the study, 193 urban high school pre-algebra and algebra students in classes with ten teachers were randomly assigned to treatment and control groups. The study was conducted within an 18 week school semester where both the treatment and control groups attended classes twice a week. In addition to attending class, the treatment group played DimensionM games for about 30 minutes each week. The games were played during the regular class time. Their study concluded that the majority of the participants’ mathematical understandings and skills improved as a result of playing the DimensionM. The majority of students also stated that they preferred playing multiplayer versus single player games (Kebrichti et al., 2008).

Overall, research indicates that computer games hold some promise to increase mathematical understanding and skills as well as motivation however, computer games are still considered to be in the early stages of development and their effectiveness has not yet been definitively proven (Tobias et al., 2011).

**Online Multiplayer Games**

Students in the DimensionM study preferred playing multiplayer games which are increasingly prevalent on the Internet. The last three Pew Research Center reports (2005, 2009 and 2011) looking at teenagers technology use found that teens are more likely to play games or use communication tools than do any other activity when they are online (Gasser, Cortesi, Malik, & Lee, 2012; Jones & Fox, 2009; Lenhart, Madden, & Hitlin, 2005). An online multiplayer game is a game that is played by two or more players on a computer connected to the Internet (Richter & Livingstone, 2011). In 2012 teens ranked playing online games a close second (83%) to using online modes of communication
(85%) as their favorite activities to do while they were online (Gasser et al., 2012). Many of the games teens play online allow them the opportunity to play against other people that are as close to them as the computer next to them or as far away as in another country (Weibel, Wissmath, Habegger, Steiner, & Groner, 2008). Researchers have found that when gamers are playing against other people, no matter where they are located, instead of a computer they are more likely to enjoy the activity. Playing against others heightens gamers level of involvement in the game facilitating and increasing their flow experiences (Inal & Cagiltay, 2007; Vorderer, Hartmann, & Klimmt, 2003). This conclusion was also supported by Weibel et al. (2008) in a study conducted with public university undergraduate students – the type of opponent students were up against had a strong influence on their experience, increasing both their enjoyment and flow (Weibel et al., 2008).

**Gender and Games**

Another factor that has been found to influence a person’s experiences while playing games is their gender. Studies have found gender specific game preferences for boys and girls. In a study conducted by Chou and Tsai (2007) 535 Taiwanese high school students completed a questionnaire regarding their computer use and gaming habits. The results of the study indicated that boys enjoyed role-playing, strategy and action games on the computer while girls enjoyed puzzle, action and role-playing games (Chou & Tsai, 2007). In another study by Hartmann and Klimmt (2006) girls were found to be less competitive and found winning less important than boys, however, girls enjoyed social interaction with in-game characters as well as other players more than the boys (Hartmann & Klimmt, 2006). Girls have also been found to enjoy the feedback received
from a game more than the competition of actually playing the game (Kickmeier-Rust & Albert, 2013).

**Conclusion and Suggested Area for Research**

The literature suggests that while boys and girls view games differently, playing games can increase the mathematics skills of students, the retention of those skills, their motivation to practice and their academic achievement. These effects are also intensified when the skills of the game are in a student’s ZPD, students receive appropriate feedback as to their progress in the game and when students play the games with others. Many research studies have been conducted that examine how games, and more specifically computer games, increase elementary school children’s knowledge of basic mathematics skills. However, there are very few studies examining how games can increase high school students’ lack of knowledge of basic skills. The power and ability of online mathematics skills games to increase high school students’ motivation to practice, automaticity and consequently their mathematics achievement needed to be explored. Therefore, this study used previous knowledge of basic addition and subtraction facts, knowledge of integer addition facts, a flow score and the type of computer practice students participated in as research variables. Descriptions of these variables are provided in the next chapter.
CHAPTER III

RESEARCH METHODOLOGY

Purpose of the Study

The purpose of this research study was to investigate the possible effects that online integer skills games from the Arcademics website (See appendix A) had on the engagement and achievement of high school students’ knowledge and automaticity with basic integer addition facts (See appendix B).

Research Questions

1. When given time to play integer addition games on the computer will students be engaged more than those students who practice adding integers using flashcards on the computer as demonstrated by self-reported ratings of engagement?

2. Does practicing integer facts using games on the computer increase student recall of integer math facts to a greater extent than those using flashcards on the computer?
3. Is there a relationship between participating students’ recall of integer mathematics facts and the extent to which those students have mastered their basic addition and subtraction facts?

4. Do multiplayer games with competition differ from single player games in:
   a. Student engagement as measured by eGameFlow survey score?
   b. Student achievement as measured by gain score on pre and posttests of integer addition facts?

5. Does gender play a role in the engagement and achievement of students playing multiplayer versus single player games as evidenced by eGameFlow survey score and gain score?

**Research Design**

The research design for this study was a quasi-experimental design. This design was chosen because participants had been pre-assigned to Algebra classes at a comprehensive high school in the Midwestern US. All three classes were taught by the same teacher, Mrs. Brown (a pseudonym) where one of the classes was randomly assigned as the control group that practiced integer addition facts using a flashcard approach on the computer. The other two classes were assigned to practice integer facts using a multiplayer game from the Arcademics website on the computer competing against three other students in the class of their own choosing.

This study incorporated a qualitative component with quantitative measures taking the primary role and qualitative methods taking on a secondary role (Creswell & Clark, 2007). The design that was used was a mixed methods convergent parallel design (See Figure 1) which consisted of two independent strands of quantitative and qualitative
data collection in a single phase (Creswell & Clark, 2007). In this design, quantitative and qualitative data are collected at the same time and then the results are mixed during the overall interpretation looking for convergence, divergence, contradictions, or relationships between the two sets of data. This method was chosen because it allows the qualitative data to refine and elaborate on the general findings of the study while providing an in-depth understanding of the quantitative data (Creswell & Clark, 2007).

According to Creswell and Clark (2007) incorporating qualitative methods into a quantitative study can be beneficial in helping the researcher bring together a more comprehensive account of the area of inquiry and can provide a contextual understanding of the relationships that may exist among the variables under study. Use of qualitative data also enhance findings and make them more useful to practitioners (Bryman, 2006).

Figure 1. Mixed Method Research Design – Convergent Parallel

The qualitative measures that were used were observations and interviews. Observations were completed of students practicing on the computer using both practice methods by the classroom teacher using an observation protocol (See appendix C). The researcher also observed students practicing integer facts on the computer during two sessions of the intervention. Interviews were conducted after the intervention ended with six students (three per class) and the teacher (See appendix D).
Mrs. Brown’s three classes were assigned to one of two playing conditions:

2. Online integer addition fact practice using Arcademics games versus three other students in the class chosen by the students themselves.

**Variables**

The three independent variables (IV) for this study were the two methods of practice on the computer: 1) computer-based flashcard practice, 2) Arcademics game versus other students in the class and gender. The dependent variables (DV) were pre/posttest gain scores and flow score. Gain scores were calculated using the range of students’ pre and posttest integer addition scores. These scores were used because gain score analysis has been found to be an appropriate DV for non-equivalent groups and is seen as superior to ANCOVA for this purpose (Fitzmaurice, Laird, & Ware, 2012). Flow score was determined by the sum of all student answers on the eGameFlow survey. An additional IV, pretest score, was created using previous knowledge of basic addition and subtraction facts in order to examine its relationship with student achievement using student gain scores. This continuous variable was determined by combining the total number of items answered correctly on the timed basic addition and subtraction pretests for each student. Each basic facts test contained one hundred fifty items for a total possible score of three hundred.

**Participants and Setting**

Cleveland State University (CSU) Institutional Review Board (IRB) procedures were followed and once IRB approval was obtained consent were received from
participants, their parents and the participating teachers. The study then took place in an urban comprehensive high school in a large urban city in the Midwest. Table 1 summarizes the enrollment of the school broken down by subgroups. The students that participated in the study were from three ninth grade classrooms at the school taught by the same teacher, Mrs. Brown. The intervention took place in the students’ classroom during daily instruction as well as in the school’s media center during a two week period. Mrs. Brown was required by the school district’s Algebra curriculum to teach the concepts taught and practiced in this study. These concepts would have been taught and practiced during the school year regardless if students were participating in this study or not.

Table 1
2012-2013 School Enrollment

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Enrollment #</th>
<th>Enrollment %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asian or Pacific Islander</td>
<td>37</td>
<td>3.3%</td>
</tr>
<tr>
<td>African American, Non-Hispanic</td>
<td>323</td>
<td>29.1%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>517</td>
<td>46.6%</td>
</tr>
<tr>
<td>Multiracial</td>
<td>50</td>
<td>4.5%</td>
</tr>
<tr>
<td>White, Non-Hispanic</td>
<td>178</td>
<td>16.0%</td>
</tr>
<tr>
<td>Students with Disabilities</td>
<td>385</td>
<td>34.8%</td>
</tr>
<tr>
<td>Economically Disadvantaged</td>
<td>1,109</td>
<td>100.0%</td>
</tr>
<tr>
<td>Limited English Proficiency</td>
<td>408</td>
<td>36.8%</td>
</tr>
</tbody>
</table>

Note. Data from school’s state report card (http://reportcard.education.ohio.gov/Pages/default.aspx).

Eighty-six ninth grade students from Mrs. Brown’s three different ninth grade Algebra 1 classes were asked to participate in this study. The IRB process was followed...
requiring parent consent and giving students the opportunity to dissent from the study.

The school was recruited through the researcher’s professional connections at the school.

The student subgroups for each class are displayed in tables 2-4.

**Class Profiles**

**Table 2**  
*Class 1 Descriptive Statistics (Algebra 1 - Arcademics Game Group)*

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Enrollment #</th>
<th>Enrollment %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hispanic</td>
<td>7</td>
<td>32%</td>
</tr>
<tr>
<td>African American</td>
<td>7</td>
<td>32%</td>
</tr>
<tr>
<td>White</td>
<td>8</td>
<td>36%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>22</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Table 3**  
*Class 2 Descriptive Statistics (Algebra 1 - Flashcard Group)*

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Enrollment #</th>
<th>Enrollment %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hispanic</td>
<td>13</td>
<td>48%</td>
</tr>
<tr>
<td>African American</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>White</td>
<td>7</td>
<td>26%</td>
</tr>
<tr>
<td>Asian American</td>
<td>3</td>
<td>11%</td>
</tr>
<tr>
<td>Undeclared</td>
<td>4</td>
<td>15%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>27</strong></td>
<td></td>
</tr>
</tbody>
</table>
Table 4
*Class 3 Descriptive Statistics (Algebra 1 Honors - Arcademics Game Group)*

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Enrollment #</th>
<th>Enrollment %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hispanic</td>
<td>7</td>
<td>23%</td>
</tr>
<tr>
<td>African American</td>
<td>14</td>
<td>45%</td>
</tr>
<tr>
<td>White</td>
<td>7</td>
<td>23%</td>
</tr>
<tr>
<td>Asian American</td>
<td>3</td>
<td>10%</td>
</tr>
<tr>
<td>Total</td>
<td>31</td>
<td></td>
</tr>
</tbody>
</table>

**Instruments and Data Collection**

Instruments for this study included a demographic survey (See appendix E) pretests of basic addition and subtraction facts, pre/posttest of basic integer addition facts (See appendix B), and an eGameFlow questionnaire (See appendix F). Students in all classes completed the pre and posttests as well as the eGameFlow questionnaire, which is described below. The participating teacher observed students during their practice time in the media center using an observation protocol (See appendix C) and six students (one low and one high performing student from each class) as well as the participating teacher were interviewed after the intervention (interview questions can be found in appendix D). The researcher also observed students as they practiced integer facts on the computer during two intervention sessions, the first and the last. See Table 5 for the study timeline.
Table 5  
**Measures Timetable**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Administered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic Survey</td>
<td>Week 1</td>
</tr>
<tr>
<td>Pretests of basic addition and subtraction facts</td>
<td>Day 1</td>
</tr>
<tr>
<td>Integer addition Pretest</td>
<td></td>
</tr>
<tr>
<td>Integer Lesson 1</td>
<td>Day 2</td>
</tr>
<tr>
<td>Computer Lab Practice Session 1</td>
<td></td>
</tr>
<tr>
<td>Observations in Lab by researcher and teacher</td>
<td></td>
</tr>
<tr>
<td>Integer Lesson 2</td>
<td>Day 3</td>
</tr>
<tr>
<td>Computer Lab Practice Session 2</td>
<td>Day 4</td>
</tr>
<tr>
<td>Observations in Lab by teacher</td>
<td></td>
</tr>
<tr>
<td>Integer Lesson 3</td>
<td>Week 2</td>
</tr>
<tr>
<td>Computer Lab Practice Session 3</td>
<td>Day 1</td>
</tr>
<tr>
<td>Observations in Lab by teacher</td>
<td></td>
</tr>
<tr>
<td>Computer Lab Practice Session 4</td>
<td>Day 2</td>
</tr>
<tr>
<td>Observations in Lab by researcher and teacher</td>
<td></td>
</tr>
<tr>
<td>eGameFlow Survey</td>
<td>Day 3</td>
</tr>
<tr>
<td>Integer Addition Posttest</td>
<td></td>
</tr>
<tr>
<td>Interviews</td>
<td>Week 3</td>
</tr>
<tr>
<td></td>
<td>Day 1</td>
</tr>
</tbody>
</table>

**Student Performance Measures**

**Pre and PostTests of Basic Addition and Subtraction Facts**

Measures of student knowledge and automaticity of basic facts were measured using a gain score created from a traditional three-minute basic addition of integer facts test given before the start of the study and at the completion of data collection (See
The basic facts test used was modified from traditional 100 item timed test to a 150 item timed test in order to avoid ceiling effects. Directions for the tests explained to students that they were not expected to answer all questions in the time allotted. This test was used as an achievement test for integer addition for each student. Using this specific test as a DV was appropriate because the purpose of this study was to determine if any of the methods of practice used significantly increased a students’ automaticity with integer facts. This score was calculated using the range of each child’s pre and posttest score. These measures were used to answer research questions 2, 3 and 5.

Students also completed an addition and subtraction facts test before the start of the study. Student scores on the two tests were added to create a new variable, pretest score. This variable was used in a multiple regression in order to determine if there was a relationship between prior arithmetic knowledge and integer fact recall after the intervention, answering research question 3.

**eGameFlow Questionnaire**

The eGameFlow questionnaire is an instrument that measures learners’ enjoyment of e-learning games (Fu, Su, & Yu, 2009). The eGameFlow questionnaire is a 42 item questionnaire consisting of eight dimensions of flow, or engagement that takes approximately twenty minutes to complete. For this study, however, the questionnaire was modified to include only 21 items because some dimensions measured on the questionnaire were not relevant to the activity (See appendix F for a complete listing of survey questions). The survey then took approximately fifteen minutes to complete. Four dimensions were included. They were; concentration, challenge, social interaction and knowledge improvement (See Table 6).
<table>
<thead>
<tr>
<th>Dimension</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Concentration</strong> (6)</td>
<td>“a complete focusing of attention on the task at hand” (Csikszentmihalyi, 1990, p. 58)</td>
<td>I am not distracted from tasks that I should concentrate on</td>
</tr>
<tr>
<td></td>
<td>“games must provide activities that encourage the player’s concentration while minimizing stress from learning overload, which may lower the player’s concentration on the game” (Fu et al., 2009, p. 105)</td>
<td></td>
</tr>
<tr>
<td><strong>Challenge</strong> (6)</td>
<td>“an activity that contains a bundle of opportunities for action that require appropriate skills to realize” (Csikszentmihalyi, 1990, p. 50)</td>
<td>The difficulty of challenges increases as my skills improve</td>
</tr>
<tr>
<td></td>
<td>“the game should offer challenges that fit the player’s level of skills; the difficulty of these challenges should change with the increase in the player’s skill level” (Fu et al., 2009, p. 106)</td>
<td></td>
</tr>
<tr>
<td><strong>Social Interaction</strong> (4)</td>
<td>peer collaboration (Zheng, 2012)</td>
<td>Racing against other students in the game helps me learn</td>
</tr>
<tr>
<td></td>
<td>“tasks in the game should become a means for players to interact socially” (Fu et al., 2009, p. 106)</td>
<td></td>
</tr>
<tr>
<td><strong>Knowledge improvement</strong> (5)</td>
<td>active acquisition of information (Zheng, 2012)</td>
<td>The game increases my knowledge</td>
</tr>
<tr>
<td></td>
<td>“the game should increase the player’s level of knowledge and skills while meeting the goal of the curriculum” (Fu et al., 2009, p. 106)</td>
<td></td>
</tr>
</tbody>
</table>

All items were answered using a Likert-type scale ranging from one to five, with a one indicating “strongly disagree” and five indicating “strongly agree”. Questions were
answered by students after their last computer lab session using a SurveyMonkey link. This survey instrument was used to answer research questions number 1 and 5.

The authors of the eGameFlow questionnaire conducted five validity tests on the eGameFlow questionnaire. They were: content validity, construction validity, criterion-related validity, convergent validity, and divergent validity (Fu et al., 2009). Content validity was validated using expert validity and “by using data collected in pretests to conduct factor, reliability, item-scale correlation, and test-retest” (Fu et al., 2009, p. 109). Structure validity was verified through exploratory factor analysis after the data were determined to be suitable for a factor analysis using Kaiser-Meyer-Olkin measure of sampling adequacy (0.87) and Bartlett’s test of sphericity (7088.42, p<0.01) (Fu et al., 2009). Factors were then extracted using the principal-axis factoring method and in total the eight factors explained 74.29% of the total variance in the learner’s enjoyment of e-learning in computer games. The scale was found to have convergent validity through the high correlations (p<0.01) between the eight sub-scales and the overall scale. The authors also concluded that the instrument had divergent validity because the correlations between the eight sub-scales and the overall scale were almost entirely higher than the correlations among the sub-scales themselves (range was 0.51 to 0.81).

The eGameFlow instrument was found to have high internal consistency and reliability with Cronbach’s alpha of 0.942 for the 42 items as a group and > 0.8 for each of the separate dimensions (Fu et al., 2009). The test-retest reliability of the instrument was verified with a statistical significance (p<0.01) for each subscale. The reliability of the modified instrument was verified using split-halves. The modified eGameFlow instrument was also checked for understandability. After receiving IRB permission, a
group of 21 students from the same high school but different classes and different teachers read the survey in order to make sure it was understandable. Students expressed that they were able to understand all questions on the survey. Reliability of pilot student responses were then analyzed using the split-halves method and found to be reliable with the Spearman-Brown coefficient, \( r = .921 \). The study group surveys were also analyzed for reliability using the split-halves method and was also found to be reliable, \( r = .692 \).

**Qualitative measures**

A convergent parallel design was used in this study in which a qualitative study helped evaluate and interpret the results of the largely quantitative study (Morgan, 1998). Qualitative data were collected at the same time as the quantitative data. Qualitative measures that were used were observations and interviews. Observations of students playing the online math games were conducted in this study because a person’s behavior may not be stable across all environments, their behavior can be specific to certain situations (Hintze, Volpe, & Shapiro, 2002). Students may not act in the same manner in the computer lab playing games as they would in the classroom learning environment or practicing the same topic in a different setting. In order to help the teacher identify significant student behaviors she was asked to complete an observation protocol (See appendix C) as students played the games in the computer lab. The teacher watched the students’ behaviors and documented everything she observed that was relevant to the research. The researcher also collected observation data from all participating classes during two intervention sessions in the computer lab, the first and the last.

Interviews were used to gather information about teacher and student perceptions of online math games (See appendix D). The purposes of the interviews were to give
participants an opportunity to contribute a detailed account of their experience of the
phenomenon being studied which supplemented the quantitative data gathered. These
interviews provided a context for participants’ current knowledge as well as their
experiences participating in the study. The interviews were conducted at the end of data
collection in an informal, open-ended manner and carried out in a conversational style by
the researcher. Interviews were recorded and transcribed at a later date. A total of seven
interviews were conducted; six students (three per class, including one high achieving
and one low achieving student) chosen using purposive sampling and one adult interview.
The adult that was interviewed was the classroom teacher.

**Procedure**

Upon approval from the IRB, a letter explaining the purpose of the study, the role
of the participants, and the intended use and distribution of data were given to
participants and their parent(s)/guardian(s) by the researcher in all participating classes.
Each letter included parent/guardian and student consent and assent forms. See appendix
G for a copy of the consent and assent forms. Letters were collected by the researcher
before implementation of the intervention. The participating teacher also received an
introduction to the study and was asked to give consent to participate by the researcher.
The researcher then trained the participating teacher on how to use the observation
protocol.

During a two week time span students in three different Algebra 1 classes from an
urban comprehensive high school taught by the same teacher participated in integer
lessons and online integer facts practice sessions. The purpose of the intervention was to
examine how the method of integer addition practice influenced student automaticity
adding basic integer facts from -9 to 9 and their engagement to practice those facts to automaticity (See Figure 2 for a timeline of events).

Figure 2. Data Collection Timeline 2014

Adding integers method of practice
Practice was completed using games on the computer but using two different methods:
- **Method 1**: control condition; integer addition fact practice using online flashcards from the ThatQuiz.com website (See appendix H)

- **Method 2**: Experimental condition; Student vs. other students integer addition practice on the Arcademics website using the Orbit Integers race game (See appendix A) [http://www.arcademicskillbuilders.com/](http://www.arcademicskillbuilders.com/)

During weeks 1-2 students played the Orbit Integers game which required that they add integers to make their space ship go faster. Students used the multiplayer version of the game which allowed them to race against three other students of their own choosing.

Students answered a short demographic survey and then were given pretests measuring their basic addition and subtraction fact knowledge as well as a test that measured their automaticity with integer addition facts (See appendix B). During the intervention students were taught three integer lessons, one lesson after each practice session (See appendix I). Each week students also went to the schools’ media center to practice adding integers for thirty minutes, two times per week for two weeks. Each class used a different method of practice. At the end of the intervention all students completed an eGameFlow questionnaire through SurveyMonkey to measure their engagement during the practice sessions (See Appendix F). This survey was tested for reliability using split-halves with a pilot group of students (n=21) that were not part of the study but were from the same school. The results of the reliability test using the Spearman-Brown coefficient was $r = .921$. Analyzing survey results from participating student surveys (n=43), also using split-halves, yielded a Spearman-Brown reliability coefficient of $r = .692$. 

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Students then took a posttest measuring their automaticity adding integers.

**Confidentiality**

Steps were taken to ensure the confidentiality of participants throughout this study. Confidentiality was discussed at each stage of the study with participants. During each stage the participants were informed that the information they provided would remain confidential, unless it involved harming oneself or others. All student participants were provided with an identification number that served as their identity throughout the data collection and analysis process on all forms and tests. All of the participants were treated in accordance with the ethical guidelines of the American Psychological Association and the CSU IRB. Although there are no identifiable risks for participating in this study careful consideration was taken in dealing with the children involved. The material reviewed in this study was part of the prescribed Algebra 1 curriculum that is taught by this teacher. These skills would have been taught and reinforced with the students in this teachers’ classroom whether or not they participated in this study. Students and their parents were given information about the study and were given ample opportunity to ask questions about the study and were able to opt out of the study if they so desired.

Parents were given a consent form allowing their children to participate. Students were given an assent form where they were given the opportunity to choose not to participate in the study. Confidentiality was maintained by assuring that observations were only conducted by the teachers involved without names being written on any of the observation forms and the changing of names of participants to numbers in all written materials. Since interviews were documented through a voice recording, students were
not asked to identify themselves on the recording. Actual names of participants, schools and the school district were not used. Recordings were transcribed by the researcher only, without using participants’ names. Recordings were labeled with “Student S1”, “Student S2”, “Student S3”, “Student S4”, “Student S5” and “Student S6”. Student names did not appear in any data collected through pre/posttests, questionnaires and observations or interviews. Recordings were destroyed after transcription. All other study materials will be kept in a locked cabinet where only the researcher will have access. All data transcribed on the researchers’ computer have been saved in a file that is password protected and after three years all materials will be destroyed.

**Quantitative Data Analysis**

The model that was used to analyze research questions 1, 2 and 5 in this study was the nonparametric test, Mann-Whitney U (See Table 7). This test was chosen because there was a small participant data set. Originally, Analysis of Variance (ANOVA) was to be used because it was determined to be the most appropriate test for examining if there were statistically significant differences between the two methods of practice on basic integer addition gain score and flow score for students. However, the equivalent nonparametric test, Mann-Whitney U, was ultimately used because of several unanticipated factors at the school and in the game used led to a smaller number of student participants than expected. See the results section for more detail.

For question 3, a regression was used with students’ relative standing on basic addition and subtraction facts pretests by their method of practice as IVs compared to student gain scores as the DV (See Table 7).
Question 4 was eliminated due to lack of single player game conditions on the Arcademics website. See the results section for more detail.

Table 7
*Research Questions by Method of Analysis*

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. When given time to play integer addition games on the computer will students be engaged more than those students who practice adding integers using flashcards on the computer as demonstrated by self-reported ratings of engagement?</td>
<td>Mann-Whitney U</td>
</tr>
<tr>
<td>2. Does practicing integer facts using games on the computer increase student recall of integer math facts to a greater extent than those using flashcards on the computer?</td>
<td>Mann-Whitney U</td>
</tr>
<tr>
<td>3. Is there a relationship between participating recall of integer mathematics facts and the extent to which those students have mastered their basic addition and subtraction facts?</td>
<td>Regression</td>
</tr>
<tr>
<td>4. a.) Does practicing integer facts using multiplayer games with competition differ from practice using flashcards on the computer in student engagement as measured by flow survey score?</td>
<td>Question deleted</td>
</tr>
<tr>
<td>b.) Does practicing integer facts using multiplayer games with competition differ from practice using flashcards on the computer in student achievement as measured by gain score on pre and posttests of integer addition facts?</td>
<td></td>
</tr>
<tr>
<td>5. Does gender play a role in the engagement and achievement of students playing multiplayer versus single player games as evidenced by eGameFlow survey score and gain score?</td>
<td>Mann-Whitney U</td>
</tr>
</tbody>
</table>

**Quantitative Analysis by Research Question**

**Research question number 1:**
When given time to play integer addition games on the computer will students be engaged more than those students who practice adding integers using flashcards on the computer as demonstrated by self-reported ratings of engagement?
This research question was analyzed using Mann-Whitney U. Student response data from the eGameFlow questionnaire completed using SurveyMonkey was reviewed and cleaned, when necessary. Frequency tables were constructed and mean scores were calculated for each subscale of the eGameFlow questionnaire (concentration, challenge, immersion, social interaction and knowledge improvement). The eGameFlow score for students was determined by the sum of all of the subscales answered on the questionnaire, where a higher value denoted a higher level of engagement during the practice session.

Since the data set did not meet assumptions for ANOVA a Mann-Whitney U test was conducted to determine if a significant difference between groups existed, the results had to have an effect size of at least $\eta^2=0.354$ to be trustworthy. This value was calculated with G-Power using a sensitivity analysis. These data were triangulated/supported by qualitative data from the teacher observations as well as teacher and student interviews.

Research question number 2

Does practicing integer facts using games on the computer increase student recall of integer math facts to a greater extent than those using flashcards on the computer?

Students were given pre and posttests measuring their automaticity with basic integer addition facts. They were given 150 questions to answer in three minutes. A gain score was then determined by calculating the range of each student’s responses on the pre and posttests. This gain score was included in a Mann-Whitney U test with method of practice as the IV and gain score as the DV to determine if there were any statistically
significant differences between method of practice and the gains students made from the integer addition pretest to the posttest. The Mann-Whitney U test did not reveal a significant difference. These data were triangulated/support by qualitative data from the teacher observations as well as teacher and student interviews.

**Research question number 3**
Is there a relationship between participating students’ recall of integer mathematics facts and the extent to which those students have mastered their basic addition and subtraction facts?

An examination of the data was performed to determine if the data met assumptions in order to analyze the data with a linear regression. Since the assumptions of independence, homogeneity of variance, normality and linearity were met a linear regression analysis was conducted to determine if the student recall of integer facts demonstrated by the gain score could be predicted by mastery of basic addition and subtraction facts and the method of practice. These data were triangulated/support by qualitative data from the teacher observations as well as teacher and student interviews. Effect size should be at least \( R = .267, \alpha = .05 \), to be trustworthy (calculated with G-Power).

**Research question number 4a**
Does practicing integer facts using multiplayer games with competition differ from practice using other methods in student engagement as measured by flow survey score?

**Research question number 4b**
Does practicing integer facts using multiplayer games with competition differ from practice using other methods in student achievement as measured by gain score on pre and posttests of integer addition facts?
Question 4 was eliminated due to lack of single player game conditions on the Arcademics website. See the results section for more detail.

**Research question number 5**

Does gender play a role in the engagement and achievement of students playing multiplayer versus single player games as evidenced by eGameFlow survey score and gain score?

Two separate Mann-Whitney U tests were performed to see if there was a difference in the student engagement and achievement of students by gender as displayed in student eGameFlow survey score and integer addition gain score by the method of practice the students participated in throughout the study. Since the Mann-Whitney U test determined a significant difference in the results of flow score by gender the effect size must at least $r=0.278$ to be trustworthy calculated using $\frac{\alpha}{\sqrt{N}}$, $\alpha=.05$, $Z=1.645$ (from G-power sensitivity analysis) and $N=39$. These data were triangulated/supported by qualitative data from the researcher and teacher observations as well as teacher and student interviews.

**Qualitative Data Analysis**

The observations and interviews of students and the participating teacher were analyzed qualitatively using a convergent parallel design (See Figure 3). Quantitative and qualitative data were independently gathered and analyzed and then merged for interpretation. The purpose of choosing this design was to gather different but complementary data in order to gain a deeper understanding of the experiences students had while practicing integer facts on the computer (Creswell & Clark, 2007).
Figure 3. Visual Model for Mixed Methods Procedures - Convergent Parallel Design

**Procedures:**
- Select classes
- Administer pretests
- Administer interventions
- Administer survey and posttest

**Products:**
- Pretest score
- Gain score
- Flow score

**Procedures:**
- Conduct observations during intervention
- Select students for interviews
- Semi-structured interviews

**Products:**
- Observations
- Transcripts

**Procedures:**
- Descriptive Statistics
- Group Comparisons

**Products:**
- Classify whether ratings converge
- Means, SDs, correlation
- Significance values, effect sizes

**Procedures:**
- Constant comparative thematic analysis

**Products:**
- Themes identified

**Procedures:**
- Compare/contrast qualitatively derived groups with quantitative variables

**Products:**
- Table of Themes
- Matrix relating qualitative themes to quantitative variables

**Procedures:**
- Consider how merged results produce a better understanding

**Products:**
- Discussion

Adapted from Creswell and Clark (2007, p. 118, Figure 4.3)
Once all interviews were conducted and transcribed the constant comparative method (CCM) of analysis was used to compare the interviews to one another and then merge the qualitative data together. CCM is a method of data analysis by which all data in a study are systematically compared to all other data in the study allowing rich descriptions to emerge from the organizing of the data (Fram, 2013). CCM was conducted using a step by step approach where the transcripts from the interviews and observations were used as the inputs for the qualitative analysis process (Boeije, 2002). This process helped make sense of the data and allowed for the reconstruction of the perspectives of the students and teacher in the study. Analysis in CCM consists of two activities, fragmenting and connecting (Boeije, 2002). Fragmenting and connecting allowed pieces, or fragments, from the interviews and observations to be analyzed and interpreted and then connected to one another to accentuate the context and richness of the data (Boeije, 2002). A three-step analysis procedure was used to compare the interviews and observations in this study:

1. Comparison within a single interview/observation.
2. Comparison between interviews/observations in the same practice groups.
3. Comparison of the interviews/observations of different practice groups and the teacher.

Step 1: Comparison within a single interview/observation

At the start of the analysis one interview and or observation was compared to itself. In this process of open coding using NVIVO, every passage of the interview/observation was studied to determine exactly what had been said/heard and
then each statement was coded with an appropriate code. After a code was identified the rest of the interview was examined for other statements that should be given the same code. When multiple references were made to the same code those statements were compared in order to find out if new information about that code was given or if the same information was repeated. The statements were then analyzed further in order to find similarities and differences. The purpose of this internal comparison within each interview/observation was to develop categories and label them with the most appropriate themes. This process represented an attempt to interpret the parts of the interview in the context of the entire study as it was lived by the participants (Boeije, 2002). A summary of each interview/observation, themes and memos were generated during this process.

Step 2: Comparison between interviews/observations of students in the same practice group.

All subsequent interviews/observations were coded as described in step one. Themes and memos increased as a result. As soon as the second interview/observation was analyzed it was compared to the first interview/observation from the same method of practice group. The aim of this step was to compare and contrast the themes that emerged within a group. This step resulted in verification of the themes that were created and identification of relevant characteristics of the experience of the participants from each of the two practice groups.

Step 3: Comparison between interviews/observations of students from the two practice groups and the teacher.
In this step interviews/observations from the two different practice groups were compared. The flashcard group’s responses were compared to the game group’s responses as well as to the teacher’s responses and the observations. The purpose of comparing interviews/observations between groups is to give a richer description of the experiences students and the teacher had while practicing integer facts on the computer. The results from this step did not generate any new themes it only deepened the description of the experience students had while practicing facts on the computer.

Strategies for Validating Qualitative Findings

Credibility for this study was achieved using the validation strategies of triangulation, researcher reflexivity and thick, rich descriptions. Triangulation in qualitative research contributes to the validity of research results when multiple methods or researchers are employed to achieve a high level of accuracy (Farmer, Robinson, Elliott, & Eyles, 2006). Analysis and verification of the themes depends on the ability to confirm the same information from more than one source (Creswell & Clark, 2007). The data in this study was triangulated using various forms of data including observations, interviews, reflective journal entries and field notes by the researcher. Investigator triangulation was also used in the analysis and coding of interviews and observations. A peer researcher independently coded the interviews and observations after which both researchers met and discussed each other’s codes, compared results, and agreed on the included themes in this study. The peer researcher independently coded four themes in the interviews and observations labeling them with levels of Bloom’s Taxonomy. After discussing themes it was concluded that three of the levels the peer researcher identified were consistent with three of the researchers’ themes, achievement, automaticity and competition. In the subsequent analysis and discussion between the researchers three
other themes emerged as relevant to this study, engagement, extended learning and game features.

Credibility was established by researcher reflexivity analyzing the data through the process of reflecting, exploring and judging the relevance of the themes that were established.

Reliability was achieved for this study through the use of a protocol for interviews and observations. According to Tellis (1997) the protocols used in a study should contain procedures and general rules that should be followed while using the instrument. The researcher and participating teachers met at the outset of the intervention to discuss the observation protocol in order to ensure inter-rater reliability. Creswell and Clark (2007) also state that reliability is enhanced in a qualitative study when the researcher takes detailed field notes and transcribes recordings which was also completed in this study.

**Summary of Chapter III**

This section reviewed the methodology used in this study, beginning with the research questions and description of the population studied. In addition, participants, procedures, instruments used, effect size and data analysis techniques were discussed. The IRB procedures were detailed along with procedures for maintaining confidentiality and validating findings.
CHAPTER IV

RESULTS

This study looked closely at the effects playing online skills games had on the automaticity and engagement of high school students as they practiced adding integers. Further, this study sought to develop a deeper understanding of the following:

1. When given time to play integer addition games on the computer will students be more engaged than those students who practice adding integers using flashcards on the computer as demonstrated by self-reported ratings of engagement?

2. Does practicing integer facts using games on the computer increase student recall of integer math facts to a greater extent than those using flashcards on the computer?

3. Is there a relationship between participating students’ recall of integer mathematics facts and the extent to which those students have mastered their basic addition and subtraction facts?

4. Do multiplayer games with competition differ from single player games in:
   a. Student engagement as measured by flow survey score?
b. Student achievement as measured by gain score on pre and posttests of integer addition facts?

5. Does gender play a role in the engagement and achievement of students playing multiplayer versus single player games as evidenced by eGameFlow survey score and gain score?

During data collection for this study several unanticipated factors at the school and in the game used for the online practice sessions led to some variations in the initial plan. To begin with, the district where the school is located mandated two tests be given to ninth grade students during the time of the study. The first test, Northwest Education’s Measures of Academic Progress (MAP), is a fee-based, computerized adaptive test that measures academic progress of students towards mastering curricular and state goals. This test required that all computer labs in the school be reserved only for the MAP tests and make-ups at the same time of the study. The second test was an Algebra 1 End Of Course Test that was mandated and given to the students with very short notice, also during the data collection phase of this study. These unanticipated tests caused the number of practice sessions in the study to be reduced from eight to four. Another issue that arose during the study was the time of the school year in which the study took place. The practice sessions occurred two weeks prior to the district’s spring break. Unfortunately, during this time student attendance dropped in the Algebra classes. From the seventy-eight students that began the study and participated in the practice sessions only thirty-nine students completed the posttest on the final day of data collection, a drop of almost fifty percent. Due to these unforeseen conditions, the number of students that participated in the entire study was fewer than anticipated and for the quantitative data
Another unforeseen issue that affected the number and type of practice groups also arose. The Arcademics website modified the games on their website in a manner that did not allow for students to play the games by themselves against the computer. All students playing games on the website were automatically placed in a multiplayer game competing against other students playing the same game at the same time. An alternate method was attempted that allowed students to only play against the computer; however, once students learned that they could play against other students in the class they resisted playing any other way. Due to this game condition data were collected for only two groups and analyzed; 1) those using flashcards on the computer (See Table 8) and 2) those practicing integer addition facts playing the multiplayer version of the Arcademics game on the computer (See Table 9).

**Participating Students by Method of Practice**

<table>
<thead>
<tr>
<th>Table 8</th>
<th>Flashcards on the Computer Practice Group Descriptive Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>12</td>
</tr>
<tr>
<td>Males</td>
<td>5</td>
</tr>
<tr>
<td>Females</td>
<td>7</td>
</tr>
<tr>
<td>Subgroups</td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>5</td>
</tr>
<tr>
<td>African American</td>
<td>0</td>
</tr>
<tr>
<td>White</td>
<td>2</td>
</tr>
<tr>
<td>Asian American</td>
<td>2</td>
</tr>
<tr>
<td>Undeclared</td>
<td>3</td>
</tr>
<tr>
<td>Pretest</td>
<td>Group Mean</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
</tr>
</tbody>
</table>
Table 9
ArcadeMics Game on the Computer Practice Group Descriptive Statistics

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>27</td>
</tr>
<tr>
<td>Males</td>
<td>17</td>
</tr>
<tr>
<td>Females</td>
<td>10</td>
</tr>
<tr>
<td>Subgroups</td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>9</td>
</tr>
<tr>
<td>African American</td>
<td>8</td>
</tr>
<tr>
<td>White</td>
<td>5</td>
</tr>
<tr>
<td>Asian American</td>
<td>3</td>
</tr>
<tr>
<td>Undeclared</td>
<td>2</td>
</tr>
<tr>
<td>Pretest</td>
<td></td>
</tr>
<tr>
<td>Group Mean</td>
<td>171.81</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>63.46</td>
</tr>
</tbody>
</table>

The two groups consisted of three classes of Algebra I students taught by the same teacher, Mrs. Brown. Students in the Flashcards group were from one general education Algebra I class with twenty-seven students in the general and bilingual education programs. Students in the Game group were from two classes, one was a general education class and the other class was listed as an honors Algebra 1 class, however, the teacher stated that students in the honors class had similar achievement levels as students in the other two classes. This was also confirmed by the number of students mastering the number sense standard on the eighth grade Ohio Achievement test (See Table 10).
Table 10

<table>
<thead>
<tr>
<th></th>
<th>Above Standard</th>
<th>At Standard</th>
<th>Below</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flashcard Group</td>
<td>3</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>Game Group – Class 1</td>
<td>9</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Game Group – Class 2(Honors)</td>
<td>5</td>
<td>14</td>
<td>7</td>
</tr>
</tbody>
</table>

*Note. Indicates number of students at each classification on the 8th grade Ohio Achievement Test.*

Quantitative Analysis

**Analysis of student engagement**

The first research question (When given time to play integer addition games on the computer will students be engaged more than those students who practice adding integers using flashcards on the computer as demonstrated by self-reported ratings of engagement?) was analyzed using the nonparametric test, Mann-Whitney U to determine if there was a statistically significant difference in the DV (flow score), based on the types of practice groups (flashcards, game). The nonparametric equivalent of the ANOVA, Mann-Whitney U, was used because the data did not meet the necessary assumptions for ANOVA, the sample size was small (Leech & Onwuegbuzie, 2002) and results for the Kolmogorov-Smirnov test for normality (Field, 2009) indicated that the flow score distribution deviated significantly from a normal distribution (D = .241, p = .053). Thirty-five students participated in the intervention, completed the eGameFlow survey (See Appendix F) and were subsequently included in this portion of the data analysis (See Table 11). Student engagement was measured using a flow score calculated as the sum of all responses on the eGameFlow survey. The survey was given to students at the completion of the practice sessions using a SurveyMonkey link.
Table 11  
*Descriptive Statistics for Students Completing eGameFlow survey*

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
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<td>Gender</td>
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<tr>
<td>Male</td>
<td>21</td>
</tr>
<tr>
<td>Female</td>
<td>14</td>
</tr>
<tr>
<td>Age</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td>17</td>
<td>3</td>
</tr>
<tr>
<td>Not reported</td>
<td>1</td>
</tr>
<tr>
<td>Race/Ethnicity</td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>6</td>
</tr>
<tr>
<td>Asian American</td>
<td>5</td>
</tr>
<tr>
<td>Hispanic</td>
<td>14</td>
</tr>
<tr>
<td>Undeclared</td>
<td>4</td>
</tr>
<tr>
<td>White</td>
<td>6</td>
</tr>
<tr>
<td>Class Status</td>
<td></td>
</tr>
<tr>
<td>Freshman</td>
<td>35</td>
</tr>
<tr>
<td>Sophomore</td>
<td>0</td>
</tr>
<tr>
<td>Junior</td>
<td>0</td>
</tr>
<tr>
<td>Senior</td>
<td>0</td>
</tr>
<tr>
<td>Language Spoken at Home</td>
<td></td>
</tr>
<tr>
<td>Chinese</td>
<td>3</td>
</tr>
<tr>
<td>English</td>
<td>12</td>
</tr>
<tr>
<td>Nepali</td>
<td>1</td>
</tr>
<tr>
<td>Spanish</td>
<td>16</td>
</tr>
<tr>
<td>Undeclared</td>
<td>3</td>
</tr>
</tbody>
</table>

Assumptions for the Mann-Whitney U test were analyzed. First, it was determined that the data did meet the conditions for this test because the data collected contained one DV, flow score, that was measured at the continuous level. The data also consisted of one IV, method of practice, consisting of two independent groups. Lastly, all observations were independent (Ho, 2006). The following histogram (See Figure 4) gives a visual display showing that the distributions of the flow scores of the two groups did
not have the same shape. This lack of similarity in the two groups meant that the Mann-Whitney U test was used to determine if there were differences between the distributions of the two groups not their medians. Therefore, the differences in distributions, lower/higher scores and mean ranks were analyzed (See Tables 12 and 13).

Figure 4. Frequency Distributions of Two Practice Groups by Flow Score

<table>
<thead>
<tr>
<th>Flow Score Descriptive Statistics by Method of Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flashcards</strong></td>
</tr>
<tr>
<td>N</td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Median</td>
</tr>
<tr>
<td>Std. Deviation</td>
</tr>
<tr>
<td>Std. Error</td>
</tr>
<tr>
<td>Variance</td>
</tr>
<tr>
<td>Minimum</td>
</tr>
<tr>
<td>Maximum</td>
</tr>
</tbody>
</table>
Table 13

<table>
<thead>
<tr>
<th>Method of Practice</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flashcards</td>
<td>12</td>
<td>16.17</td>
<td>194.00</td>
</tr>
<tr>
<td>Game</td>
<td>23</td>
<td>18.96</td>
<td>436.00</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results demonstrated a lack of statistical significance ($U=116.00$, $p = .461$) indicating no significant difference in engagement between students that practiced their integer facts on the computer using flashcards and those that practiced using a game on the Arcademics website with a small effect size, $\eta^2=.257$.

**Analysis of integer fact recall**

The analysis for the second research question of this study (Does practicing integer facts using games on the computer increase student recall of integer math facts to a greater extent than those using flashcards on the computer? ) was also modified to use nonparametric tests because the sample size was small. A total of thirty-nine students completed the intervention, required tests and were included in this portion of the analysis. Students completed an integer addition facts test that consisted of 150 integer addition facts (See Appendix B). Pre and posttests were administered in the classroom where students were given three minutes to complete as many problems as they could. Both tests were scored based on the number of correct answers attained with 150 being a perfect score. The mean score for all participating students on the pretest was 24.18 and the mean score for the posttest was 42.51 (See Table 14). Table 15 displays mean scores by method of practice. A gain score was then constructed by calculating the difference between each child’s pre and posttest score (See Table 16). Students in the game group
had a higher post test score than students in the flashcard group, although this difference was not found to be statistically significant (See Figure 5).

Table 14
*Adding Integers Pretest and Posttest Descriptive Statistics*

<table>
<thead>
<tr>
<th></th>
<th>Pretest integers</th>
<th>Posttest integers</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>39</td>
<td>39</td>
</tr>
<tr>
<td>Mean</td>
<td>24.18</td>
<td>42.51</td>
</tr>
<tr>
<td>Std. Error of Mean</td>
<td>2.70</td>
<td>4.43</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>16.86</td>
<td>27.64</td>
</tr>
<tr>
<td>Variance</td>
<td>284.26</td>
<td>763.99</td>
</tr>
<tr>
<td>Range</td>
<td>76.00</td>
<td>120.00</td>
</tr>
<tr>
<td>Minimum</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Maximum</td>
<td>78</td>
<td>125</td>
</tr>
</tbody>
</table>

*Note. Maximum score for each test = 150.*

Table 15
*Adding Integers Pretest and Posttest Descriptive Statistics by Method of Practice*

<table>
<thead>
<tr>
<th>Method of Practice</th>
<th>Pretest integers</th>
<th>Posttest integers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flashcards, N=12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>21.83</td>
<td>36.08</td>
</tr>
<tr>
<td>Std. Error of Mean</td>
<td>3.03</td>
<td>7.72</td>
</tr>
<tr>
<td>Median</td>
<td>23.50</td>
<td>31.50</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>10.50</td>
<td>26.73</td>
</tr>
<tr>
<td>Variance</td>
<td>110.15</td>
<td>714.27</td>
</tr>
<tr>
<td>Range</td>
<td>38.00</td>
<td>96.00</td>
</tr>
<tr>
<td>Game, N=27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>25.22</td>
<td>45.37</td>
</tr>
<tr>
<td>Std. Error of Mean</td>
<td>3.68</td>
<td>5.40</td>
</tr>
<tr>
<td>Median</td>
<td>19.00</td>
<td>39.00</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>19.11</td>
<td>28.05</td>
</tr>
<tr>
<td>Variance</td>
<td>365.18</td>
<td>786.86</td>
</tr>
<tr>
<td>Range</td>
<td>73.00</td>
<td>115.00</td>
</tr>
</tbody>
</table>
Originally a single factor analysis of variance (ANOVA) was to be conducted to answer question two. The data did not meet the assumptions for ANOVA, Originally, the data were to be analyzed using a single factor analysis of variance (ANOVA) however, the data did not meet the assumptions for ANOVA because the sample size was small (Leech & Onwuegbuzie, 2002) and results for the test of homogeneity of variance (Field, 2009) indicated that the gain score variance in the groups were significantly different in the two groups $F(1,37)=3.64, p=.06$, consequently its nonparametric equivalent, the
Mann-Whitney U test, was used to determine whether there was a statistically significant difference in the DV (gain score), in terms of the two practice groups (flashcards, game).

Assumptions for the Mann-Whitney U test were analyzed. First, it was determined that the data did meet the conditions for this test because the data collected contained one DV, gain score, that was measured at the continuous level. The data also consisted of one IV, method of practice, consisting of two independent groups. Lastly, all observations were independent (Ho, 2006). The following histogram (See Figure 6) gives a visual display showing that the distributions of the gain scores of the two groups did not have the same shape. This lack of similarity in the two groups meant that the Mann-Whitney U test was used to determine if there were differences between the distributions of the two groups not their medians. Therefore, the differences in distributions, lower/higher scores and mean ranks were analyzed (See Table 17).

Figure 6. Frequency Distributions of Two Practice Groups by Gain Score
Table 17
*Gain Score Ranks by Method of Practice*

<table>
<thead>
<tr>
<th>Method of Practice</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain Score</td>
<td>12</td>
<td>17.17</td>
<td>206.00</td>
</tr>
<tr>
<td>Game</td>
<td>27</td>
<td>21.26</td>
<td>574.00</td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Distributions of the gain scores for the two practice groups were not similar, as assessed by visual inspection. A Mann-Whitney U test was then completed and it was determined that there was a lack of statistical significance (U=128.00, p =.313) indicating that there was not a statistically significant difference in gain score between practice groups with a small effect size observed, r= -.166.

**Analysis of effect of previous automaticity with addition and subtraction facts**

The third research question (Are student gain scores at the end of the intervention significantly predicted by the students’ prior mastery of basic addition and subtraction facts?) was analyzed using a linear regression that compared the IV, pretest score, to the DV, gain score, of each student. The variable pretest score was calculated using the sum of the total correct responses on the addition and subtraction pretests students were given at the outset of the study. Each test had a total possible score of 150 resulting in the variable, pretest score, having a total possible score of 300 (See Table 18). The range of student scores was between seventy-three and three-hundred. An acceptable fluency rate for these basic addition and subtraction tests is about thirty-three facts per minute. Therefore, proficient students are expected to be able to complete about one-hundred facts in the allotted three minute time limit. Proficient students would have a total score on both the addition and subtraction tests combined of about two-hundred. The students
in the three Algebra 1 classes in this study were at varying levels of proficiency with their basic addition and subtraction facts as evidenced by the large range in pretest score values (See Table 18).

Table 18
*Pretest Score Descriptive Statistics by Practice Group*

<table>
<thead>
<tr>
<th></th>
<th>Flashcards</th>
<th>Game</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>12</td>
<td>27</td>
</tr>
<tr>
<td>Mean</td>
<td>139.92</td>
<td>171.81</td>
</tr>
<tr>
<td>Median</td>
<td>128.50</td>
<td>143.00</td>
</tr>
<tr>
<td>Minimum</td>
<td>73</td>
<td>97</td>
</tr>
<tr>
<td>Maximum</td>
<td>234</td>
<td>300</td>
</tr>
<tr>
<td>Std. Error of Mean</td>
<td>14.12</td>
<td>12.21</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>48.93</td>
<td>63.46</td>
</tr>
<tr>
<td>Variance</td>
<td>2394.08</td>
<td>4027.46</td>
</tr>
<tr>
<td>Range</td>
<td>161</td>
<td>203</td>
</tr>
<tr>
<td>% Students Proficient (Pretest Score ≥ 200)</td>
<td>17%</td>
<td>22%</td>
</tr>
</tbody>
</table>

*Note. Pretest Score = sum of addition and subtraction basic facts test for each student, maximum score = 300.*

A linear regression was performed to determine if a relationship existed between student’s gain score and the extent to which the students had mastered their basic arithmetic facts.

Before analysis of the data began the data were checked to determine if they met all assumptions of linear regression. First, it was established that a linear relationship did exist between the two variables. Next, the Durbin-Watson statistic was calculated (d=1.655) and found to be approximately equal to two (See Table 19), consequently, it was determined that the data did meet the independence of observations assumption (Field, 2009).
Table 19  
*Model Summary*

<table>
<thead>
<tr>
<th>R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
<th>Std. Error of the Estimate</th>
<th>Durbin-Watson</th>
</tr>
</thead>
<tbody>
<tr>
<td>.345</td>
<td>.119</td>
<td>.095</td>
<td>15.642</td>
<td>1.655</td>
</tr>
</tbody>
</table>

*Note.  a. Predictors: (Constant), pretest score  
b. Dependent Variable: gain score.*

Homoscedasticity was verified by creating a scatterplot of the residuals (See Figure 7). Lastly, the residuals were checked for normality using a histogram (See Figure 8) and the Normal P-P Plot (See Figure 9). The standardized residuals appeared to be approximately normally distributed. All assumptions for regression were met therefore the analysis was completed as planned.

Figure 7. Homoscedasticity Scatter Plot
The results of the linear regression established that a student’s previous knowledge of basic addition and subtraction facts could statistically significantly predict gain score on addition of integers tests, $F(1, 38) = 5.00, p < .05$ (See Table 20). Table 20
shows the correlations between variables, the unstandardized regression coefficients (B), the intercept, the standardized regression coefficients (β), the semi partial correlations, R, R², and the adjusted R². On the construct of previous knowledge of addition and subtraction facts as a predictor of integer addition gain score, R for regression was statistically significantly different from zero, F (1,38) = 5.00, p = .032, with R² at .119 (.095 adjusted). This indicates that approximately 11.9% of the variability in gain score can be predicted by previous knowledge of addition and subtraction facts. The regression equation is: gain score = 3.17 + 0.09 x (pretest score). Using G-Power post-hoc power analysis for linear regressions (Adj. R² = .10) a large effect size of r=.563 was observed.

<table>
<thead>
<tr>
<th></th>
<th>Unstandardized</th>
<th>Standardized</th>
<th>95% confidence interval for β</th>
<th>R²</th>
<th>Std. error</th>
<th>β</th>
<th>t</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Model bound</td>
<td></td>
<td></td>
<td></td>
<td>R² adjusted</td>
<td>Std. error</td>
<td>β</td>
<td>t</td>
<td>Sig</td>
</tr>
<tr>
<td>1 (Constant)</td>
<td>--</td>
<td>3.17</td>
<td>7.23</td>
<td>--</td>
<td>.44</td>
<td>.66</td>
<td>-11.48</td>
<td>.01</td>
</tr>
<tr>
<td>Pretest Score</td>
<td>.09</td>
<td>.04</td>
<td>.35</td>
<td>.35</td>
<td>2.24</td>
<td>.03</td>
<td>.01</td>
<td></td>
</tr>
</tbody>
</table>

Note. F (1, 38) = 5.00, p < .05; R = 0.35, R² = 0.10.

Analysis of effects of multiplayer games on engagement and achievement

4a) Does practicing integer facts using multiplayer games with competition differ from practice using other methods in student engagement as measured by flow survey score?
4b) Does practicing integer facts using multiplayer games with competition differ from practice using other methods in student achievement as measured by gain score on pre and posttests of integer addition facts?

This question was eliminated due to the lack of the third practice group that would have allowed for a comparison between single player and multiplayer versions of the game.

**Analysis of gender role in achievement and engagement**

Research question number five had to be rewritten because of the change in practice groups that occurred during the data collection in this study. Originally, question number five asked if there was a difference between the achievement and engagement of girls and boys who played multiplayer versus single player games. The game on the Arcademics website did not allow for the creation of both a multiplayer and a single player group, there was only a multiplayer group. Therefore, the question was reworded to ask, does gender play a role in the achievement and engagement of students practicing addition of integer facts on the computer as evidenced by eGameFlow survey score and gain score?

To analyze if achievement and engagement were statistically significantly different depending on the students’ method of practice two Mann-Whitney U tests were performed. Two single factor ANOVAs were originally to be used to assess this question however, the number of participants was small and the non-parametric test, Mann-Whitney U, was used instead first with the gender of the students (male, female) as the IV and achievement (gain score) as the DV. The second test compared the gender of students (male, female) as the IV and engagement level (flow score) as the DV. These tests were
completed to determine if there were differences between genders as they practiced their addition of integer facts on the computer.

In order to analyze the data with the Mann-Whitney U test the assumptions were verified. First, it was determined that the data did meet the conditions for this test because the data collected contained DVs, gain score and flow score, that were measured at the continuous level. The data also consisted of one IV, gender, consisting of two independent groups. Lastly, all observations were independent (Ho, 2006). The following histograms (See Figures 10 and 11) give a visual display showing that the distributions of the gain scores and flow scores of the two groups did not have the same shapes. This lack of similarity in the two groups meant that the Mann-Whitney U test was used to determine if there were differences between the distributions of the two groups not their medians. Therefore, the differences in distributions, lower/higher scores and mean ranks were analyzed (See Tables 21 and 22).

Figure 10. Distributions of Gain Score by Gender – All Students
Figure 11. Distributions of Flow Score by Gender – All Students

Table 21
Descriptive Statistics of Gain Score by Gender – All Students

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>21</td>
<td>19.10</td>
<td>23.0</td>
<td>72</td>
</tr>
<tr>
<td>Females</td>
<td>14</td>
<td>18.36</td>
<td>13.5</td>
<td>63</td>
</tr>
</tbody>
</table>

Table 22
Descriptive Statistics of Flow Score by Gender – All Students

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>21</td>
<td>84.62</td>
<td>84.0</td>
<td>30</td>
</tr>
<tr>
<td>Females</td>
<td>14</td>
<td>78.93</td>
<td>78.5</td>
<td>29</td>
</tr>
</tbody>
</table>
Table 23  
*Flowscore for Gender by Practice Group*

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th>Females</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard Dev.</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Flashcard</td>
<td>81.40</td>
<td>4.34</td>
<td>80.86</td>
</tr>
<tr>
<td>Game</td>
<td>85.63</td>
<td>6.67</td>
<td>77.00</td>
</tr>
<tr>
<td>Total</td>
<td>84.62</td>
<td>6.37</td>
<td>78.93</td>
</tr>
</tbody>
</table>

A Mann-Whitney U test was then completed and it was determined that there was a lack of statistical significance (U=165.00, p =.547) in the distribution of gain scores by gender indicating that there was not a statistically significant difference in gain score between males and females. However, the second test determined that there was a statistically significant difference (U=87.50, p=.044) in the distribution of flow score across the genders.

Analysis showed that there were differences in flow score (engagement) between the two genders practicing integer math facts on the computer. Distributions of the flow scores for the two genders were not similar, as assessed by visual inspection. The flow score for males (mean rank = 20.83) was statistically significantly higher than for females (mean rank=13.75), U = 87.50,  z = -2.01, p= .04, r= -.340 using an exact sampling distribution for U (Dinneen & Blakesley, 1973) therefore, the null hypothesis was rejected (See Table 24).
Analyzing each group separately resulted in a more detailed analysis with no statistically significant difference in the flashcard group’s flow score (engagement) by gender (See Figures 12 and Table 25). However, analysis did show significant differences in flow score between the two genders practicing integer math facts on the computer using the game condition (See Table 26). Distributions of the flow scores for the two genders were not similar, as assessed by visual inspection (See Figure 13). The flow score for males (mean rank = 13.91) was statistically significantly higher than the females (mean rank=7.64), \( U = 25.50, z = -2.04, p= .04 \).

Figure 12. Distribution of Flow Score by Gender – Flashcard Group
Table 25
*Flow Score Ranks by Gender – Flashcard Group*

<table>
<thead>
<tr>
<th>Gender</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Score</td>
<td>Male</td>
<td>5</td>
<td>6.90</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>7</td>
<td>6.21</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

Figure 13. Distribution of Flow Score by Gender – Game Group

Table 26
*Flow Score Ranks by Gender – Game Group*

<table>
<thead>
<tr>
<th>Gender</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Score</td>
<td>Male</td>
<td>16</td>
<td>13.91</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>7</td>
<td>7.64</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>23</td>
<td></td>
</tr>
</tbody>
</table>

**Qualitative Analysis**

The purpose of the qualitative data in this study was to explore student and teacher perceptions of learning basic integer addition skills using online computer
methods. Learning mathematics is a complex process and using qualitative methods in conjunction with quantitative methods is seen as an effective way to not only know if a particular intervention improves learning but also how and why the results are achieved (Hart, Smith, Swars, & Smith, 2009). Quantitative and qualitative data were independently gathered and analyzed and then merged for interpretation using a convergent parallel design (See Figure 3). The purpose of choosing this design was to gather different but complementary data in order to gain a deeper understanding of the experiences students had while practicing integer facts on the computer (Creswell & Clark, 2007).

**Interviews**

Data were collected through several observations and six interviews (See Table 27) and analyzed using NVIVO. Six students were chosen to be interviewed, three from each method of practice. Students were chosen based on their level of achievement during the intervention, at least one high and one low performing student from each group was chosen.
<table>
<thead>
<tr>
<th>Student</th>
<th>Gender</th>
<th>Method of Practice</th>
<th>Facts Pretest</th>
<th>Integer Pretest</th>
<th>Gain Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>female</td>
<td>flashcards</td>
<td>73</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td>male</td>
<td>flashcards</td>
<td>174</td>
<td>2</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>female</td>
<td>flashcards</td>
<td>87</td>
<td>16</td>
<td>-1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S4</td>
<td>male</td>
<td>game</td>
<td>136</td>
<td>19</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S5</td>
<td>male</td>
<td>game</td>
<td>299</td>
<td>78</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>104</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S6</td>
<td>female</td>
<td>game</td>
<td>173</td>
<td>36</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>63</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td>162.00</td>
<td>24.18</td>
<td>18.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>82.34</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| n=39   | n=39   | n=39               |

Interview data were augmented using the observation data resulting in a rich collection of information. The data were coded and initially entered into ‘nodes’ using the NVIVO program. A pre-defined set of themes, automaticity, engagement and achievement, were derived from the research questions to begin the analysis. Each theme then became a node. As each interview was analyzed, additional themes were identified and nodes were created (See Table 28). In step one of the coding process the nodes were modified as data were extracted from each interview and observation referring to the same theme and a range of themes were created. Continued analysis of the emerging themes was merged with the quantitative data and resulted in a much more complete picture of the impact using flashcards or the Arcademics game for practicing math facts.
had on student learning and automaticity. After completing step two, comparing interviews within the same method of practice, the themes of extending learning and game features were added.

Table 28
Interview Themes

<table>
<thead>
<tr>
<th>Theme</th>
<th>Sample Quote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achievement</td>
<td>S2 “yes, I like it. It made it easier to understand because writing it I have a more difficult time. Writing it I get confused a lot.”</td>
</tr>
<tr>
<td>Automaticity</td>
<td>S4 “Mhm (the game) it helped me learn them (the facts) quicker and better.”</td>
</tr>
<tr>
<td>Competition</td>
<td>S5 “I like the competition. It wasn’t supposed to be a competition but we turned it into a competition.”</td>
</tr>
<tr>
<td>Engagement</td>
<td>S6 “That game was fun. We wasn’t supposed to play with each other but we were up in each other’s game and you know, it was fun trying to beat other people.”</td>
</tr>
<tr>
<td>Extended Learning</td>
<td>S4 “I want to keep doing but with other things besides integers like, power, radicals, and radicands.”</td>
</tr>
<tr>
<td>Game Features</td>
<td>S5 “So every time you win a game you get 80 points if you get first if you get second it’s 60. So you get points like that by winning.”</td>
</tr>
</tbody>
</table>

**Achievement**
Mathematics achievement is defined in this study as the ability to perform mathematical procedures for manipulating representations to find mathematical solutions (Hatano, 1996). Several students referred to how practicing their integer facts on the computer helped them “learn them better”. This was true for students in both the flashcard and the game groups.

**Flashcard Group:**

S1: …because as time went by it was getting easier. The first time I started doing it I didn’t know how to do it but the second time,
then the third time it started getting easier and easier, and now I know how to do it.
I think it’ll help me a lot. Last year I didn’t even know how to do that.

**Interviewer:** So you got better?
**S2:** yes. I like it; it made it easier to understand because writing it I have a more difficult time. Writing it I get confused a lot.

**S3:** Yeah it helped me with a lot of stuff I didn’t know.
**Interviewer:** Did it (practicing adding integer facts on the computer) help you with adding?"
**S3:** Yeah, it helped me a lot.

**Game Group**

**Interviewer:** So do you think practicing the math facts using the game, do you think it helped you learn them?
**S4:** Definitely. Mhm it helped me learn them quicker and better.

The participating teacher believed that both groups enjoyed practicing integer facts on the computer however, the group that played the game, she claimed, learned more.

**Teacher:**

“And even the ones who just did flashcards, they didn’t really like doing the flashcards because they heard about the game, but they still tried, they still tried to improve, and they did improve.”

“They definitely improved on their basic skills. The second group improved more. The ones who played the game improved more than the flashcard group.”

**Automaticity**

Automaticity in this study is an “intentional, goal-directed process that becomes more efficient over time and practice until (it can be done) without conscious guidance”
(Bargh & Chartrand, 1999, p. 463). Again, students in both practice groups believed they were able to answer the integer facts a little faster after the intervention.

**Flashcard Group:**

**Interviewer:** So how do you think it’s (practicing on the computer) going to help you?

**S1:** Cause when we get tested on it, I’ll do it fast but before I just didn’t know how to do them.

**Game Group:**

**Interviewer:** How did they (the math lessons) help you?

**S4:** It helped me learn the answer. But Miss Brown helped me learn it faster so that I could answer the questions quicker.

**Interviewer:** Do you remember how exactly? What did she tell you that helped you? Do you remember anything specific?

**S4:** Just teaching me. I kind of got the answers quickly by playing each time.

**Interviewer:** So do you think practicing the math facts, do you think it helped you learn them?

**S4:** Mhm it helped me learn them quicker and better

**Interviewer:** Do you have any ideas or any ways that you think that we should use the computer in the math class to help kids learn? Do you think that’s good? Bad?

**S4:** In school, definitely cause it helps people learn. Like it helped me learn that quick and answer questions. For me normally, I’m a person that thinks about the question before answering, but in the game you don’t have time to think about it. You have to answer quick, like instantly once you see it.

**Teacher:**

“They’re giving answers faster now and they’re not relying on the calculator. One of them today even said, we don’t need a calculator for that, we can use our brains. (laughs) They definitely improved.”
**Competition**

Competition in this study is defined as two or more people or groups having directly opposing goals where they can either measure themselves against others or measure themselves against an ideal (Ciampa, 2014).

**Game Group:**

**Interviewer:** What was your favorite part of the game?
**S4:** When I went against S7, S8 and S9 at the same time.

**Interviewer:** How is practicing those problems on the computer, how is it the same or different than learning it in class?
**S4:** For me, it’s better because I actually learn faster instead of just sitting in the classroom and looking at the board. With this one I interact and with other people, so we compete to see who’s the smartest.

**Interviewer:** What was your favorite part of the game?
**S5:** I like the competition. It wasn’t supposed to be a competition but we turned it into a competition.

**S6:** That game was fun. We wasn’t supposed to play with each other but we were up in each other’s game and you know, it was fun trying to beat other people.

**Teacher:**

“I was impressed with how enthused the students were. Especially when they got to compete against each other, they really got into it. They were doing it at home, they were doing it at other times.”

“It was the game aspect that they liked doing it so it was you know a little more interesting than just flashcards and they could compete against each other, so they enjoyed it more.”

“I think that it (the competition) really inspired them to get better.”
**Engagement/Flow**

Engagement in this study is defined as feeling involved in an activity (Nkhoma et al., 2014).

**Flashcard Group**

**S1:** One time, I had a 100% on all of them.

**Game Group:**

**Interviewer:** How is practicing those problems on the computer, how is it the same or different than learning it in class?

**S6:** I think it’s better on the computer because it entertains us rather than doing a boring lesson in the classroom. We just get bored and look at it. But yeah, when we in class, people don’t pay attention, they talk and all that. But when we in the computer room and Ms. Brown’s talking to us, everybody is on track and it just better on the computer.

**Interviewer:** How do you think learning or practicing math in the game helps you perform in math class? Does it make math class easier? harder?

**S6:** I think it will.

**Interviewer:** How?

**S6:** Because it’s interesting. And you can get the hang of a game easier than on paper.

**Interviewer:** Do you think the games will make learning math better? Worse?

**S6:** Better, more fun.

**Extending Learning**

The definition of extending learning for this study is practicing facts outside of class.
Flashcard Group:

**Interviewer:** Did you ever practice any of the facts at home, outside of class?  
**S1:** One time, I had a 100% on all of them.

Game Group:

**Interviewer:** Did you ever practice any of the facts at home, outside of class?  
**S4:** mhm a lot.

**S6:** I played the game outside of class.  
**Interviewer:** Where’d you play it at?  
**S6:** At home.  
**Interviewer:** On your computer or your phone?  
**S6:** Both.

Teacher:

“I was impressed with how enthused the students were. Especially when they got to compete against each other, they really got into it. They were doing it at home, they were doing it at other times.”

**Observations**

Observations of students practicing the integer addition facts online were completed by the participating teacher during four computer lab sessions for the three Algebra 1 classes. The researcher observed the practice sessions twice, the first and the last session. Another teacher was able to observe once. A total of seventeen observation sheets were completed throughout the intervention.

The observation protocol that was used asked teachers to observe and quantify the percentage of time students exhibited three behaviors for each class during the practice sessions (See appendix C). The three behaviors were; percent of students that were on
task, percent of student interactions that were centered around content issues, not procedural and student engagement. The values were analyzed and the resulting data are reported in Table 29.

Table 29

<table>
<thead>
<tr>
<th>Student Behavior</th>
<th>Flashcard Group (1 class)</th>
<th>Game Group (2 classes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>On task</td>
<td>86</td>
<td>85</td>
</tr>
<tr>
<td>Interactions</td>
<td>82</td>
<td>82</td>
</tr>
<tr>
<td>Engagement</td>
<td>78</td>
<td>88</td>
</tr>
<tr>
<td>Total # of Observations</td>
<td>5</td>
<td>12</td>
</tr>
</tbody>
</table>

*Note. Maximum score = 100.

Observers were also asked to write down statements students made as well as any notable non-verbal behaviors they witnessed. Observations were coded using the same three step process outlined for the interviews and the following themes and quotes were identified.

**Achievement**

**Observer 1 - Flashcard Group**

“still some confusion when signs are different”

“students asked for help especially if they scored 50% on their first round

“we did some ‘acting’(walking an imaginary number line) then "got it"”

“yes! 100% finally!”

“after their mini lesson much more positive”

**Observer 1 – Game Group**

“students compared results tried to beat classmates times tried to be first”
“all students trying to improve scores and time”
“they love it! they are determined to get better scores”
“They have started to compare speed instead of looking at 1st, 2nd, etc”
“fewer students counting on fingers”

Observer 2 - Flashcard Group
“I'm just not good at this”

Observer 2 - Game Group
"I can't get to 50 seconds"

Automaticity
Observer 1 – Game Group
“Student extremely focused, competitive”
“students are actively playing”
“all students trying to improve scores and time”
“they love it! they are determined to get better scores”
“all students trying to improve scores and time”

Observer 3 – Game Group
“smiles, concentration on the screen”

Competition
Observer 1 – Game Group
“students compared results tried to beat classmates times tried to be first”
"I'm whooping you!"
“someone join my game" "How much time before we have to leave?"
"you got a tie!" "first time ever for a tie!"
"where's your name? I'm gonna get you"

“very competitive”

“students seem to enjoy doing the activities. They were trying to compete against each other.”

“checking each other's scores and times”

“they complained that they couldn't play against each other after 20 minutes of "private" game time they started joining others - more enthusiastic”

“looking to see what friends were getting”

**Observer 1 – Flashcard Group**

“positive toward activity/ comparing results with friends”

**Observer 2 – Game Group**

“"I'm in first place" (singing) - girl reluctant to start but once she started she was singing”

"I win!", "play me", "I'm whooping you", "I came in third", "who is...", "click play now"

"I came in first", "hey, I'm in third ... second..." "who is...", "P won!", "rematch!"

"Oh!" "Can I win please?"

**Observer 3 – Game Group**

“students didn't work quietly. some checked/compared scores”

**Engagement/Flow**

**Observer 1 – Flashcard Group**

“students were positive toward activity/ comparing results with friends”

“students annoyed when their friends are playing and they are waiting to log into computer”
Observer 1 – Game Group

"I'm whooping you!"

"You've never given us math that was so much fun!"

"Students enjoyed playing /one student asked to try (and succeeded) playing on his phone"

"smiles, excitement"

"students were anxious to get to lab - logged in quickly"

"someone join my game" "How much time before we have to leave?"

"even students that say they ‘suck’ at integers are playing"

"you got a tie!" "first time ever for a tie!"

"where's your name? I'm gonna get you"

"students are very competitive"

"how long do we have to do the activity?" "why can't we stay in on the computers"

“students seem to enjoy doing the activities. They were trying to compete against each other.”

“Eyes were focused on the screen. Students remained in their seats.”

"K's winning because he plays all the time on his phone"

males - very enthusiastic, females - less enthusiastic

"How did you get a star?"

Observer 2 – Flashcard Group

“all students on task”

“students logged in and started working”

Student asked, “why does it have to be 100?”

“2 girls reluctant to start”
Observer 2 – Game Group

"I win!" "play me" "I'm whooping you" "I came in third" "who is..." "click play now"

3 girls off task, one student didn't feel well and had head down

"ready to go?" "you've never given us some math to do that was so much fun"

"What time are you guys going to be in the lab tomorrow? I'm not going to be in school" (student wants to play students on his phone when he's not in school)

"Oh!" "Can I win please?"

"Is class almost over? I want to quit playing"

“all students working but with some prompting to get started. Once they started they’re all were working”

Observer 3 – Game Group

“students didn't work quietly. some checked/compared scores”

After themes were identified quotes from observations and interviews were compared for consistency (See Table 30).
Table 30

*Comparison of Information from Interviews and Observations*

<table>
<thead>
<tr>
<th>Theme</th>
<th>Interviews</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achievement</td>
<td>“it started getting easier and easier, and now I know how to do it”</td>
<td>“all students trying to improve scores and time”</td>
</tr>
<tr>
<td>Automaticity</td>
<td>“I’ll do it fast (now) but before I just didn’t know how to do them”</td>
<td>”I came in first&quot; &quot;hey, I'm in third ... second...&quot; &quot;who is...&quot; &quot;P won!&quot; &quot;rematch!&quot;</td>
</tr>
<tr>
<td>Competition</td>
<td>“We wasn’t supposed to play with each other but we were up in each other’s game and you know, it was fun trying to beat other people.”</td>
<td>“students compared results tried to beat classmates times tried to be first”</td>
</tr>
<tr>
<td>Engagement</td>
<td>“it’s better on the computer because it entertains us”</td>
<td>”You've never given us math that was so much fun!”</td>
</tr>
<tr>
<td>Extending Learning</td>
<td>“I played the game outside of class.”</td>
<td>”S4's winning because he plays all the time on his phone”</td>
</tr>
</tbody>
</table>

**Summary of Chapter IV**

Chapter four addressed the aims of the current study and laid out the results of the four research questions. The purpose of this study was to understand the relationship between students’ engagement to practice mathematics integer skills on the computer using a multiplayer race game or flashcards on the computer and their automaticity with integer addition facts. This study looked closely at the impact a multiplayer online integer addition game from the Arcademics website had on students’ desire to practice integer addition facts achieving automaticity as compared to students who used online flashcards.
to practice those same facts. One of the unique factors of this study was the education level of the participating students. This study was completed in an urban high school Algebra 1 class. Most other studies that have examined automaticity with basic mathematics facts have studied students at the elementary school level or students with special needs, not high school students in the general education population.

Two quantitative models were used to analyze the various research questions of this study. The first question that looked at the engagement of students who used different practice methods on the computer to practice integer addition facts utilized the Mann-Whitney U test. The second question that explored the method of practice students used on the computer and its effect on automaticity was also analyzed using the Mann-Whitney U test. The third question which looked at whether or not the recall of integer addition facts was mediated by whether or not students had mastered their basic addition and subtraction facts was analyzed with a linear regression. Lastly, the fourth question looked at the role gender plays in the engagement and achievement of students who practice their integer addition facts on the computer and was analyzed with two separate Mann-Whitney U tests, one for gender and engagement and the other for gender and achievement.

Qualitative data were collected from student observations and students and teacher interviews. That data were collected using a convergent parallel design and analyzed using the constant comparative method.

The quantitative and qualitative findings of this study indicate inconsistent results similar to other research conducted on using games for instruction (Ke, 2009; Kebritchi et
al., 2010; Randel & Morris, 1992). The quantitative results indicated no statistical significance that practicing integer addition facts using a multiplayer computer race game on the computer promoted a higher level of automaticity or engagement than students who practiced their integer addition facts with flashcards on the computer. However, qualitative findings from student observations and student and teacher interviews were able to be more sensitive to the context of the study suggesting the opposite is true. Gender was not found to play a significant role in the recall of integer addition facts using either method of practice however, gender was found to be statistically significant in flow score for students that used the Arcademics game to practice their integer addition facts.

Chapter five speaks to these findings and implications for future practices and research.
CHAPTER V

DISCUSSION

Summary of the Study

Findings from this study indicated no statistically significant difference in flow score (engagement) by method of practice (flashcards, game). Students in the game group had higher gain scores than the students in the flashcard group, however, this difference was not found to be statistically significant. Automaticity of integer addition facts was found to be mediated by the extent to which students had previously mastered their basic addition and subtraction facts. This study did not find any statistically significant difference between a students’ gender and their automaticity with integer addition facts as evidenced by their gain score, however, there was a statistically significant difference of flow score by gender. Qualitative findings suggest students in this study had a very positive and mathematically enriching experience increasing both their automaticity of integer addition skills and their engagement to practice those skills.
Significance of Results

The results of this study are significant because online multiplayer math skills games from the Arcademics website were found to be an important tool to motivate students to spend the time necessary to achieve automaticity with basic integer addition facts.

While the results of the quantitative analysis using the Mann-Whitney U test (\(U=116.00, p = .461\)) did not find a statistically significant difference in engagement between students that practiced their integer facts on the computer using flashcards and those that practiced using a multiplayer game on the Arcademics website, the qualitative data from interviews and observations described something different. The teacher commented several times that she did observe a difference in the engagement level between the two groups.

“I was impressed with how enthused the students were. Especially when they got to compete against each other, they really got into it.”

“It was the game aspect that they liked doing it so it was, you know, a little more interesting than just flashcards and they could compete against each other, so they enjoyed it more.”

Students’ comments documented by teachers on the observation protocol (See Appendix C) also demonstrated that practicing basic facts using the game was more engaging than practicing integer facts using flashcards on the computer. During the practice sessions the students that used the flashcards were only quoted once during all four practice sessions making a comment that demonstrated excitement, “yes, 100%, finally!” The students that practiced using the multiplayer game, however, made three to four comments daily in each class demonstrating excitement over getting correct answers.
or beating someone else’s time in the game. Some statements were, “I win!”, “Play me!”, "I came in first!", and "I'm in first place" (singing). By the end of the intervention a total of 98 comments were recorded by the teachers during the game group’s practice sessions while only 15 comments were recorded for the flashcard group. Although the game group included one more class than the flashcard group the number of comments written by the teachers was more than six times greater. The classroom teacher’s comments during the multiplayer computer game practice sessions also indicated students were engaged, “They love it! They are determined to get better scores.”, “(students are) actively playing”, and “They have started to compare speed (rate) instead of looking at 1st, 2nd, etc.”

While observing practice sessions teachers also indicated on the observation protocol (Appendix C) the level of engagement they witnessed during practice sessions using a linear scale. The scale asked teachers to rate the level of engagement they witnessed in the computer lab from a low of ‘students are hesitant to enter into the activity’ to the high value of ‘students actively and enthusiastically participate in the activity’. Analysis of this data indicated that the flashcard group (M=78) had a lower average engagement level than the game group (M=88) throughout the intervention (See Table 29).

The qualitative results of this study are consistent with previous research concluding that allowing students to practice mathematics skills using multiplayer games can increase their engagement and motivation to practice. In a research study conducted with fifth grade students playing arithmetic games on the computer researchers found an increase in students’ engagement and achievement after playing games (Huang & Ke,
Another study with seventh grade boys concluded that the most common cognitive-affective state the boys were in while playing arithmetic games on the computer was engagement (Rodrigo, 2011). More studies by McDonald and Hannafin (2003), Rosas et al. (2003), Ke and Grabowski (2007), Ke (2008), Huang and Ke (2009) Der Ching and Yi Fang (2010), Nejem and Muhanna (2013), and Ciampa (2014) found that playing games has a positive effect on elementary level students learning motivation. The researcher identified only a few studies that were conducted with high school students (Groff, Howells, & Cranmer, 2010; Kebritchi et al., 2008; Shirvani, 2010) with conflicting results. Groff et al. (2010) wrote a report on the uses of educational games in Scottish primary and secondary schools. While researchers concluded that game-based approaches were highly motivational and engaged students in learning, only eight of the nineteen participating schools were secondary schools. Also, the participating secondary schools were not included in the entire study because they were found to lack integration of game-based learning approaches into instruction. Kebritchi et al. (2008) conducted a mixed methods study which found no statistically significant difference in the engagement between the control and experimental groups that played a mathematics game, DimensionM in their Pre-Algebra and Algebra classrooms. However, the interviews researchers conducted with teachers and students identified game-play as a positive factor on student motivation. Lastly, Shirvani (2010) found that Algebra 1 students that practiced algebra skills using computer assisted software had significantly higher positive attitudes towards mathematics after their intervention.

While the quantitative results of students’ integer addition fact recall by method of practice did not rise to a significant level, the game group’s mean gain score was larger
(M=45.37) than the flashcard group’s mean gain score (M=36.08) (See Figure 5). These results are consistent with other studies that suggest neither using flashcards to learn basic facts (Henry & Brown, 2008) nor using more traditional skill practice on the computer (Wong & Evans, 2007) contribute dramatically to automaticity with basic facts. However, when using games on the computer to practice those skills, automaticity can effectively be increased (Rice, 2007). The non-significant result in this study may have occurred because of the low number of practice sessions that students participated in. The study originally called for eight practice sessions interspersed throughout four weeks and only half of those sessions were actually completed during two weeks of the intervention. Another contributing factor may have been the small number of students that completed all aspects of the intervention.

Qualitative evidence collected during the study suggests that students in the game group demonstrated the most cited conditions necessary for automaticity, being motivated to spend the time necessary to improve their performance while repeatedly performing the same task (Ericsson, Krampe, & Tesch-Römer, 1993). The teacher also noted another key aspect of achieving fluency with basic skills, the diminishing use of a counting strategy (Hecht, 2002; Price et al., 2013; Woodward, 2004). The teacher noticed that as students played the game more they used their fingers less making the comment on her observation sheet: “fewer students counting on fingers”.

Competition, a major part of the Arcademics multiplayer game, has also been identified in the research as a key factor that increases student automaticity and achievement when students are engaged in fluency tasks (Lam, Yim, Law, & Cheung, 2001). The teacher noticed that students were trying to do better even if they didn’t know
their integer addition facts very well before the start of the study; “even students that say they ‘suck’ at integers are playing”. The teacher also realized the importance of competition and its effect on student achievement in this study. When asked what she would change in the study she replied:

“I don’t know, I think the (integer addition) lessons helped them enough. I would do just the game more than the flashcards. Maybe use the flashcards as a pre-assessment test so that they didn’t have to use paper. If they prefer that and then just play the game and let everybody compete against each other. I think that really inspired them to get better. They’re still talking about who got the most points.”

The experiences of the students and the teacher are consistent with the literature stating that participating in competition inherent in computerized mathematics games have been shown to increase student achievement as well as engagement (Chang et al., 2008; Faye et al., 2012; Federation of American Scientists, 2005; Kebritchi et al., 2008; Laffey et al., 2003; Lam et al., 2001; Nejem & Muhanna, 2013; Shirvani, 2010). While some forms of competition are seen as a barrier to motivation and achievement (Kohn, 1986), the indirect competition afforded by the Arcademics game helped students experience practicing integer addition facts as a challenging activity. Consistent with previous research, challenging activities, or the race in this instance, along with the immediate feedback provided by the game increased student focus and motivation to practice their math facts (Ciampa, 2014; Hays, 2005; Hogle, 1996).

The results from this study also confirm other studies’ findings that previous knowledge of, and automaticity with basic arithmetic facts is a significant predictor of mathematics performance (Price et al., 2013; Rutherford-Becker & Vanderwood, 2009; Sinclair, 2005; Stickney et al., 2012). Students must achieve automaticity with their basic
addition and subtraction facts during elementary and/or middle school in order to be successful in high school mathematics. Price et al. (2013) recent study using neuroimaging data was the first to demonstrate neurologically the connection between the brain mechanisms involved with basic arithmetic calculations and math achievement at the end of high school. Achieving automaticity with basic facts was found to be an important indicator for future mathematical success.

The qualitative findings of this study also support these quantitative findings. Student S5 that received the highest facts pretest score, gain score and flow score (See Table 27) commented in his interview that playing the games on the computer was easy:

“It was easy for me because I had practice when I wasn’t in Ohio. I was in California, I had practice. So teachers would give us timed sheets with integers, multiplication, division, addition, and subtraction. So I already knew all of that.”

If, however, students do not achieve automaticity before reaching high school they must be given the opportunity to practice and learn their basic facts achieving automaticity in order to be successful in higher level mathematics classes. Games on the Arcademics website can motivate students to spend the time necessary to achieve automaticity.

This study found a statistically significant difference ($U=87.50, p=.044$) in the distribution of flow score (engagement) across the genders in the group of students that used games to practice their integer addition facts. These results are consistent with previous research with games. Boys have consistently been found to find the competition in games more engaging than girls (Chou & Tsai, 2007; Kickmeier-Rust & Albert, 2013).
This finding was also noticed by the classroom teacher that noted in her observation remarks: “males - very enthusiastic; females - less enthusiastic”.

A female student however, during her interview made some remarks that contradict these findings. S6, a female, made several remarks which indicated that she was very engaged with the game and even attempted to download it to her phone.

S5: “That game was fun. We wasn’t supposed to play with each other but we were up in each others game and you know, it was fun trying to beat other people.”

“I think it’s better on the computer because it entertains us rather than doing a boring lesson in the classroom. We just get bored and look at it. But yeah, when we in class, people don’t pay attention, they talk and all that. But when we in the computer room and Ms. Brown’s talking to us, everybody is on track and it just better on the computer.”

S5: “I played the game outside of class.”
Researcher: “Where’d you play it at?”
S5: “At home.”
Researcher: “On your computer or your phone?”
S5: “Both.”
Researcher: “Did you download it on your phone?”
S5: “Nope, it don’t got it on windows phone but I had to go online to play it. But I liked that game.”

The peer researcher that also coded the interviews stated that he first thought S6 was a male student because of the nature of her comments.

Applications for Future Practice
The overarching factor that engaged students in this study and increased their automaticity with integer facts was competition. The competitive multiplayer games from the Arcademics website engaged students by focusing their attention on the skills needed to compete in the game successfully. This finding is consistent with previous research that found that computer games engage students by eliminating boredom (Lawrence, 2004; Nejem & Muhanna, 2013). Students agreed that the game engaged them by making
statements in interviews indicating learning facts are “better on the computer (with games) because it entertains us”.

The Arcademics games achieve this collaborative form of positive competition by first allowing students to choose their opponents. Once students finish a race the website then focuses their attention on their progress. A chart is displayed with the rate at which they answered the questions and the specific facts that they answered incorrectly. This feedback gives students information on how they can do better in the next race. The game on the Arcademics website motivates students to improve their skills by causing all students to mutually strive for excellence using the multiplayer option. This is also a feature that researchers have found to increase the effectiveness of educational games, getting players to focus attention on the learning process, pushing each other to improve their skills not just celebrating the results of one single race in the competition (Bredemeier & Shields, 2010; Cantador & Conde, 2010; Lalonde, 2013).

Online mathematics skills games are an effective practice method to increase student recall of basic arithmetic facts because they engage students to spend the time necessary to achieve automaticity. Students need to be proficient with basic facts to have the foundation and confidence to be successful in higher level mathematics (Price et al., 2013). Online multiplayer skills games can be an important tool to motivate students to spend the time necessary to achieve automaticity and improve their performance in upper level mathematics courses. These games need to be introduced to students that are struggling with their math facts and students should be given multiple opportunities to play the games during their early high school years in order to promote academic achievement.
Recommendation for Future Studies

Based on the limitations of the current study, it is recommended that follow up studies be considered utilizing a larger sample size and using a game that can be played as both a single player and multiplayer game. This researcher believes the fact that students were able to play against other students in the class greatly influenced their desire to practice their skills while playing the game. This hypothesis could not be verified because a single player version of the game was not included in this study. Future studies should also try to have a classroom set of computers or Internet devices dedicated only to the study so that practice time is not dictated by unanticipated events in the school or district that can limit the amount of practice time.

A study is also recommended that would identify and have students practice the integer addition facts that were answered with the worst accuracy and response time while playing the game. Of the eight worst facts by accuracy and response time by the game group in this study there was one fact that was in both groups (See Table 31). Another interesting outcome of this study can be seen in the table of facts with the best accuracy for the game group (See Table 31). All of the facts answered were either adding a number with zero or addition of two negative numbers.
Table 31
*Integer Addition Fact Accuracy Tables*

<table>
<thead>
<tr>
<th>Item</th>
<th>Worst Accuracy</th>
<th>Item</th>
<th>Worst Response Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>-3+5</td>
<td>56%</td>
<td>-7+8</td>
<td>3.15 sec</td>
</tr>
<tr>
<td>-3+10</td>
<td>67%</td>
<td>-9+7</td>
<td>3.08 sec</td>
</tr>
<tr>
<td>-7+9</td>
<td>68%</td>
<td>-8+7</td>
<td>3.05 sec</td>
</tr>
<tr>
<td>-5+7</td>
<td>70%</td>
<td>-5+9</td>
<td>3.05 sec</td>
</tr>
<tr>
<td>-3+5</td>
<td>71%</td>
<td>-8+6</td>
<td>2.98 sec</td>
</tr>
<tr>
<td>-8+10</td>
<td>72%</td>
<td>-7+4</td>
<td>2.97 sec</td>
</tr>
<tr>
<td>-4+5</td>
<td>73%</td>
<td>-7+9</td>
<td>2.96 sec</td>
</tr>
<tr>
<td>-5+3</td>
<td>74%</td>
<td>-5+8</td>
<td>2.95 sec</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Best Accuracy</th>
<th>Item</th>
<th>Best Response Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10+-7</td>
<td>96%</td>
<td>-2+-2</td>
<td>0.98 sec</td>
</tr>
<tr>
<td>-4+-2</td>
<td>96%</td>
<td>-3+0</td>
<td>1.04 sec</td>
</tr>
<tr>
<td>-4+-10</td>
<td>96%</td>
<td>-3+-3</td>
<td>1.24 sec</td>
</tr>
<tr>
<td>-4+-1</td>
<td>96%</td>
<td>-4+0</td>
<td>1.29 sec</td>
</tr>
<tr>
<td>-8+0</td>
<td>96%</td>
<td>-3+-7</td>
<td>1.34 sec</td>
</tr>
<tr>
<td>-9+0</td>
<td>95%</td>
<td>3+3</td>
<td>1.34 sec</td>
</tr>
<tr>
<td>-10+-6</td>
<td>95%</td>
<td>-2+-10</td>
<td>1.35 sec</td>
</tr>
<tr>
<td>-7+0</td>
<td>95%</td>
<td>-2+-5</td>
<td>1.37 sec</td>
</tr>
</tbody>
</table>

This study found conflicting results according to gender. While much of the data suggests a significant difference in engagement by gender, the interview with S6 leaves some doubt suggesting girls may be motivated to practice using mathematics skills games. A more in depth study as to how multiplayer games on the Arcademics website affect boys’ as well as girls’ mathematical skills knowledge and achievement would add important data to this area of study.
Lastly, another study that is recommended is to look at the relationship between high school students’ automaticity with basic facts as they enter high school and their achievement during their high school mathematics classes as evidenced by their GPA, mathematics courses taken and/or standardized test scores. This study could provide evidence that using mathematics skills games can be an appropriate pedagogical method to increase high school students’ automaticity with basic math facts as well as increase their achievement and/or participation in higher level mathematics courses.

Study Delimitations
The findings of this study are generalized to low-income, urban high school adolescent populations using the integer addition game on the Arcademics website.

Study Limitations
While a great deal of time and effort went into designing this study to make it a thorough investigation of online skills games there are several limitations to its findings. First, the study was limited by the fact that the researcher did not have complete control over the game that was used for students to practice their integer addition facts. The Arcademics website, like any good website, is constantly being upgraded and the fact that the researcher is not affiliated with the website creators in any way did not afford advance knowledge of planned changes in the game and how those changes would impact this study. In the short span of a couple of months the website went from having students follow a specific procedure to join a multiplayer game to automatically placing players in multiplayer games. The researcher contacted a representative of the website who gave a different strategy to have students play against the computer but once students experienced the game playing against other students they refused to play the
single player version. This change caused the elimination of one of the treatment groups for this study, the single player version of the game.

A second limitation was the lack of computer labs available in the school during the time of the study. The principal gave permission for this study to take place in the school’s computer labs but the MAP test schedule was not available when planning for the study took place. Therefore, during the study all three computer labs in the school were unavailable for student use. The entire school of over 1000 students had to share the computers in the media center. This fact along with another previously unscheduled end of course Algebra 1 exam cut the studies planned eight practice sessions to only four. Although an increase in gain score was achieved by the multiplayer game group in only four practice sessions much more could have been done with the originally planned eight practice sessions.

A third limitation was the sample size of the study. Student attendance in the ninth grade which was consistently high throughout the year (>90%) dropped at the time of the study, just before spring break. This fact and the inability to have three groups made the sample size small and very uneven in the two remaining groups.

Finally, results when using a survey instrument are subject to the known reliability and validity of that instrument. Although some information about the instrument in regard to reliability and validity was known, the survey used in this study was modified and may have limitations in measuring what it was intended to measure.

In spite of these limitations the researcher is confident that the findings of this study are valid with the group that participated. There are observations and interviews
with the students that help clarify the findings and fill in the blanks. High school students get excited and practice more when they can practice essential mathematics skills using an online multiplayer game.

**Summary of Chapter V**

In summary, the current study sought to look closely at the effects playing online skills games had on the automaticity and engagement of high school students as they practiced adding integers using a game on the Arcademics website. Overall, findings of this study are consistent with current research that is conflicted. Basic mathematics multiplayer games were found to be engaging during the qualitative analysis but did not rise to a level of significance in the quantitative analysis. Students can be motivated to practice their basic arithmetic facts to automaticity raising their level of knowledge even when they reach high school age and this automaticity is important for their ultimate success in mathematics.
REFERENCES


Bredemeier, B. L., & Shields, D. L. (2010). Competition was Kohn RIGHT? Kohn was right about one type of competition. But that's not the whole story. *Phi Delta Kappan, 91*, 62+.


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APPENDIX
Appendix A - Arcademics Game

Arcademics Report
Appendix B- Basic facts tests, Integer Pre and Post Test Fact Sheet

Integer Addition Worksheet

Complete the following problems as fast as you can.
Please note that there are more problems listed than you will be able to complete in the time allotted.

1. 0 + 6 =
2. -9 + -1 =
3. -8 + 2 =
4. -5 + 1 =

5. 4 + 5 =
6. 1 + (-3) =
7. 2 + (-1) =
8. 3 + (-2) =

9. 8 + (-8) =
10. -9 + 4 =
11. 6 + (-1) =
12. -7 + (-7) =

13. -2 + (-6) =
14. 8 + (-2) =
15. 0 + 6 =
16. 8 + (-9) =

17. -6 + 6 =
18. 2 + 9 =
19. 7 + 1 =
20. -7 + (-7) =

21. -3 + (-1) =
22. -2 + (-5) =
23. 3 + 9 =
24. -2 + (-6) =

25. -3 + (-6) =
26. -8 + 5 =
27. -3 + 8 =
28. 1 + (-8) =

29. 5 + 2 =
30. 5 + (-7) =
31. -3 + 0 =
32. -8 + (-3) =

33. -3 + 0 =
34. -7 + (-8) =
35. -1 + 6 =
36. -2 + (-9) =

37. -1 + 5 =
38. -3 + (-1) =
39. 8 + (-6) =
40. 2 + (-4) =

41. 1 + 2 =
42. 2 + 8 =
43. 0 + (-9) =
44. -7 + (-4) =

45. 8 + 3 =
46. 5 + 9 =
47. -5 + 2 =
48. 0 + (-4) =

49. 5 + 1 =
50. -8 + (-3) =
51. 7 + (-6) =
52. -6 + 6 =

53. -3 + (-9) =
54. -1 + (-4) =
55. -6 + 4 =
56. 8 + (-5) =

57. -2 + (-8) =
58. -5 + 3 =
59. 9 + 6 =
60. -7 + 7 =

61. -5 + 6 =
62. 3 + (-5) =
63. -4 + (-1) =
64. 8 + 7 =

65. 5 + 4 =
66. -6 + 7 =
67. -8 + (-4) =
68. 6 + (-8) =

69. -1 + (-2) =
70. 9 + (-5) =
71. -6 + 7 =
72. -3 + 5 =

73. -3 + (-6) =
74. 3 + (-2) =
75. -9 + 6 =
76. 1 + (-9) =

77. -4 + (-4) =
78. 9 + (-8) =
79. -3 + (-2) =
80. 0 + 5 =

81. -3 + 2 =
82. 2 + 4 =
83. 2 + (-4) =
84. 1 + (-8) =

85. -5 + 9 =
86. -5 + (-6) =
87. 2 + (-2) =
88. 8 + 9 =

125
<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>89.</td>
<td>-6 + 7 =</td>
<td>90.</td>
</tr>
<tr>
<td>93.</td>
<td>-4 + (-7) =</td>
<td>94.</td>
</tr>
<tr>
<td>97.</td>
<td>8 + (-7) =</td>
<td>98.</td>
</tr>
<tr>
<td>101.</td>
<td>6 + (-4) =</td>
<td>102.</td>
</tr>
<tr>
<td>105.</td>
<td>6 + (-1) =</td>
<td>106.</td>
</tr>
<tr>
<td>109.</td>
<td>-7 + (-6) =</td>
<td>110.</td>
</tr>
<tr>
<td>113.</td>
<td>-1 + 8 =</td>
<td>114.</td>
</tr>
<tr>
<td>117.</td>
<td>7 + (-8) =</td>
<td>118.</td>
</tr>
<tr>
<td>121.</td>
<td>9 + 5 =</td>
<td>122.</td>
</tr>
<tr>
<td>125.</td>
<td>6 + 3 =</td>
<td>126.</td>
</tr>
<tr>
<td>129.</td>
<td>8 + (-1) =</td>
<td>130.</td>
</tr>
<tr>
<td>133.</td>
<td>2 + (-3) =</td>
<td>134.</td>
</tr>
<tr>
<td>137.</td>
<td>6 + 5 =</td>
<td>138.</td>
</tr>
<tr>
<td>141.</td>
<td>-9 + (-2) =</td>
<td>142.</td>
</tr>
<tr>
<td>145.</td>
<td>0 + (-3) =</td>
<td>146.</td>
</tr>
<tr>
<td>149.</td>
<td>-3 + 3 =</td>
<td>150.</td>
</tr>
</tbody>
</table>
Addition facts pretest

Math Worksheet

Complete the following problems as fast as you can.
Please note that there are more problems listed than you will be able to complete in the time allotted.

1. \(3 + 3 = \)
2. \(8 + 5 = \)
3. \(9 + 6 = \)
4. \(6 + 9 = \)
5. \(0 + 0 = \)
6. \(1 + 0 = \)
7. \(2 + 2 = \)
8. \(2 + 3 = \)
9. \(0 + 0 = \)
10. \(4 + 6 = \)
11. \(5 + 6 = \)
12. \(6 + 3 = \)
13. \(4 + 4 = \)
14. \(0 + 0 = \)
15. \(5 + 1 = \)
16. \(5 + 6 = \)
17. \(0 + 8 = \)
18. \(6 + 5 = \)
19. \(6 + 5 = \)
20. \(9 + 8 = \)
21. \(7 + 2 = \)
22. \(7 + 1 = \)
23. \(7 + 7 = \)
24. \(4 + 0 = \)
25. \(2 + 1 = \)
26. \(2 + 3 = \)
27. \(1 + 2 = \)
28. \(6 + 8 = \)
29. \(5 + 4 = \)
30. \(5 + 5 = \)
31. \(6 + 0 = \)
32. \(8 + 1 = \)
33. \(2 + 6 = \)
34. \(9 + 5 = \)
35. \(7 + 1 = \)
36. \(6 + 3 = \)
37. \(5 + 7 = \)
38. \(8 + 3 = \)
39. \(5 + 8 = \)
40. \(9 + 6 = \)
41. \(0 + 6 = \)
42. \(9 + 6 = \)
43. \(8 + 3 = \)
44. \(2 + 5 = \)
45. \(1 + 8 = \)
46. \(2 + 7 = \)
47. \(4 + 6 = \)
48. \(1 + 8 = \)
49. \(9 + 4 = \)
50. \(9 + 2 = \)
51. \(1 + 2 = \)
52. \(9 + 6 = \)
53. \(7 + 0 = \)
54. \(6 + 9 = \)
55. \(0 + 7 = \)
56. \(9 + 7 = \)
57. \(0 + 5 = \)
58. \(9 + 7 = \)
59. \(4 + 0 = \)
60. \(0 + 3 = \)
61. \(8 + 0 = \)
62. \(4 + 8 = \)
63. \(2 + 2 = \)
64. \(2 + 6 = \)
65. \(6 + 1 = \)
66. \(2 + 8 = \)
67. \(7 + 3 = \)
68. \(0 + 5 = \)
69. \(0 + 1 = \)
70. \(0 + 8 = \)
71. \(9 + 6 = \)
72. \(5 + 2 = \)
<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>73.</td>
<td>$3 + 5 =$</td>
<td>74.</td>
<td>$0 + 3 =$</td>
<td>75.</td>
<td>$3 + 6 =$</td>
<td>76.</td>
</tr>
<tr>
<td>77.</td>
<td>$5 + 1 =$</td>
<td>78.</td>
<td>$2 + 2 =$</td>
<td>79.</td>
<td>$1 + 1 =$</td>
<td>80.</td>
</tr>
<tr>
<td>81.</td>
<td>$4 + 7 =$</td>
<td>82.</td>
<td>$1 + 7 =$</td>
<td>83.</td>
<td>$5 + 2 =$</td>
<td>84.</td>
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<tr>
<td>85.</td>
<td>$9 + 9 =$</td>
<td>86.</td>
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<td>87.</td>
<td>$3 + 3 =$</td>
<td>88.</td>
</tr>
<tr>
<td>89.</td>
<td>$4 + 4 =$</td>
<td>90.</td>
<td>$6 + 3 =$</td>
<td>91.</td>
<td>$9 + 9 =$</td>
<td>92.</td>
</tr>
<tr>
<td>93.</td>
<td>$1 + 4 =$</td>
<td>94.</td>
<td>$2 + 3 =$</td>
<td>95.</td>
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<td>96.</td>
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<tr>
<td>97.</td>
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<td>$1 + 4 =$</td>
<td>99.</td>
<td>$6 + 6 =$</td>
<td>100.</td>
</tr>
<tr>
<td>101.</td>
<td>$1 + 0 =$</td>
<td>102.</td>
<td>$8 + 5 =$</td>
<td>103.</td>
<td>$9 + 7 =$</td>
<td>104.</td>
</tr>
<tr>
<td>105.</td>
<td>$8 + 1 =$</td>
<td>106.</td>
<td>$9 + 6 =$</td>
<td>107.</td>
<td>$7 + 4 =$</td>
<td>108.</td>
</tr>
<tr>
<td>109.</td>
<td>$2 + 3 =$</td>
<td>110.</td>
<td>$5 + 2 =$</td>
<td>111.</td>
<td>$9 + 8 =$</td>
<td>112.</td>
</tr>
<tr>
<td>113.</td>
<td>$9 + 3 =$</td>
<td>114.</td>
<td>$9 + 3 =$</td>
<td>115.</td>
<td>$9 + 9 =$</td>
<td>116.</td>
</tr>
<tr>
<td>117.</td>
<td>$3 + 6 =$</td>
<td>118.</td>
<td>$7 + 2 =$</td>
<td>119.</td>
<td>$2 + 6 =$</td>
<td>120.</td>
</tr>
<tr>
<td>121.</td>
<td>$0 + 2 =$</td>
<td>122.</td>
<td>$8 + 2 =$</td>
<td>123.</td>
<td>$1 + 0 =$</td>
<td>124.</td>
</tr>
<tr>
<td>125.</td>
<td>$1 + 7 =$</td>
<td>126.</td>
<td>$3 + 9 =$</td>
<td>127.</td>
<td>$7 + 7 =$</td>
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</tr>
<tr>
<td>129.</td>
<td>$0 + 3 =$</td>
<td>130.</td>
<td>$3 + 8 =$</td>
<td>131.</td>
<td>$1 + 7 =$</td>
<td>132.</td>
</tr>
<tr>
<td>133.</td>
<td>$9 + 3 =$</td>
<td>134.</td>
<td>$9 + 1 =$</td>
<td>135.</td>
<td>$0 + 7 =$</td>
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<td>$6 + 2 =$</td>
<td>139.</td>
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</tr>
<tr>
<td>141.</td>
<td>$6 + 9 =$</td>
<td>142.</td>
<td>$0 + 4 =$</td>
<td>143.</td>
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<td>144.</td>
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<tr>
<td>145.</td>
<td>$7 + 1 =$</td>
<td>146.</td>
<td>$0 + 5 =$</td>
<td>147.</td>
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</tr>
<tr>
<td>149.</td>
<td>$8 + 5 =$</td>
<td>150.</td>
<td>$3 + 3 =$</td>
<td></td>
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</tr>
</tbody>
</table>
Subtraction facts pretest

Complete the following problems as fast as you can.
Please note that there are more problems listed than you will be able to complete in the time allotted.

1. 15 - 8 =  
2. 4 - 0 =  
3. 11 - 4 =  
4. 12 - 7 =  
5. 14 - 9 =  
6. 3 - 3 =  
7. 12 - 9 =  
8. 6 - 6 =  
9. 0 - 0 =  
10. 12 - 8 =  
11. 10 - 4 =  
12. 9 - 9 =  
13. 3 - 0 =  
14. 12 - 8 =  
15. 5 - 2 =  
16. 8 - 1 =  
17. 17 - 9 =  
18. 11 - 4 =  
19. 6 - 1 =  
20. 10 - 8 =  
21. 6 - 0 =  
22. 8 - 3 =  
23. 12 - 8 =  
24. 10 - 6 =  
25. 6 - 4 =  
26. 13 - 6 =  
27. 4 - 2 =  
28. 8 - 4 =  
29. 9 - 1 =  
30. 2 - 2 =  
31. 9 - 6 =  
32. 10 - 5 =  
33. 13 - 6 =  
34. 11 - 4 =  
35. 7 - 7 =  
36. 6 - 0 =  
37. 8 - 8 =  
38. 4 - 0 =  
39. 17 - 9 =  
40. 4 - 2 =  
41. 13 - 7 =  
42. 14 - 7 =  
43. 2 - 1 =  
44. 7 - 7 =  
45. 6 - 5 =  
46. 18 - 9 =  
47. 2 - 2 =  
48. 6 - 3 =  
49. 8 - 5 =  
50. 12 - 6 =  
51. 14 - 8 =  
52. 10 - 6 =  
53. 9 - 9 =  
54. 9 - 1 =  
55. 14 - 8 =  
56. 5 - 5 =  
57. 16 - 8 =  
58. 18 - 9 =  
59. 16 - 9 =  
60. 13 - 7 =  
61. 8 - 8 =  
62. 4 - 0 =  
63. 12 - 9 =  
64. 7 - 7 =  
65. 15 - 7 =  
66. 8 - 8 =  
67. 15 - 9 =  
68. 4 - 3 =  
69. 9 - 8 =  
70. 8 - 2 =  
71. 8 - 5 =  
72. 12 - 3 =  
73. 13 - 9 =  
74. 5 - 5 =  
75. 13 - 7 =  
76. 13 - 6 =  
77. 5 - 2 =  
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79. 4 - 0 =  
80. 11 - 8 =
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<td>148.</td>
<td>8 - 6 =</td>
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Appendix C- Observation Protocol

PRE OBSERVATION DATA

Teacher/Observer ___________________ Date ___________ Computer Lab Session week# ___

Class period or time of class ________________

Class composition

<table>
<thead>
<tr>
<th>Students #</th>
<th>Absent</th>
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<tr>
<td>Females</td>
<td>______</td>
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<tr>
<td>Males</td>
<td>______</td>
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<tr>
<td>Totals:</td>
<td>______</td>
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OPERATIONAL DEFINITIONS FOR STUDENT BEHAVIORS

The scales include undesirable student behaviors on the left and desirable student behaviors on the right. For each indicate the degree or percentage of desirable and undesirable behavior.

- most students off task = 50% or more of the students are not on task for at least 50% of the class period.
- most students on task = 90 - 100% of students are on task for the entire class period 90-100% of the time.
- students interact with each other around procedural issues = they are asking one another such things as, “What did he say?” or, “Do we answer questions 5 and 6 or just 6?”
- students interact with each other around content issues = students are actively interacting around the lesson or topic. In some cases students may seem off topic because they are talking about a related issue. Even if the issue is not directly related it should be considered as interacting around content issues.
- students are hesitant to enter into the activity = students do not actively engage in activity and are only sitting at the computer. You may see body language that corroborates their reluctance
- students actively and enthusiastically participate in the activity = during the activity, students are enthusiastically participating in the practice session. During an activity, students are actively engaged.
**Student Behaviors:**

most students on task

off task on task

students interact with

students interact with

each other around

each other around

non-academic or content

procedural issues issues

students are

students actively and

hesitant to enter enthusiastically

into the participate in the

activity activity

Please be sure not to include any student names.

1 - Overall, what happened during the classroom observation?

2 - What didn’t happen (e.g., students didn’t grasp the idea of the activity)?

3 – Statements you heard students saying as they completed the activity on the computer:

4 - Characterize students and their attitudes toward the activity on the computer:

5 - Notable non-verbal behavior:

6 - Surprises/concerns, especially related to the activity:
Appendix D- Interview Questions

Student Interview Questions

1. Which version of practice did you do?
2. If you played the game, did you win any of the games? Why or why not?
3. How did you do? What was your score?
4. What part of practicing math facts on the computer did you like?
5. What part did you not like?
6. How did you answer the questions on the computer? Did you have all the facts memorized or did you use a different strategy to answer the question?
7. Did the math lessons in class help you get better at the game/integer facts?
8. Did you practice the facts outside of class?
9. Did practicing on the computer help you learn the math facts? If so, how did it help you? If not, why not?
10. How are practicing math skills on the computer the same or different from learning them in the classroom?
11. How do you think learning or practicing math in the game helps you perform in math class? Does it make math class easier? harder?
12. Describe how you use the math you learned/practiced in this study in your classes? Probe with - do the games make learning during math class better, worse, easier, harder?
13. Do you have any ideas/thoughts on how online math practice should be used in school to help you or other students learn math better?
14. How do you use what you learn in math class and the math games in other classes?

Teacher Interview Questions

1. Please describe your experience participating in this study.
2. What do you think your students learned throughout this study?
3. Did one method seem to work better than the others? Which one? Why do you think?
4. Do you think the practice helped your students learn the math facts? Why or Why not?
5. Were the classroom lessons helpful in addressing student misconceptions? How? Why or why not?
6. What differences did you see in student behavior between learning operations with integers in the classroom and practice in the computer lab?
7. How would you change the design of the lessons and practice sessions?
Appendix E – Demographic Survey

Sex/Gender:
__Female
__Male

Age
__12
__13
__14
__15
__16

Race/Ethnicity:
__African American/Black
__Asian/Pacific Islander
__Hispanic/Latino
__Multiracial
__Native American/American Indian
__White
__Not Listed (please specify) _________________
__Prefer not to respond

Class status:
__Freshman
__Sophomore
__Junior
__Senior

Language you speak at home:
__English
__Spanish
__Chinese
__Arabic
__Other: _________________
__Prefer not to respond
Appendix F- eGameflow Questionnaire by Subscales

Concentration
C3 Most of the game is related to what I am learning
C4 Nothing in the game distracts me from answering questions
C5 Most of the time I stay concentrated on the game
C6 I am not distracted from problems that I should answer
C7 I don’t have to answer questions that are not related to integers
C8 The number of questions I have to answer in the game is ok

Challenge
H3 The game provides “hints” that help me correct mistakes
H4 The game provides “online support” that helps me correct mistakes
H5 The game provides video or audio hints that help me correct my mistakes
H8 The difficulty of problems increases as my skills get better
H9 The game gives me new problems with appropriate time to answer
H10 The game provides different levels of challenges that can help different students

Social Interaction
S1 I feel like I worked with my classmates while playing the game
S2 I worked with other classmates while playing the game
S3 Racing against other students in the game helped me learn
S4 The game supports communication between the players

Knowledge Improvement
K1 The game increases my knowledge
K2 I understand the problems I practiced
K3 I try to apply what I learned in Algebra class in the game
K4 The game motivates me to use the math I learned in class
K5 I want to learn more about the problems I practiced so I can learn them better
### Online Mathematics Skills Games

To what extent do you agree or disagree with the following statements.

1. **The game provided “online support” that helped me correct mistakes.**
   - Strongly Disagree
   - Disagree
   - Neither Agree nor Disagree
   - Agree
   - Strongly Agree

2. **The game provided video or audio hints that helped me correct my mistakes.**
   - Strongly Disagree
   - Disagree
   - Neither Agree nor Disagree
   - Agree
   - Strongly Agree

3. **The difficulty of problems in the game increased as my skills got better.**
   - Strongly Disagree
   - Disagree
   - Neither Agree nor Disagree
   - Agree
   - Strongly Agree

4. **The game gave me new problems with enough time to answer them.**
   - Strongly Disagree
   - Disagree
   - Neither Agree nor Disagree
   - Agree
   - Strongly Agree

5. **The game provided different levels of challenges that can help all students.**
   - Strongly Disagree
   - Disagree
   - Neither Agree nor Disagree
   - Agree
   - Strongly Agree

6. **I feel like I worked with my classmates while playing the game.**
   - Strongly Disagree
   - Disagree
   - Neither Agree nor Disagree
   - Agree
   - Strongly Agree

7. **I worked with other students in my class while playing the game.**
   - Strongly Disagree
   - Disagree
   - Neither Agree nor Disagree
   - Agree
   - Strongly Agree

8. **Racing against other students in the game helped me learn.**
   - Strongly Disagree
   - Disagree
   - Neither Agree nor Disagree
   - Agree
   - Strongly Agree

9. **The game allowed me to communicate with other players.**
   - Strongly Disagree
   - Disagree
   - Neither Agree nor Disagree
   - Agree
   - Strongly Agree

10. **The game increased my knowledge about adding integers.**
    - Strongly Disagree
    - Disagree
    - Neither Agree nor Disagree
    - Agree
    - Strongly Agree

11. **I understood the problems I practiced.**
    - Strongly Disagree
    - Disagree
    - Neither Agree nor Disagree
    - Agree
    - Strongly Agree
### Online Mathematics Skills Games

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<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
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<td>12.</td>
<td>I tried to apply what I learned in Algebra class while I played the game.</td>
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<td>13.</td>
<td>The game motivates me to use the math I learned in class.</td>
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<td>14.</td>
<td>I want to learn more about the problems I practiced so I can do better in the game.</td>
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<td>15.</td>
<td>Most of the game that I played had something to do with what I am learning in class.</td>
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<td>16.</td>
<td>Nothing in the game distracted me from answering questions in the game.</td>
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<td>17.</td>
<td>Most of the time I stayed concentrated on the game.</td>
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<td>18.</td>
<td>While playing the game I was not distracted from problems that I should answer.</td>
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<td>19.</td>
<td>I answered questions that were not related to integers.</td>
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<td>20.</td>
<td>The number of questions I had to answer in the game was ok.</td>
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<td>21.</td>
<td>The game provided “hints” that helped me correct mistakes.</td>
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Appendix G- Consent and Assent forms

CONSENT TO PARTICIPATE IN A RESEARCH STUDY A QUANTITATIVE STUDY OF LINCOLN WEST HIGH SCHOOL

Dear Parent or Guardian:

I am a graduate student in the department of Doctoral Studies at Cleveland State University and as you might be aware, for the past three years I have been a teacher at Lincoln West. During the second half of the 2013-2014 school year, I will be conducting research that examines the experiences of students as they play online math skills games in their algebra classes and the computer lab in order to see if these games help them learn and remember their integer math facts.

In order to evaluate these experiences, I am requesting your permission to include your child in a study that will help inform this research and provide meaningful insight into how these games help children learn. Your child has been selected to participate in this study with other algebra students in the 9th grade. As part of the study your child will complete addition and subtraction math facts tests before starting the study and at the end of the study. These tests will not be used in calculating your child’s grade for their algebra class.

I would also like to interview your child with questions regarding their experience using the computer and these games to learn their math facts. The interviews will last about 20 minutes and will be conducted during regular school hours at a time arranged by the 9th grade teacher at Lincoln West.

Participation in the study is completely voluntary. Your decision whether or not to allow your child to participate will have no effect on his or her enrollment and education at Lincoln West. On the day that the math practice and/or interview is scheduled, your child will be asked if he/she would like to participate, and will be free not to participate without any consequences. The risks of this study are not beyond those experienced in daily living. The benefits of the study have the potential to enhance your child’s mathematics knowledge and retention.

The interviews will be administered by myself under the supervision of Dr. Joanne Goodell, Professor, Mathematics Education, at CSU. Your child’s responses to the interview questions will not include any identifying information, such as your child’s name. Answers to the questions in the interviews will be recorded using hand-written notes and an electronic recording, but no identifying information about specific individuals will be recorded. The recording will be transcribed and then destroyed. If at any point your child does not want to continue, or appears uncomfortable, he/she can stop.
immediately. In addition, students may speak with me, their teacher, or the principal if they feel uncomfortable. There is no cost for your child to participate in the study. At any point, you may choose to withdraw your consent. Your child may choose to stop his/her participation at any time without penalty. This consent form with your child’s name will be kept in a locked cabinet at Cleveland State University. This information is strictly confidential. The hand-written interview notes will also be kept in a locked cabinet at CSU.

If you have any questions now or at any time during the study, please contact me at lisa@lisasuarez.net.
If you have any questions about your son/daughter’s rights as a participant in this study, please feel free to contact the Cleveland State University Institutional Review Board at 216-687-3630.

Thank you for your time.
Sincerely,
Lisa Suarez
Graduate Student
Doctoral Studies
Mathematics Teacher
Lincoln West High School

There are two copies. One copy is to be returned to Lisa Suarez, and one copy is for your records.
I understand that if I have any questions about my child’s rights as a research subject, I can contact the CSU Institutional Review Board at (216) 687-3630.
I have read and understand this informed consent document. I understand the purpose of this study and what my son or daughter will be asked to do.
I understand that my son/daughter may stop participation in this study at any time without any consequence/penalty.
I understand that researchers will keep the information they receive confidential.
I understand that I should keep copy of this informed document for my personal reference.
Please indicate below whether you want your son/daughter to participate. We would appreciate your signature and the return of this signed permission to your son/daughter’s teacher.

I give my consent for my son/daughter to participate in the Lincoln West study:

My child’s name is (please print):
_______________________________________________________

Parent/Guardian Signature: _________________________________Date: ________________
ASSENT TO PARTICIPATE IN A RESEARCH STUDY

This letter is to ask if you want to be part of a research study on playing online games on the computer to practice integer math facts. We might also watch you play the games or ask you questions about the online math games that you played, and how you learn math skills in your Algebra class. Your parent or guardian has said that it’s OK for you to be part of this study, if you want.

Ms. Lisa Suarez, who is a teacher at your school and is a graduate student in the Department of Graduate Studies, at Cleveland State University, is completing the study.

You don’t have to be part of the study if you don’t want to, and nothing bad will happen to you if you say “no.” Please ask questions if there is something you don’t understand.

If you decide to be part of the study, you will take a short quiz on basic math facts, then practice online math skills games on the computer and be asked questions about your experiences using the computer to practice math skills. All of these questions will have to do with what you like, what you don’t like, what you think works well, what does not work well, what you would want to do differently, and other similar topics. Ms. Suarez will ask these questions. Your teachers will not ask the questions. Ms. Suarez may also observe your class as they play the games on the computer in the computer lab.

Anything you say in the interviews will not be shared or identified with other people. That means that I will not write down or ask you to say your name when you are interviewed. I will only record what you say or how you answer the questions. The informed assent with your name on it will be kept in a locked cabinet which only Ms. Suarez and her research team has access to. When we write reports about what we learn from responses of students like you, we will tell only about how groups of students responded and not identify any student by name. While you are completing these questions, you can tell us that you want to stop at any time. It’s up to you.

If you have any questions now or at any time during the study, please contact Ms. Suarez at 216-338-8180.

If you have any questions about your rights as a participant in this study, please feel free to contact the Cleveland State University Institutional Review Board at 216-687-3630.

________________________  _________________________
Date         Signature of Student

________________________
Printed Name of Student

________________________
Person providing information and witness to assent
CONSENT TO PARTICIPATE IN A RESEARCH STUDY
A QUANTITATIVE STUDY AT LINCOLN WEST HIGH SCHOOL

Dear Lincoln West Teacher/Staff:

I am a graduate student in the department of Doctoral Studies at Cleveland State University. I have taught at Lincoln West for the past three years. During the course of the 2013-2014 school year, I will be conducting research that examines the experiences of students as they practice integer math facts using the computer. You have been identified as a teacher or staff member that will be involved in this process.

In order to evaluate these experiences, I am requesting your participation in a study that will help inform this research and provide meaningful insight into student experiences as they practice math facts on the computer. In this aspect of the study, you would participate in an individual interview that asks questions about your thoughts and experiences as you observed students learning or practicing their math facts. The interview will last about 20 minutes and will be conducted at a location mutually determined by you and me (i.e., a location at Lincoln West or CSU). It will be digitally recorded; once it is transcribed the recording will be destroyed.

Participation in the study is completely voluntary. Your decision whether or not to participate will have no effect on your employment in CMSD. Before the interview is conducted, you will be asked to provide your signed consent form, if it has not been returned already, and you will be free not to participate without any consequences. The risks of this study are not beyond those experienced in daily living. The benefits of the study have the potential to enhance the educational experience of students as they learn math facts.

The interview will be administered by myself under the supervision of Dr. Joanne Goodell, Professor, Mathematics Education, at CSU. If at any point you do not want to continue, you can stop immediately. In addition, you may speak with me or Dr. Goodell if you feel uncomfortable. There is no cost to participate in the study. At any point, you may choose to withdraw your consent.

This consent form will be kept in a locked cabinet at Cleveland State University. This information is strictly confidential. If you participate in an interview, your name will not be used in any publication or report, and will not be linked to the interview data. The digitally recorded data will be securely stored on a password-protected computer drive until the transcription is completed.
If you have any questions now or at any time during the study, please contact me at lisa@lisasuarez.net.

If you have any questions about your rights as a participant in this study, please feel free to contact the Cleveland State University Institutional Review Board at 216-687-3630.

Thank you for your time.

Sincerely,

Lisa Suarez
Graduate Student
Doctoral Studies
Mathematics Teacher
Lincoln West High School

There are two copies. One copy is to be returned to Lisa Suarez, and one copy is for your records.

I understand that if I have any questions about my rights as a research subject, I can contact the CSU Institutional Review Board at (216) 687-3630.

I have read and understand this informed consent document. I understand the purpose of this study and I will be asked to do.
I understand that I may stop participation in this study at any time without any consequence/penalty.
I understand that researchers will keep the information they receive confidential.
I understand that I should keep copy of this informed document for my personal reference.
Please indicate below whether you want to participate.

I am 18 years old or above and give my consent to participate in the Lincoln West study:

My name is (please print):

_______________________________________________________

Signature: _________________________________ Date: ______________________
Appendix H- ThatQuiz.com Student screen

Teacher Report

Grade Report

Sort: Name Percentage Clock
Grades: 1
Average: 80

test, test 2013.09.30 18:32 Addition (-) [YNGNVXIP]
Percentage: 80 Points: 16/20
Completed: 20, Unanswered: 0, Clock: 0.50, Average Time: 2.5 Correct: 16, Incorrect: 4
Incorrect Answers:
9. -2 + (-3) = -5 (5)
12. -8 + 4 = -4 (-12)
14. 3 + (-4) = -1 (7)
18. 8 + (-3) = 5 (-5)
Appendix I- Mathematics Lessons
Integer lessons will be completed, one per week for three weeks in order to address any misconceptions or lack of understandings that may exist in student understanding of the concept of adding integers.

Lesson 1:

Representing and ordering integers using an elevator model. Illuminations website integers lesson number 1 – elevator arithmetic
http://illuminations.nctm.org/LessonDetail.aspx?ID=L733

Students will use vertical movement of an elevator to evaluate signed number expressions.

Lesson 2:

Adding integers with the same sign

Lesson 3:

Adding integers with different signs