Measuring Engagement Effects of Educational Games and Virtual Manipulatives on Mathematics

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ABSTRACT

Educational games have been demonstrated to increase engagement and engagement has been demonstrated to increase achievement. Therefore, the researcher attempted to investigate how to better measure engagement and refine the measurement of engagement in this study. To frame the engagement, three domains of engagement – behavioral, cognitive, and emotional– are analyzed in detail to be able to examine the qualities of each type. Moreover, three game attributes –clear goals, immediate feedback, and balance between challenges and skills- are presented and discussed as fundamental features of virtual manipulatives and educational games used in this study to make an impact on students' engagement. To measure effects of educational games and virtual manipulatives on three domains of engagement, the researcher designed an engagement survey that examines each domain separately with their sub-domains. The Cronbach's alphas for engagement pre-test and post-test were found .89 and .91 respectively. In this pre-test and post-test quasi-experimental design, four fifth-grade classrooms (N=86) from four schools in southwest Virginia were assigned as three experimental groups and one control group. In the first experimental group, participants played an educational game called Candy Factory and in the second experimental group, the students played another educational game called Pearl Diver on iPod Touch for eight days consecutively, for 20 minutes each. In the third experimental group, participants performed activities with virtual manipulatives, whereas in the control group, participants did paper-and-pencil

drills for the same duration. All of the groups studied on the same topic, fractions. According to the results of ANCOVA, experimental group students' engagement scores were found significantly higher than control group students', $F(1,80)=11.568$, $p=.001$. When three domains of engagement were analyzed, significant differences were found among all three domains between experimental and control groups. When the researcher conducted separate analysis for educational games group and virtual manipulatives group, students who played educational games were also found significantly different than control group students in terms of all three domains of engagement and general engagement, $F(1, 58)= 8.883$, $p=.004$. In addition to this, students who did activities with virtual manipulatives showed significantly higher engagement than students who did paper-and-pencil drills in control group, $F(1, 46)= 7.967$, $p=.007$. Statistical difference was found in emotional and cognitive engagement while the results showed no significant difference in behavioral engagement between virtual manipulatives and control group students. Therefore, the three game attributes were considered as the main determining factors to engage students more to the content.

This dissertation is dedicated to my lovely wife, Pinar Samur, my unique son, Yigit Mete Samur, and my wonderful family.

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Table of Contents

List of Figures

List of Tables

Chapter 1: Introduction

Recent research studies demonstrate that students are disengaged from school, in general, and from mathematics courses, in particular (Fredricks, Blumenfeld, & Paris, 2004; National Research Council [NRC], 2004). Students who are not engaged present significant challenges when it comes to learning mathematics (Williams & Ivey, 2001). Educational researchers have been trying to resolve this issue for years because student engagement has the largest positive effect on mathematics achievement (Bodovski & Farkas, 2007). Therefore, the question is: How can we measure students' engagement and what can be done to further students' engagement in mathematics so that they become more successful?

It is not always easy to engage students in mathematics; most students do not enjoy mathematics as a course of study. Recently, efforts to prepare students with adequate knowledge and skills in mathematics have increased. These efforts have been based on the results from international studies such as NRC indicating that US students have performed poorly in contrast to those from other nations (NRC, 2004). One of these reports is driven by the No Child Left Behind legislation which states that all children must score at proficient or advanced level in mathematics based on statewide assessments by 2014 (U. S. Department of Education [USDOE], 2010). Therefore, mathematics education is at the top of the national policy agenda in order to improve American students' mathematical skills, especially students in upper elementary and middle school grade levels who are most in need of attention (NRC, 2009). However, Newmann (1992) states that the most important and urgent issue is not the students' achievement but their disengagement. As traditional approaches are still used, it might be inferred that they do

not sufficiently provide engaging experiences for mathematics teaching and learning (Childs, Mor, Winters, Cerulli, & Bjork, 2006) and ways of engaging students and measuring their engagement should be sought. According to Suh (2005, p.1), "high quality mathematics instruction depends on students' engagement with meaningful learning tasks." However, the literature delineates that we need to have a validated and reliable instrument to measure students' engagement (Kong, Wong, & Lam, 2003). Therefore, to move the field forward, we need to more carefully measure what we mean by engagement and develop more refined measures of engagement. To test students' engagement, meaningful and engaging experiences for learning mathematics, such as leveraging from virtual manipulatives and educational games, are used to address this issue. The popularity of using educational games and virtual manipulatives in mathematics deserves attention and it appears that they will be increasingly incorporated into the educational settings every day. Hence, doing a research study is important for the trajectory of these learning environments.

Engagement

Although the necessity of the emphasis on students' success in mathematics is unquestioned, the potential contribution of engagement to the students' achievement "has yet to be realized" (Fredricks et al., 2004, p. 83). A consensus on the definition of engagement in the literature has not been reached (Appleton, Christenson, & Furlong, 2008); however, based on the related literature, *engagement* is defined as a student's high level of interest in a particular task demonstrating *behavioral*, *cognitive,* and *emotional* qualities (Connell & Wellborn, 1991; Finn, 1993; Hoffman & Nadelson, 2010; Rozendaal, Braat, & Wensveen, 2010; Skinner & Belmont, 1993). This multidimensional

definition of engagement has also been supported by many researchers and is coherent with the theories of behavior, cognition, and emotion (Annetta, Minogue, Holmes, & Cheng, 2009; Appleton et al., 2008; Finn, 1993; Fredricks et al., 2004; Jimerson, Campos, & Greif, 2003; Kong et al., 2003).

There are many studies examining these three domains and their specific qualities, but there is limited number of measures and/or empirical studies covering these three domains concurrently. When the literature on engagement has been examined, general studies on engagement (such as school and classroom engagement) stand out because of the students' boredom and drop out problems (Fredricks et al., 2004). However, engagement on a specific task as it was stated in the current definition of engagement is the focus in this study. Although these general issues are important, studies on engagement must address the specific elements that support an individual's behavior, cognition, and emotion.

As is the case with the definition of engagement, no consensus has been reached on how to measure engagement (Appleton et al., 2008). Instruments were developed to measure engagement. Pintrich, Smith, Garcia, and McKeachie (1991) developed *The Motivated Strategies for Learning Questionnaire (MSLQ)* to assess college students' motivational orientations and their use of different learning strategies including self-regulation strategies. *Research Assessment Package for Schools (RAPS)* developed by Institute for Research and Reform in Education (IRRE) has a part on student engagement to measure students' ongoing engagement such as effort, attention, and value (IRRE, 1998). However, efforts were mainly spent for general engagement such as school level engagement and little attention was given developing engagement instruments for a

course (Kong et al., 2003). In addition, some researchers suggested using empirical methods where the researchers can measure engagement precisely for different domains (Hoffman & Nadelson, 2010). When the literature is reviewed in detail, to explore the underlying conditions of engagement, some common attributes for each domain are emerged to be able to measure engagement effectively.

Behavioral engagement. When literature on *behavioral engagement* is examined, students' positive and negative behavior, distraction from the task (Finn, 1993), persistence in the task, and participation (Annetta, Minogue, et al., 2009; Finn, Pannozzo, & Voelkl, 1995; Fredricks et al., 2004) have constituted *behavioral engagement*, which is suitable for the objectives of this study. Behavioral engagement constructs one of the most important elements of engagement because all definitions of engagement include behavioral components according to Appleton et al.'s (2008) research.

Behavioral engagement includes "involvement in academic and social or extracurricular activities and it is considered crucial for achieving positive outcomes" (Fredricks et al., 2004, p.60). By being more *involved in academic activities*, as mentioned in the definition of behavioral engagement, *persisting on doing the tasks* and showing *effort* during the learning activities (Annetta, Minogue, et al., 2009; Finn et al., 1995), students are expected to be more engaged and therefore they can be more successful. This study attempts to address most of the qualities of behavioral engagement individually so that students' behavioral engagement can be measured and analyzed thoroughly to get the most reliable results.

Cognitive engagement. Helme and Clarke (2001) observed mathematics courses to see the signals of *cognitive engagement* in behavior to understand the relationship

between cognitive engagement and learning. They found that behaviors, such as verbalizing thinking, questioning, and justifying an answer are indicators of cognitive engagement (Annetta, Minogue, et al., 2009; Helme & Clarke, 2001). Other researchers focus on students' planning, monitoring, and regulating behaviors to understand the cognitive engagement although those activities are considered as self-regulating activities (Blumenfeld & Meece, 1988; Hoffman & Nadelson, 2010; Pintrich, 2000; Pintrich, Smith, Garcia, & McKeachie, 1991). Therefore, there is a close relationship between cognitive engagement and self-regulation theory. These two terms are still used interchangeably in some studies.

While there is not a decisive separation, the difference between behavioral and cognitive engagement can be described as follows; in cognitive engagement there is more inner psychological quality and investment for learning strategically (Fredricks et al., 2004); whereas behavioral engagement includes students' observable actions or performance (Jimerson et al., 2003). Therefore, it is sometimes difficult to determine students' cognitive engagement while they are working on a specific task.

The measures of cognitive engagement are limited. Although observational data have been collected to analyze students' cognitive engagement in many studies (Annetta, Minogue, et al., 2009; Fredricks et al. 2004), some researchers are opposed to observational data collection because of the nature of cognition, which is not always observable. Therefore, more useful and effective methods of collecting cognitive engagement data are needed. For this reason, the related literature is analyzed diligently on cognitive engagement for a specific task (e.g. Fredricks et al., 2004; Hoffman & Nadelson, 2010; Pintrich & De Groot, 1990; Pintrich et al., 1991).

Emotional engagement. High involvement with the task (Fredricks et al. 2004), affective reactions in the classroom, such as interest, happiness, and boredom (Annetta, Minogue, et al., 2009; Skinner & Belmont, 1993), and losing the awareness of time and space (Csikzentmihalyi, 1988) are considered shared qualities of *emotional engagement*. What makes emotional engagement different from the behavioral engagement is that the qualities of emotional engagement are the externalized version of feelings, whereas the behavioral engagement is the externalized version of conduct.

When the literature on measuring emotional engagement is examined in detail, it is not surprising to see the lack of instruments used to measure emotional engagement. Additionally, the instruments used lack more differentiated questions, in terms of specific qualities or tasks of emotional engagement (Fredricks et al., 2004). By asking task-specific and quality-specific questions to the students, the researcher is expected to explore the source of students' emotional engagement.

Summary. It seems obvious that measuring a multi-dimensional engagement by covering these three domains is not an easy job to do. It also seems obvious that these three domains of engagement are interrelated with each other and they are not completely separable from each other (Fredricks et al., 2004). Therefore, there might be some overlaps among these domains because of their multifaceted nature (Annetta, Minogue, et al., 2009; Fredricks et al., 2004; Jimerson et al., 2003). Taking the definition of engagement as a starting point, and the three domains of engagement – behavioral, cognitive, and emotional engagement – with their indicators in behavior; the researcher proposes an engagement instrument to measure them separately.

In order to answer the question, how can we measure students' engagement and what can be done to further students' engagement in mathematics so that they become more successful, it must be broken into two sections. For the first part of the question, engagement and the qualities of each domain are analyzed. Addressing the most distinct qualities among domains was considered sufficient by the experts in this field to assess the domain-based engagement types. As for the second part, in order to establish an impact on students' engagement, research studies on the related technologies used in mathematics have been examined. According to the most recent position statement of National Council of Teachers of Mathematics (NCTM) (2008) about the use of technology in learning and teaching mathematics:

> Technology is an essential tool for learning mathematics in the 21st century, and all schools must ensure that all their students have access to technology. Effective teachers maximize the potential of technology to develop students' understanding, stimulate their interest, and increase their proficiency in mathematics. When technology is used strategically, it can provide access to mathematics for all students. (p. 1)

Therefore, the most appropriate technologies, beginning from paper-and-pencil to concrete materials and from computerized environments to virtual manipulatives and educational games have been investigated in a general sense to discuss their use in mathematics and engagement by presenting the related literature. Suitable content-related media are examined below to support the qualities of engagement described previously.

Traditional Technologies for Mathematics Learning

According to the NCTM (2008), it is essential to integrate technology into lesson plans when teaching mathematics. It is found that the students who have access to suitable technologies enjoy learning and demonstrate learning gains in mathematics (Suh, Moyer, & Heo, 2005). Therefore, one possible solution to the problem of increasing student achievement scores in mathematics is to engage students more into the *doing* of mathematics rather than focusing solely on being an expert in memorized knowledge (Oner, 2008).

Aligned with this position, Greeno (1988) suggested that the manipulation of concrete equivalents of mathematical concepts to engage students could be a meaningful mathematical activity. In addition, recent studies have also shown that students are able to understand mathematical activities through computerized devices although those mathematical activities are not concrete (Clements, 2002). Moreover, computerized environments sometimes offer equally, and often times, more engaging activities to the students when compared to the traditional teaching and learning environments where mostly direct instruction is presented with abstract knowledge (McCollister, Burts, Wright, & Hildreth, 1986).

Virtual manipulatives. Virtual manipulatives allow students to connect their previous knowledge and experiences to abstract concepts in mathematics, especially with younger children (Suh, 2005). A virtual manipulative is described as "an interactive, web-based visual representations of a dynamic object that presents opportunities for constructing mathematical knowledge" (Moyer, Bolyard, & Spikell, 2002, p.372). Since the early 90s, physical and virtual manipulatives have been used to help students

reinforce mathematical knowledge on various topics. Specifically, National Library of Virtual Manipulatives (NLVM) has been providing various types of activities to the students and teachers free since 1999.

Although those computerized environments were initially welcomed in computer labs with internet access, most of these environments presented drill-and-practice type of exercises and could not break with direct instruction (Kim, 1993). Therefore, research studies have analyzed the effect of virtual manipulatives on students' engagement and mathematics learning (Kim, 1993; Reimer & Moyer, 2005; Smith, 2006; Suh, 2005; Suh et al., 2005). In general, students like studying with virtual manipulatives; however, most of the studies on virtual manipulatives provide observational or qualitative data without quantitative support. Drickey (2000) also observed students while they were studying with virtual manipulatives and found that all students were actively engaged. The existence of relatively few empirical studies to measure engagement in the context of using virtual manipulatives increases the need for this study to move the field forward.

Furthermore, attributes of those technologies that might engage students more to the subject are needed for more effective mathematics learning. That is, the question surrounding mathematics engagement has not been answered sufficiently yet. Unfortunately, it was mentioned in the report of NCTM (2008) that technology should be given more attention when it comes to learning mathematics and stimulating students' interest, not much attention has currently been given to the attributes of these technologies used for mathematics learning and teaching. Similar to the advances in the technology and video games, developments have been started in educational games as well (Kebritchi & Hynes, 2010). Consequently, educational researchers have begun to

design and incorporate games into education. One of the most important potential benefits of using an instructional game is that its unique features engage students by presenting an enjoying game play environment for the learning activities that are aligned with the instructional objectives (Hays, 2005, 2010). Therefore, the answer of the question asked at the beginning of this chapter has started to pursue an interesting line, educational games.

Educational (Digital) Games

Game is an interactive problem-solving activity that has goal(s), conflict(s), rule(s), challenge(s) to engage players (Schell, 2008). *An educational game* is described in this study as any kind of game that can be played with computerized systems (video games, computer games, and mobile games) to foster learners' academic and psychological growth (such as learning gains, skills, experiences, motivation, and engagement). Charles, Bustard, and Black (2009) state that educational games can improve student engagement in learning and this might increase students' achievement and allow students to undertake rewarding experiences. As understood from this study, as long as the engagement in learning is increased, achievement increases in the same direction. Although educational games are considered effective tools to develop students' engagement in mathematics (NRC, 2009), educational games that are well integrated with a robust understanding of engagement have been inadequately researched. Educational games help students to "a) use action instead of explanation b) create personal motivation and satisfaction c) accommodate multiple learning styles and skills d) reinforce mastery skills and e) provide interactive and decision-making contexts" (Charles & McAlister, 2004; Holland, Jenkins, & Squire, 2002; Sheffield, 2005, as cited in Kebritchi & Hynes,

2010, p. 121). When the literature is examined more deeply, it is seen that there are mixed results in terms of the effect of educational games on engagement. More detailed literature review is presented in the next chapter.

Extensive reviews on educational game research have been conducted by various researchers, however, they did not encounter an important relationship between achievement and educational games (e.g. Dempsey, Lucassen, Gilley, & Rasmussen, 1993; Emes, 1997; Kebritchi, Hirumi, & Bai, 2010). Although there is a growing body of literature related to the use of educational games in different contexts, the findings indicate that there are mixed results in terms of the effectiveness of educational games (Harris, 2001; Hays, 2005; Pierfy, 1977; Randel, Morris, Wetzel, & Whitehill, 1992). There is also difficulty in generalizing the findings of these research studies because of the wide range of methodologies adopted. There are different criteria defining research procedures (e.g. duration of the study, instruments used, and individual differences) which create conflicting results (Hays, 2005). On the other hand, some research studies give promising results for educational games indicating that they have a positive effect on increasing students' engagement and therefore achievement (Echeverria, Garcia-Campo, Nussbaum, Gil & Villalta, 2011; van der Spek, Wouters, & van Oostendorp, 2011).

Research studies on mathematics and educational games have also been conducted (Ke & Grabowski, 2007; Kebritchi et al., 2010; Suh et al., 2005). Because of the advances in technology, popularity of games, and the potential positive effects of educational games on engagement, many researchers have used various types of educational games in their research for instructional purposes to support learning mathematics and have found positive results in terms of engagement and achievement

(Bottino, Ferlino, Ott, & Tavella, 2007; Ke, 2008b; Kebritchi et al., 2010). However, there is scant *sound* empirical research reporting the effects of educational games on academic issues, e.g. supporting engagement in mathematics and therefore achievement (Ke, 2008b; 2008c). Still, there are many qualitative studies suggesting that educational games engage students in learning various contents (Barab, Sadler, Heiselt, Hickey, & Zuiker, 2007; Ke, 2008c). Therefore, research must go a step further for more refined work to be able to understand the various qualities of engagement measured by game play and virtual manipulatives activities. However, these media are not the sole tools to impact students' engagement; their unique attributes are expected to establish an effect on students' engagement. Therefore, those attributes are briefly presented in the next section.

Main Attributes of Virtual Manipulatives and Educational Games

Although there are various types of attributes that researchers can focus such as fantasy, mystery, conflict, or interaction in games (Garris, Ahlers, & Driskell, 2002; Hays, 2005; Wilson et al., 2009), three main attributes of virtual manipulatives and educational games are the focus in this study. They can also be called as interactive media attributes or video game attributes as they are used for common purposes. *Clear goals, immediate feedback, and balance between challenges and skills* are the common and fundamental features of the National Library of virtual manipulatives and educational games used in this study. They are important elements of any type of learning environments and educational games (Atkinson & Hirumi, 2010; Bowman, 1982; Garris et al., 2002; Hays, 2005; Prensky, 2001; Stahl, 2006; Wilson et al., 2009).

There are some common challenges in designing effective educational games, such as: they do not have solid pedagogical foundations behind their design (Kebritchi &

Hirumi, 2008), they do not force students' abilities (challenge), they do not provide enough feedback (assessment), and they do not present clear goals. The researcher wants to focus on these three main attributes of educational games and virtual manipulatives - challenge, feedback, and goals- with this study to measure if they create an impact on students' engagement. Although it has not been proven yet, educational games that have multiple levels are considered to provide high levels of engagement (Gee, 2007). Malone (1981) argues that challenge is one of the most important attribute of an educational game to engage students. Prensky (2008) argues that if students know that they are doing right or wrong during the learning process, it will increase students' engagement. Garris et al. (2002) stated that clear and specific goals help students to understand the relationship between goal and feedback, which are the essential elements in triggering greater engagement.

As Schell (2008) asks, the central question for the design of any type of learning environment (educational games or virtual manipulatives) must be what elements should be included in the game in order to achieve the desired experience? As demonstrated in Figure 1, although it is a difficult task, educational games that are more overlapped with the instructional objectives can establish a more effective instruction. Therefore, the answer of Schell's (2008) question can be answered: as long as various characteristics of games are leveraged, the desired experience can be achieved based on the Hays' (2005) description. Hence, the specific game attributes such as clear goals, challenge, and feedback are expected to impact students' engagement in this study. As educational games and virtual manipulatives used in this study have their own instructional objectives integrated within them, game characteristics that mentioned previously are expected to

create more effective instruction for students. Therefore, the researcher expects to see the impact of this effective instruction on students' three domains of engagement.

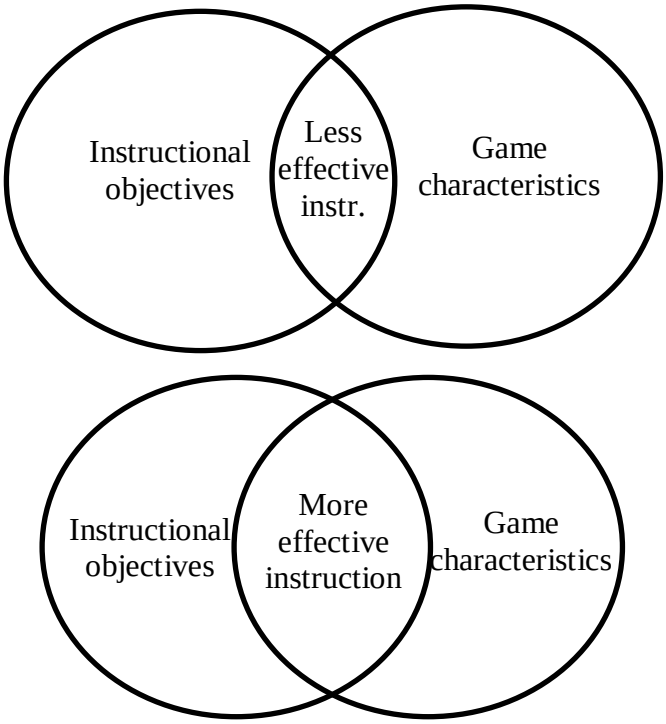

Figure 1. Instructional effectiveness as degree of overlap among instructional objectives and game characteristics (Hays, 2005, p. 49)

As it is not guaranteed that students will be engaged more when they play games or do virtual manipulatives activities, however leveraging from media, which have those elements, might have an effect on their engagement towards content. Garris et al. (2002) state that further research is needed to examine the characteristics of games. Wilson et al. (2009) conclude that researchers must first explore the attributes of games or any type of media to understand their effects on the results. Therefore, the researcher postulates that these three features are the most important elements to ensure engagement through educational games and virtual manipulatives and rigorous discussion is provided in the literature review section (chapter 2).

Significance of the Study

Most significantly, engagement is related to academic achievement (Hoffman & Nadelson, 2010) and it is a prerequisite for learning (Appleton et al., 2008). Therefore, this study analyzed students' engagement before and after the treatment with educational games and virtual manipulatives to determine whether there is a significant relationship between students' pre-and-post engagement scores. Besides, leveraging from clear and achievable goals, providing immediate feedback, and enriching the tasks with challenges are considered as three fundamental game attributes that might create an impact on students' engagement. Therefore, the focus of this dissertation is not to demonstrate the efficacy of educational games and virtual manipulatives but to take educational game designers' and researchers' attention to their unique features by conducting sound and data-driven research. In addition, this dissertation attempted to design valid and reliable instrument to measure students' engagement in three domains as a contribution to the field. Consequently, this dissertation study attempts to fill the gaps mentioned in the next paragraphs.

When the literature on the use of educational games and virtual manipulatives to promote engagement in mathematics is examined closely, there are three important gaps to be filled by empirical research. The first is the way *engagement* was assessed by the researchers, as they preferred using observational data in most studies, which has some limitations. The second is the *limited number of empirical educational game studies* done in the actual classroom setting. Third is about trying to solve targeted students' problem in mathematics, more specifically on *fractions*. These three important gaps serve as the

basis of the study. Therefore, the following paragraphs will describe each gap as it relates to the investigation.

First, as well as the empirical research that focuses on different kinds of engagement while students are playing an educational game or virtual manipulatives is limited, most of the studies assess engagement as a broader term and use observational data (such as engagement protocol for classroom observation) to analyze students' engagement (Annetta, Mangrum, Holmes, Collazob, & Cheng, 2009; Annetta, Minogue et al., 2009; Barab et al., 2007; Echeverria et al., 2011; Hoffman & Nadelson, 2010). There is limited number of studies using engagement survey data to investigate the specific qualities and three domains of engagement quantitatively. In some studies, the researchers stated that students are appeared as engaged (Barab et al., 2007; Echeverria et al., 2011).

Therefore, this study will contribute to the research studies on engagement by examining the three domains of engagement as defined in psychology literature thereby allowing the researcher to measure engagement effects of educational games and virtual manipulatives within different domains of engagement. This was done by investigating each domain of engagement separately with an engagement survey (quantitatively) unlike the previous studies most of which relied on observational data to analyze engagement. Some authors suggested future researchers to place more emphasis on empirical methods as they measure more precisely than observations, in this study, the researcher will be able to describe the qualities of engagement in behavioral, cognitive, and emotional domains (Hoffman & Nadelson, 2010). Therefore, the engagement survey, research design, and data collection strategies are expected to add to the field of study.

According to a prominent game scholar, James Gee, educational researchers need to examine the best commercial video games to understand better how learning occurs among middle school-age youth (Gee, 2007). Although researchers try to use educational games more in their studies, the educational games used in those studies do not always guarantee that students are engaged in learning behaviorally, cognitively, and emotionally. Therefore, exploring the underlying attributes in this study, engagement for a successful mathematics gaming practice may create a significant contribution to the related literature (Ke, 2008a). While analyzing engagement, the researcher examined resources from educational psychology to provide the most suitable underlying theories covering the three domains of engagement defined above. Despite there has been an increased interest in educational games research, little empirical research studies have actually been conducted on the topic, especially on the three domains of engagement. As Fredricks et al. (2004) mentioned, "robust bodies of work addressing each of the components separately" are needed (p. 61). What is more, each domain must be analyzed and tested concurrently and vigorously. Therefore, three domains of engagement and their antecedents and consequences, in this sense, were presented separately to provide enough theoretical background to gather the needs of this study.

Second, according to Ke (2008c), the literature indicates that there are limited empirical studies conducted in actual classroom environments using educational games. One reason for this problem might be that it is difficult to integrate the educational games in the formal schooling system (Brom, Preuss, & Klement, 2011). Therefore, sufficient reliable results related to understanding the effects and attributes of educational games on engagement in real classroom settings are lacking. In a recent study, Kebritchi et al.

(2010) found that students who played educational games in the classroom setting exhibited greater motivation than students who played educational games in school labs only. Their results also showed that educational games resulted in significant improvements in mathematics achievement. In this respect, this study is expected to contribute to the existing empirical literature on students' engagement done in classroom settings. The researcher cannot claim that this study will teach students everything about fractions, but the focus of this study is to measure students' engagement to see if those media with their attributes have an impact on engagement. Related to this issue, Ke (2008a) mentions the problem of interrupting flow by integrating instructional support while students play the game in the classroom. The study asks, "Will instructional support features appear so intentional and detached from the game world that they reduce a game's engaging power?" (Ke, 2008a, p. 1619). In this study, there was no instructional support for the students. Therefore, the study was able to provide an answer to this question. The researcher was able to see if students' engagement was impacted positively when there was no direct instruction given to support students. As van Eck (2006) states that ''anything that causes us to 'leave' the game world interrupts flow" (p. 22), the researcher analyzed students' flow -defined as a part of emotional engagement in this study- without any interruption during the game experience.

As a third issue, fractions as a content area are difficult to teach and learn as research in the area has demonstrated (Norton & Wilkins, 2009). A significant problem with the teaching and learning of fractions is that, according to data from 323 interviews with students, "students need classroom experiences which assist them to understand more clearly the roles of the numerator and denominator in a fraction, the meaning of

improper fractions, and the relative sizes of fractions" (Clarke, Roche, Mitchell & Sukenik, 2006; as cited in Clarke & Roche, 2010, p. 19). As students have problems while learning fractions, it is important to engage students in classroom activities that involving sharing or partitioning sets of objects, in support of students' construction of initial fractions concepts (Norton & Wilkins, 2009; 2010). Any attempt to influence the teaching and learning of fractions should provide sufficient engagement and time to encounter these difficult areas. Therefore, a potential solution requires an innovative and sophisticated combination of instructional strategies, game-based mechanics, and technologies, such as virtual manipulatives.

In summary, researchers in the field of education who are interested in engagement, educational games, game attributes, and virtual manipulatives will find this study useful. Teachers who would like to use educational games and virtual manipulatives in their classrooms as a supplemental activity or a part of their instruction for mathematics might leverage the results of this study. Educational game designers who do research on game features might find this study useful for their game designs. Policy makers who would like to integrate educational games more into the educational settings and curriculum might use the findings of this study to support their argument for the effectiveness of educational games. Finally, parents may also find essential profits from the results of this study.

Purpose Statement

This study intends to determine the components of students' engagement and measure students' engagement with its three domains -behavioral, cognitive, and emotional engagement- in the context of educational games, virtual manipulatives, and

paper-and-pencil drills used as a part of the course. Rather than only focusing the fun aspect of these media different from the conventional instruction, the study expects to measure students' engagement and understand the qualities of these media to increase students' achievement in mathematics. As there is a history of presenting educational games as chocolate-covered broccoli (Laurel, 2001), which does not provide fun but gives practice and drills to the students in the name of *game*, this study is expected to determine how educational games and virtual manipulatives work within the context of mathematics to engage students more with their unique features. There is another long history of comparison studies on virtual manipulatives versus concrete manipulatives; however, students' engagement with virtual manipulatives has not been analyzed quantitatively and thoroughly. Therefore, instead of assessing general knowledge in mathematics and general engagement towards mathematics course, this research examined particular elements of engagement discussed above and specific skills in mathematics to draw conclusions that are more reliable.

Consequently, the purpose of this quasi-experimental study is to investigate the students' behavioral, cognitive, and emotional engagement effects and attributes of educational mathematics games, virtual manipulatives, and paper-and-pencil drills on 86 fifth grade students in southwest Virginia. Employing a pre-test-post-test control-group design, this study attempts to carefully measure what we mean by engagement in the context of using educational games and virtual manipulatives as treatment conditions in comparison to the control condition -paper-and-pencil drills-. The independent variable is generally defined as variables that (probably) cause, influence, or affect outcomes (Creswell, 2003). The dependent variables are generally defined as variables that depend

on the independent variables; they are the outcomes or results of the influence of the independent variables (Creswell, 2003).

Contingent upon the discussion above, it can be argued that researchers have extensively explored that students are engaged while they are playing educational games and while they are dealing with virtual manipulatives through observations. What remains to be explored, however, is to present empirical findings on the underlying conditions of engagement that might have a positive impact on students' mathematics engagement in general. For this aim, the investigator chose educational games and virtual manipulatives activities that have three unique features (goal, feedback, and challenge) integrated. In addition, they are suitable with the mathematics content (fractions), research questions of the study, and the engagement theory with three domains behind the study. After analyzing the literature on engagement, a survey was developed to identify probable variables affecting student engagement within these three domains. This is unlike the previous research on educational games and virtual manipulatives in which other researchers have mostly analyzed qualitative data.

Organization of the Proposed Study

Chapter 1 provides an introduction to the study, problem of engagement, traditional technologies for mathematics learning, virtual manipulatives and educational games in addition to main game attributes studied in this research. Moreover, the gaps found in the literature, the purpose and the significance of the study are presented in the first chapter. Chapter 2 presents a review of the literature on engagement with three domains – behavioral, cognitive, and emotional engagement – followed by the technologies used for engaging students more in mathematics. After presenting the

literature on virtual manipulatives and related research on engagement, the researcher introduced educational games and reviewed them in terms of engagement and mathematics achievement. The three game attributes –goals, feedback, and challenge- are presented before the research questions and hypotheses. Chapter 3 lays out in detail the study design, participants, instruments, pilot study and results, data collection procedures, data analysis techniques, and limitations related to the methodological approach to be undertaken to answer posited research questions. Chapter 4 reports the results of this study for each hypothesis with further analyses. Chapter 5 presents the findings and discusses the results as well as implications that can be drawn from the findings, and suggestions for future research.

Glossary of Terms

Attention. Attention is defined for this study as listening or paying attention to the teacher while students are dealing with the task. Rather than focusing on the cognitive part of being concentrated with mind, it is defined as attending behaviorally (behavioral engagement).

Behavioral engagement. Behavioral engagement is defined in the literature as students' active participation, persistence, diligence, and involvement towards a cause or the accomplishment of a task. It is the externalized version of conduct that one can see from students' physical activities.

Cognitive engagement. Cognitive engagement is defined in the literature as students' investment in learning, thinking strategically, and involvement in learning mentally. Activities such as students' self-checking their understanding, making plans about the task, and regulating their learning are also used to define cognitive engagement.

Desire. Desire is defined in this study as wanting to spend more time on doing the task (emotional engagement).

Diligence. Diligence is defined for this study as working hard at the task or spending extra time to understand the task (behavioral engagement).

Educational game. An educational game is any kind of game that can be played with computerized systems (video games, computer games, and mobile games) to foster learners' academic and psychological growth (such as learning gains, skills, experiences, motivation, and engagement). Game is an interactive problem-solving activity that has goal(s), conflict(s), rule(s), challenge(s) to engage players (Schell, 2008).

Emotional engagement. It is defined as desire, interest, and positive and negative feelings that students sense while dealing with the task. Besides, a state of being immersed to the task is also considered as a part of emotional engagement in this study.

Engagement. Engagement is defined in this document as a student's high level of interest in a particular task *behaviorally, cognitively,* and *emotionally.*

High level of cognitive engagement. High level of cognitive engagement is defined as applying the new knowledge to the real-life settings or thinking/developing different strategies to do the tasks, which requires higher level of thinking (cognitive engagement).

Immersion (Flow theory). Immersion can be names as flow theory in this study. It is described as losing the sense of time and place while students are dealing with the task (emotional engagement).

Interaction/Help. Interaction is defined for this study as seeking help from teacher or peer-students when students need (behavioral engagement).

Interest. Interest is defined in this study as students' positive and negative feelings about the task such as being interested, bored, excited, or happy (emotional engagement).

On-task activity. Students' on-task activities such as pretending as if studying/working / dealing with the task or getting distracted from the task are defined as a behavioral engagement quality in this study (behavioral engagement).

Participation. Participation is defined for this study as taking part in the activities or task (behavioral engagement).

Persistence. Persistence is defined for this study as continuing to do the task or making an extra effort to finish the task although it is difficult for the students (behavioral engagement).

Planning, regulating, and monitoring (Self-regulation). They are all components of self-regulation theory. Planning activities such as setting goals to organize and comprehend the material easier. Monitoring activities include tracking of one's attention, and self-testing and questioning to understand the task and integrate it with prior knowledge. Regulating refers to adjusting one's cognitive activities by checking and correcting students' thinking and learning on the task (Pintrich et al., 1991) (cognitive engagement).

Superficial level of cognitive engagement. Superficial level of cognitive engagement is defined as making students' best guess or memorizing the content while they are dealing with the task cognitively (cognitive engagement).

Virtual manipulatives. Virtual manipulatives are interactive, online visual representations of mathematical objects that allow students opportunities for constructing their conceptual mathematical knowledge (Moyer et al., 2002).

Chapter 2: Review of the Literature

This chapter presents the four main elements of the investigation. First, the related literature on engagement will be defined by three components – behavioral, cognitive, and emotional; each component will be analyzed and presented separately in this section to support the main argument. Second, technologies that have been used for engaging students in mathematics will be discussed focusing mainly on virtual manipulatives. After that, research studies on virtual manipulatives and engagement are examined. As a third point, educational games studies, the most crucial area to the problem formulation, are discussed. The empirical research studies focusing on educational games and engagement are also presented. In each section, the gaps in the literature are presented to emphasize the potential significance of the study. As a fourth issue, the three common game attributes, -goals, feedback, and challenge- are presented as fundamental features of the educational games and virtual manipulatives appropriated for this study. Chapter 2 concludes with research questions and hypotheses for the current study.

Literature Review on Engagement

According to Charles et al. (2009) and Kong et al. (2003), engagement is central to the success of student learning. Bodovski and Farkas (2007) corroborate that student engagement has the most important effect on learning particularly in mathematics. Therefore, it is suggested that researchers in education should study the relationship of engagement in increasing students' learning within various contexts. Despite this need, scholars often avoid defining engagement precisely given the inherent ambiguity of the term. This section will provide the definitions and features of engagement from the perspective of psychology. Literature review of the last 20 years demonstrates low

student engagement (Marks, 2000). Wilson et al.'s (2009) literature review indicates that educational games can lead to an increase behavioral, cognitive, and emotional outcomes. Therefore, behavioral, cognitive, and emotional domains of engagement are described in this section, first, individually in an effort to construct, eventually an integrated definition of engagement. Moreover, qualities of each domain of engagement will be presented and discussed with the related literature.

Definition. To define engagement, there are many different directions that one can follow in the psychology, education, and educational technology literature. There are varieties of theories and empirical traditions that serve different purposes in terms of defining engagement (Pintrich, 2000). Many terms have multiple and conditional definitions. For many authors engagement has a similar meaning with motivation (Oncu, 2007). According to Skinner and Belmont (1993), engagement has behavioral and emotional components. They state that it is easy to detect students who are engaged because they show their involvement in learning activities with behavior and positive emotions. In a more detailed way, engaged students select tasks at the border of their competencies. When the opportunity is given, they act quickly, try to do their best, and focus on the application of learning tasks. Concerning emotions, engaged students often show positive attitudes such as excitement, curiosity, and interest towards activities (Skinner & Belmont, 1993).

According to Rozendaal et al.'s (2010) definition of engagement, a positive state of cognition is derived. They describe engagement as "an exciting and enjoyable state of mind in which attention is willingly given and held" (Laurel 1991; Jacques et al. 1995; Webster & Ho 1997; Chapman et al. 1999; as cited in Rozendaal et al., 2010, p.193).

Hoffman and Nadelson (2010) state that engagement is related to academic achievement, motivation, and task persistence and that the balance between students' interest and the challenge level of the task determines the strength of engagement. If the task is too easy for students, engagement decreases; however, if the task is challenging and designed according to the students' level of ability, the students' engagement increases (Hoffman & Nadelson, 2010).

When studies on computerized environments, in particular, are examined in terms of engagement, Jones (1998) defines engagement as ''the nexus of intrinsic knowledge and/or interest and external stimuli that promote initial interest in, and continued use of a computer-based learning environment'' (p. 205). As understood from the definition, interest is still considered the main factor predicting engagement. As it provides intrinsic motivation for students, interest can be invoked by the external stimuli such as computerized environments. When educational game studies are examined, Atkinson and Hirumi (2010) state that in game-based learning, engagement refers to, "the involvement in the game when attention is focused on play and attention is a prerequisite for engagement in most activities" (p. 64). In this definition, they emphasize attention (cognitive) whereas, Jones (1998) concentrates on interest (emotion).

When the literature on engagement is examined more broadly, in contrast to research studies mentioned above, it is noticed that student engagement involves three components: "learning-related work habits (active participation, persistence at tasks, completing work, taking challenging classes), cognitive behaviors (attention, problem solving), and emotions (enthusiasm, interest)" (Bodovski & Farkas, 2007, p.118). Therefore, it is purported that engagement may have more than two dimensions.

Although a consensus on the definition of engagement has not been reached (Appleton et al., 2008), what is seen in these definitions is that it definitely has some common features such as cognition, attention, behavior, emotion, and interest. Therefore, after analyzing the literature on engagement, the definition of engagement for purposes of this study is as follows: Engagement refers to a student's high level of interest in a particular task *behaviorally, cognitively,* and *emotionally*. As can be seen, three domains establish a basis for the definition of engagement. This multi-faceted definition of engagement is corroborated with another novel development in psychology literature, the integration of cognition and emotion with their reflection on behavior (Annetta, Minogue et al., 2009; Appleton et al., 2008; Fredricks et al., 2004; Jimerson et al., 2003).

The main issue with studying engagement within the context of educational settings, instructional technology settings, or educational game research, is that there is not an overarching theory covering the behavioral, cognitive, and emotional domains of engagement. In terms of psychological theories of learning, there is not a specific theory that attempts to incorporate these three domains into single framework; historically, there has been a noticeable division between emotion and cognition. Cognition and emotion are not well integrated in psychological science; however, recently, some psychology papers have ventured to integrate them (e.g. Bell & Wolfe, 2004; Fredricks et al., 2004). The intersection of cognition and emotion is inevitable, as researchers have come to the understanding that cognition and emotion are bound and inseparable. Yet, there is insufficient number of research studies available that attempt to merge the two recognized domains of engagement. Therefore, more empirical studies are needed to "conceptualize relations between emotion and cognition" (Bell & Wolfe, 2004, p. 366).

The behavioral domain is interrelated with the cognitive and emotional domains of engagement even though there is lack of emphasis on the behavioral domain in previous studies (Fredricks et al., 2004). Another challenge in the psychology literature is that when the behavioral engagement is examined, the underlying theories of the behavioral engagement are often deeply related to cognition and emotion (Bell & Wolfe, 2004). Therefore, since there are not clear distinctions among behavioral, cognitive, and emotional engagement, there may be overlaps among them (Fredricks et al., 2004). Previous research may lack clear distinctions among the domains because the researchers observed behavior to determine cognition and emotions. There are ways to integrate these three domains although they have been discussed separately so far. Many studies related to these three domains and their specific qualities exist, although there are limited empirical studies covering these three domains concurrently and evidently in one study. According to Fredricks et al. (2004), "the fusion of behavior, emotion, and cognition under the idea of engagement is valuable because it may provide a richer characterization of children than is possible in research on single components" (p. 61). Therefore, the specific qualities of engagement for each domain were taken into account while designing the multi-faceted engagement instrument for this study (See Appendix C). Consequently, the following sections will provide definitions and qualities of behavioral, cognitive, and emotional engagement suitable with the definition provided earlier in this section.

Behavioral Engagement

Research studies on behavioral engagement focus on school drop-outs rates, participation in school-related activities, and classroom-level behaviors such as following

classroom rules (Appleton et al., 2008; Finn, 1993; Finn et al., 1995). Selected research studies on behavioral engagement have focused on participation, on task behavior, and academic activities (Annetta, Minogue, et al., 2009; Connell & Wellborn, 1991; Finn, 1993; Finn et al., 1995). According to Skinner and Belmont (1993), students who are more engaged behaviorally at school-level receive higher grades in courses and become more successful in general. Nevertheless, it may not be the case for task-level engagement suggesting that students who are engaged in school may not be engaged in particular academic activities. Therefore, task specific engagement could be an important research avenue to pursue in terms of students' behavioral engagement. Oncu (2007) defines behavioral engagement as "students' active participation towards a cause or the accomplishment of a task" (p. 4). Some basic and common qualities of behavioral engagement in a particular task emerge when the studies on behavioral engagement are examined. *Positive behaviors* such as completing the task, *negative behaviors* such as distraction from the task, *participation* in learning such as asking questions to get more information, *persistence* in continuing to do the task although it is difficult, and *effort* such as doing the best one can on the task have constituted behavioral engagement in a specific task according to the studies on behavioral engagement (Annetta, Minogue et al., 2009; Finn, 1993; Finn et al., 1995). In addition, there is not enough discussion on students' deep level engagement such as willingness, commitment, and persistence while completing a task in the literature (Fredricks et al, 2004).

Survey items on behavioral engagement. Many qualities mentioned above related to behavioral engagement are captured in the engagement instrument designed for this study to understand the actual source of behavioral engagement. The researcher also

leveraged from the reversed (R) items in the survey to achieve results that are more reliable. The items "I participate in discussion on fractions" and "I ask my friends or teachers for a help when I can't solve difficult fraction problems" are included to analyze students' participation and interaction (Finn, 1993; Kong et al., 2003). In addition, items on persistence include "When I see difficult fraction problems, I stop working on them (R)", "Sometimes I skip difficult fraction questions (R)", and "When I make mistakes in fractions, I work until I correct them" (Arici, 2008; Kong et al., 2003; Pierce, Stacey, & Barkatsas, 2007; Pintrich et al., 1991). To analyze the effort and diligence with which students perform, items, "I work hard at fraction tasks" and "At home I review fraction problems that I did not understand in school" are included to the survey (Arici, 2008; Cretchley, 2008; Marks, 2000; Pintrich et al., 1991; Shapka & Keating, 2003). In terms of the items related to *student on task*, two survey items were added to the survey based on Research Assessment Package for Schools (RAPS) (Institute for Research and Reform in Education [IRRE], 1998), Fredricks et al. (2005), and Annetta, Minogue, et al. (2009). "I follow my teacher's directions on fractions" and "I sometimes pretend as if I am studying fractions on math class (R)" are expected to define behavioral qualities of engagement. With these items, the researcher expects to measure students' behavioral engagement.

Research has shown that students with higher levels of behavioral engagement—exhibiting more effort and being persistent in completing tasks— tend to have greater academic achievement (Annetta, Mangrum, et al., 2009; Finn, 1993; Pintrich et al., 1991). Finn (1993) examined student participation in school and classroom activities, and students' behavioral engagement with a nationwide sample of eighth-grade students. The

results showed that students' levels of engagement and their academic achievement were positively correlated (Finn, 1993).

Cognitive Engagement

Similar to behavioral engagement, the research studies on cognitive engagement are related to school engagement (Finn et al, 1995; Fredricks et al., 2004). However, the researcher is interested in examining students' cognitive engagement on task specific activities. Educators concur that classroom activities should be designed in a way to encourage students to become more cognitively engaged in tasks (Blumenfeld & Meece, 1988). Investment in learning which includes self-regulation or thinking strategically is the part that cognitive engagement is established (Annetta, Minogue, et al., 2009; Fredricks et al., 2004). According to the literature, measures for cognitive engagement concentrated on investment in learning are missing. As mentioned previously, cognitive engagement is considered difficult to be measured because it is less observable than behavioral engagement and it can be measured with internal indicators such as self-regulation (Appleton et al., 2008).When literature on cognitive engagement is examined in detail, it is seen that some researchers divide cognitive engagement into two sub-levels; surface level and deep level of engagement which include meta-cognitive strategies such as self-regulation (Annetta, Minogue, et al., 2009; Blumenfeld & Meece, 1988; Kong et al., 2003).

For superficial level of cognitive engagement -sometimes referred to as surface level engagement- students seek help or avoid effort while dealing with the task (Fredricks et al., 2004). Researchers can assess students' superficial engagement by asking them questions during task completion. If students make their best guess, try to do

the work, and get over with it (Blumenfeld & Meece, 1988), or if they skip the hard parts of the task (Fredricks et al., 2004), they have not reached deeper levels of cognitive engagement. Furthermore, memorization is also considered as superficial level of engagement although it is identified as a rehearsal strategy (Kong et al., 2003; Pintrich et al., 1991). Memorization does not necessarily connect prior knowledge to the new information; however, it demonstrates us that students are attempting to engage with the content. Although these criteria are called "surface level" and they focus on "superficial" skills; they address a part of cognitive engagement that needs to be measured to understand the qualities of engagement.

In terms of high level engagement (some authors referred as deep level strategies), students need to go beyond the surface level and use metacognitive strategies such as planning, monitoring, and evaluating their cognition and learning while completing task(s) (Hoffman & Nadelson, 2010; Pintrich & De Groot, 1990). Students who use these high-level strategies during the task are considered cognitively engaged, self-regulated, or strategic students based on how researchers define engagement.

Self-regulation. According to Fredricks et al. (2004), researchers should consider including survey items from the self-regulation literature or observational techniques that assess the quality of cognitive engagement. Blumenfeld and Meece (1988) assessed cognitive engagement by measuring dimensions of self-regulated learning: attention, connecting, planning, and monitoring. As Hoffman and Nadelson (2010) state, "individuals who are cognitively engaged use self-regulation strategies to *plan, monitor,* and *evaluate learning*" (p. 247). Besides, researchers who write about cognitive engagement or self-regulation, or both, use the terms interchangeably, as high cognitive

engagement can be achieved by using self-regulated learning strategies (Blumenfeld & Meece, 1988) to promote deep understanding (Fredricks et al., 2004).

Therefore, the researcher has used items related to self-regulation to assess students' cognitive engagement. For example, students are asked if they miss some important points because they were thinking about something else to assess the *monitoring* dimension as monitoring activities include tracking of one's attention (Pintrich et al., 1991). They are asked if they set goals for themselves when they study a topic so that they can plan it before they start studying and try to reach their goal within the *planning* dimension of self-regulation**.** Furthermore, students are surveyed on their *regulating* dimension of self-regulation by asking if they change their strategy if they cannot reach their objective. According to Pintrich et al. (1991), regulating refers to "the fine-tuning and continuous adjustment of one's cognitive activities" (p.23). Besides, checking their knowledge as they learn is also considered as a regulating activity (Pintrich et al., 1991).

Survey items on cognitive engagement. All of the qualities mentioned above related to cognitive engagement and self-regulation theory are addressed in the engagement instrument designed for this study to determine the actual sources of cognitive engagement. For example, an item on cognitive engagement, "Sometimes I follow my best guess when I do not know the answer" is asked to indicate the superficial level of cognitive engagement (Blumenfeld & Meece, 1988). Another item on superficial level of cognitive engagement "I memorize important facts to understand fractions better" aims to indicate memorization (Cretchley, 2008; Kong et al., 2003; Pintrich et al., 1991). Other items such as, "I try to connect fractions to real life situations", "I try to think

different ways to solve fraction problems", and "I try to develop my own strategy when I solve fraction problems" are asked students to assess the high level cognitive engagement (Fredricks et al., 2005; Kong et al., 2003; Pierce et al., 2007; Pintrich et al., 1991).

In terms of the items on self-regulation, "When doing the tasks, I try to figure out which parts I don't understand well" is included to analyze students' regulating strategies; two items for monitoring strategy are asked with "When I study fractions, I ask myself questions to make sure I understand it correctly" and "I often think about something else when I study fractions (R)"; two items on regulating strategy, "When I can't solve a fraction problem, I try to change my strategy", "At home I think about what I learned about fractions" are included in the survey based on the literature (Arici, 2008; Blumenfeld & Meece, 1988; Fredricks et al., 2005; Kong et al., 2003; Pintrich et al., 1991). With all of these items, the researcher expects to assess students' cognitive engagement during the task.

Cognitive engagement in learning tasks is often considered a strong indicator of student engagement (Pintrich & Schrauben, 1992). When self-regulation strategies are used to enhance learning, students will be engaged and this will lead to high levels of cognitive engagement. This judgment is supported by Greene and her colleagues' study in which 220 high school students completed a series of questionnaires related to self-regulation over three months (Greene, Miller, Crowson, Duke, & Akey, 2004). Path analysis was used to test the predictions that motivational variables such as self-efficacy, instrumentality, and goals influence students' cognitive engagement and achievement. Their results showed that motivational factors did predict students' cognitive engagement

and achievement. These motivational factors might suggest establishing the emotional engagement domain of the survey provided in this study.

Emotional Engagement

When researchers examine students' emotional engagement (in some studies it is called affective engagement), the most common qualities of emotional engagement are the positive and negative affective reactions that students show or feel in the classroom such as *interest, happiness, willingness, desire, enjoyment, boredom, sadness, worry,* and *anxiety* (Fredricks et al., 2004; Skinner & Belmont, 1993). In some studies, emotional engagement is considered as motivational engagement where *interest, value,* and *affect* are combined for a particular task (Hoffman & Nadelson, 2010). Further, studies on engagement related to school examine having positive or negative feelings for school, belonging to school, and giving value to the school (Fredricks et al., 2004). However, in this study, rather than focusing on the emotional engagement at school level, students' feelings on specific tasks as well as the *positive and negative reactions* – such as *happiness* and *boredom* – (Skinner & Belmont, 1993), *high involvement* with the task (Fredricks et al. 2004), and *losing track of time and space* (Csikzentmihalyi, 1988) are considered as the shared qualities of emotional engagement.

The distinction between emotional and behavioral engagement is clearer than the difference between behavioral and cognitive engagement. The qualities of emotional engagement mentioned above are basically the externalized version of feelings that are observable from students' physical appearance (for example, from students' face) whereas, behavioral engagement is the externalized version of conduct that one can see from the students' physical activities (for example, students trying to participate in the

activities). However, it is difficult to differentiate the qualities of emotional engagement from the motivational research (Fredricks et al., 2004); because there are various emotions such as interest, willingness, and value that can also be considered as qualities of motivational research. However, if researchers attempt to delineate emotional engagement, for example directing questions or items toward a specific task, the source of emotional engagement can be differentiated from motivational research, as Fredricks et al. (2004) suggest. Therefore, rather than asking questions more suitable for a general definition of emotional engagement, this study addresses more differentiated questions in terms of specific qualities or tasks of emotional engagement. By asking task-specific and quality-specific questions to the students, the researcher is expecting to explore the source of students' emotional engagement.

Moreover, as mentioned in the section on cognitive engagement, there are surface and deep level forms of emotional engagement as well. Focusing on the positive and negative reactions does not differentiate the high involvement in the task from the surface level of engagement (Fredricks et al., 2004). Yet, according to the literature, flow theory makes this distinction as it describes a state of complete assimilation or simply engagement in an activity and a flawless experience (Csikzentmihalyi, 1988, 1996). For this reason, it provides an appropriate foundation to better define emotional engagement.

Flow theory. According to Csikzentmihalyi (1988; 1996), the flow state is explained as the situation where individuals abandon their self-consciousness. Individuals said to be exhibiting flow do not realize how fast the *time* has passed (hours become minutes for them), and they lose the track of *space* (Csikzentmihalyi, 1988; 1996). These high-level qualities of engagement occur when individuals are focused and concentrated

on the tasks. Moreover, the balance between the challenge of the task and players' interest defines the power of the engagement (Hoffman & Nadelson, 2010). According to Fredricks et al. (2004), the definition of flow provides a conceptualization that represents high emotional involvement or investment. Therefore, the researcher is focused on these qualities to assess students' affective reactions and high level of involvement as an indicator of emotional engagement.

Survey items on emotional engagement. Many of the qualities mentioned above related to emotional engagement and flow theory are addressed in the engagement instrument designed for this study to reveal the actual sources of emotional engagement. Mainly focusing on the qualities of interest, and positive and negative emotion such as "I am interested in learning new things in fractions", "I do not like attending math classes (R)", "Learning fractions is fun", "I feel bored when I study fractions (R)", "I feel excited when I study fractions in math class", "I am excited about solving difficult fraction problems", "I like to study other subjects rather than fractions (R)", "I feel happy when I study fractions" are included in the survey (Arici, 2008; Connell & Wellborn, 1991; Fredricks et al., 2005; Kong et al., 2003; Marks, 2000; Pierce et al., 2007; Pintrich et al., 1991; Skinner & Belmont, 1993; Connell & Wellborn, 1991). Two items on flow theory related to losing the sense of time and place "Time passes very quickly when I study fractions" and "I tend to lose track of where I am when I study fractions" are also included in the survey (Brockmyer et al., 2009; Chou & Ting, 2003; Fu, Su, & Yu, 2009; Hoffman & Nadelson, 2009). An item on desire "I want to spend more time solving fraction problems" is also placed in the engagement survey (Arici, 2008). With all of

these items, the researcher expects to analyze students' emotional engagement in the current study.

Summary. The critical point of this section on the three dimensions of engagement is that while measuring all of these three dimensions, specific qualities and tasks are addressed to reveal the indicators of each engagement type. As Fredricks et al. (2004) suggested, "Incorporating domain-specific measures can help to determine to what extent engagement represents a general tendency and to what extent it is content specific" (p. 69). Although it is difficult to distinguish the motivation literature from the engagement literature, same applies for behavioral and cognitive engagement as there are many intersections between these two constructs. For example, students might like the topic because they might be very interested in the topic (emotional-affective), or they might want to understand the topic well (cognitive-deep level), or they might want to do the activities easily (behavioral-diligence). Understanding the real source of this kind of engagement is a challenge, therefore the qualities of engagement should be addressed relative to the target task (Fredricks et al., 2004).

Assessing each domain with all of their qualities *in detail* is not feasible due to the time constraints. To get the most reliable data, researcher needs to question each quality; however, it is not possible to ask numbers of questions to the students particularly in an actual classroom setting as students' span of time on task is limited. However, addressing the most distinct qualities of each engagement type in the survey has been attempted to be able to make an assumption for each domains (Figure 2).

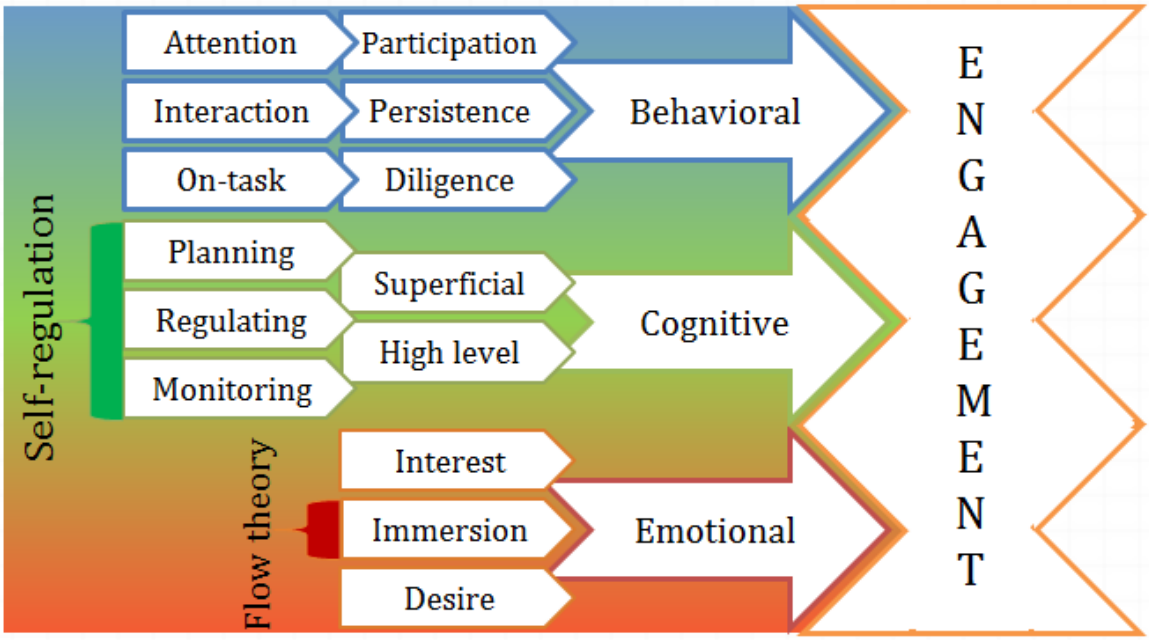

Figure 2. Conceptual representation of the constructs symbolizing the qualities of three engagement domains.

To measure students' engagement within three domains, research has been done on the related technologies used in teaching and learning mathematics. The researcher attempts to refine the measurement of engagement and test it in the context of using appropriate technologies. Hence, most appropriate technologies beginning from paper-and-pencil to concrete materials and from computerized environments to virtual manipulatives have been examined. Related literature is presented in a general sense to discuss their use and how they help students engage more in mathematics. Since disengagement in mathematics has been a serious issue in education (Kong et al., 2003).

Traditional Technologies for Mathematics

"There is a fundamental difficulty in the learning of mathematics" (Noss, Healy, & Hoyles, 1997, p. 203). One of the most challenging problems in learning and teaching mathematics is its abstract content. In response, the National Council of Teachers of

Mathematics (2000) emphasized the integration of suitable technologies into lesson plans while teaching mathematics. Suh et al. (2005) state that technology is important in understanding, enjoying, and improving mathematics content and teaching. Many technologies such as concrete materials, computers with various mathematical software, virtual manipulatives, and educational computer games have been used to engage students in mathematics and to improve students' achievement. No matter what technology is used, the central research priority is always "to find ways to help students build these links between seeing, doing, and expressing to research how mathematical meanings are structured by the tools available" (Noss et al., 1997, p. 207).

The development of software programs continues to guide mathematics in a new direction. New technology programs offer more than traditional methods to incorporate mathematics into classrooms to teach mathematics concepts and to promote thinking skills in mathematics (Smith, 2006). However, these technologies need to provide more than procedural knowledge for students.

As seen in the results of international studies, paper-and-pencil methods do not provide a solution to make meaning in mathematics (Noss et al., 1997); however, concrete equivalents of mathematical concepts have been found to engage students in mathematics learning (Greeno, 1988). The use of physical manipulatives to demonstrate mathematical concepts has been under discussion for years (Suh & Moyer, 2007) because it might help students to connect their procedural and conceptual knowledge (Balka, 1993). Some examples of these mathematical manipulatives are geoboards, bean sticks, Cuisenaire rods, and tangrams (Burns & Hamm, 2011). Although concrete materials were found to be effective in teaching mathematics, they were not widely used in classrooms

because of difficulties involving classroom management, assessment, insufficient supplies of manipulatives (Kim, 1993), as well as the problem of lost manipulatives (Smith, 2006). Simply using *matches* for learning and teaching algebraic expressions in mathematics works for visualizing algebra; however, using only concrete materials such as matches might lead algebraic contents to be presented too simplistically (Noss et al., 1997). Therefore, a variety of computer software packages have been developed to present more enriched environments for students' mathematical thinking (Kim, 1993; Noss et al., 1997). Recent studies on computerized devices have shown that students are able to understand mathematical activities, even though they do not provide a physical relation with the objects (Clements, 1999; 2002). Mathematics software were developed in the areas of drill-and-practice, tutorials, and games, but drill-and-practice types of activities have always been preferred by teachers (Kim, 1993). However, according to McCollister et al. (1986) computerized learning environments present activities that are more engaging than traditional teaching and learning environments.

Virtual Manipulatives

One main concern about young children who use computers for learning is that computer environments are not concrete and; "what is 'concrete' to a child may have more to do with what is meaningful and manipulable than with physical characteristics" (Steen, Brooks, & Lyon, 2006, p. 375). One of these environments is virtual manipulatives. With innovations in technology, concrete manipulatives and their features are integrated and enhanced with computers, creating a new level of manipulatives (Burns & Hamm, 2011). Virtual manipulatives help students link their previous knowledge of abstract concepts of mathematics on various topics to their virtual

equivalents (Suh, 2005). Virtual manipulatives are interactive, online visual representations of mathematical objects that allow students opportunities for constructing their conceptual mathematical knowledge (Moyer et al., 2002). The National Library of Virtual Manipulatives (NLVM), built by a team at Utah State University, has provided access to students and teachers to leverage this type of uniquely interactive, web-based virtual manipulatives or concept tutorials tool at no cost (NLVM, 2011). Virtual manipulatives offer unique characteristics in a two- or three-dimensional format. Teachers and students can alter the dimensions and color or create their own shapes. Therefore, many research studies have been conducted to analyze their effectiveness, and some have found a positive impact on students' engagement (Kim, 1993; Reimer & Moyer, 2005; Smith, 2006) and mathematical knowledge (Steen et al., 2006; Suh, 2005; Suh et al. 2005).

Many empirical research studies have pointed out that there is no difference in terms of learning mathematical subjects with respect to the use of concrete manipulatives and virtual manipulatives (Burns & Hamm, 2011). However, when both virtual and physical manipulatives are used together, they have been reported as very productive tools in terms of learning and engagement when used with different groups of students in a variety of contexts (Ainsa, 1999; Suh & Moyer, 2007; Terry, 1995). In terms of characteristics, virtual manipulatives, however, include more features or options and expand on what a physical manipulative can offer (Steen et al., 2006). A key ingredient of physical and virtual manipulatives is the actions and manipulations afforded to them (Burris, 2010). Furthermore, the activities of virtual manipulatives were found to provide immediate and specific feedback, they were easier and faster to use than the traditional

methods, and they provided enjoyment (Reimer & Moyer, 2005). Although limited number of empirical studies has been conducted, in some studies, students' engagement has been examined after using virtual manipulatives (Drickey, 2000; Reimer & Moyer, 2005; Smith, 2006). Some research findings on students' engagement are presented in the next section.

Research on virtual manipulatives and engagement. Dorward and Heal (1999) describe the virtual manipulatives as "concept tools" that engage students (as cited in Burris, 2010, p. 40). In addition, Reimer and Moyer (2005) found enhanced student enjoyment while learning with virtual manipulatives. In one study, most students verbalized a desire for the virtual manipulatives at the beginning of the study and anecdotal comments from students supported that students *enjoyed* using either concrete or virtual manipulatives (Burns & Hamm, 2011). Comments from students who used the virtual manipulatives included "we thought the website was fun and entertaining" (Burns & Hamm, 2011, p. 259).

Kim (1993) conducted a study with 35 kindergarten students in two classrooms. Using qualitative data (anecdotal observation and videotapes), students were more engaged in the virtual manipulatives group than in the control group with concrete manipulatives. Therefore virtual manipulatives provided students more interesting learning environment than concrete manipulatives did. However, the author did not find any significant difference between two groups in terms of achievement. For the current study, the researcher suggested doing activities with virtual manipulatives under regular classroom conditions.

In a classroom study of the use of virtual manipulatives and fractions with third grade students, Reimer and Moyer (2005) worked with 19 third grade students for two weeks on fractions. Lessons were taught to students using virtual manipulatives through a computer connected to a television. Students worked in a computer lab for four days to identify parts of a whole and parts of set in addition to comparing fractions. During the first week, students became familiar with the virtual manipulative applet. The following week, students participated in direct instruction lessons. Student scores on pre-test and post-test were analyzed in conjunction with a survey of student attitudes. According to students' attitudes questionnaire, the majority of the students were enjoyed the virtual manipulatives. Students enjoyed working with the virtual manipulatives and they thought they were fun to use. According to the researchers' observations, students were engaged in the activities during class sessions. The study found statistically significant results when students work with virtual manipulatives to learn about fraction concepts (Reimer & Moyer, 2005).

Drickey (2000) observed students while they were studying with virtual manipulatives and found that all students were actively engaged and 95% of the students were found on-task during their time in front of the computer. In the concrete and no manipulatives groups students were observed as being off-task, walking in the classroom, talking socially with their peers, or sleeping (Drickey, 2000). The estimation for the concrete and no manipulatives group students' on task was 50% (Drickey, 2000).

Smith (2006) examined 39 fifth grade students who were randomly assigned to two groups. One group worked with physical manipulatives while the other worked with virtual manipulatives to learn addition and subtraction of integers for one week and

algebra for the second week. The study compared the use of integer tiles and virtual integer chips while the algebra classrooms compared Algeblocks and virtual algebra tiles. Although no statistical significance was achieved, the researcher claimed that virtual manipulatives provide affordances for students through positive engagement and time-on-task as well as positive attitudes towards using virtual manipulatives. Finally, the study concluded that both physical and virtual manipulatives should have a place in today's mathematics classrooms (Smith, 2006).

Steen et al. (2006) did a research study with first graders. 31 students were introduced to virtual manipulatives while exploring geometric concepts and they were studied in two groups -physical versus concrete-. For 13 instructional days, students in the control group worked with physical manipulatives while students in the experimental group worked with virtual manipulatives. According to the treatment group teacher's observations regarding the student attitudes, behaviors, and interactions; the results showed increased instructional time, more repetition of practice activities, higher time-on-task, and more feedback compared to control group teacher's observations (Steen et al., 2006). The researchers found that students showed increased motivation and challenged themselves to higher levels in the treatment group. Although students in the treatment group outperformed the control group on the post-tests, these results were not statistically significant (Steen et al., 2006).

In some studies, virtual manipulatives games such as Fraction Tracks Game were played by the students however; they were not empirically analyzed in terms of their effect on engagement (Suh et al., 2005). One of the main drawbacks of these game environments is that they present drill-and-practice type of exercises and most of them

cannot avoid presenting conceptual knowledge related to the course content. Moreover, researchers who have been studying virtual manipulatives assert, "simply using manipulatives does not insure learning" (Reimer & Moyer, 2005, p. 7).

As a result, many studies concluded that virtual manipulatives provided a higher level of engagement for students than concrete manipulatives and student attitudes toward virtual manipulatives were mostly positive (Kim, 1993; Drickey, 2000; Smith, 2006). However, as can be seen, most of the studies have used observational data and studies have not been supported with quantitative data to measure students' engagement.

Research studies on virtual manipulatives have not gone beyond the comparison studies on analyzing students' engagement, motivation, achievement, attitudes, and perceptions towards various kinds of mathematics subjects. In addition, the question of which qualities of technologies have the most impact on students' various domains of engagement in mathematics has not been adequately replied. However, with the advances in the technology and video games, educational researchers have also begun to give importance on the design of educational games and they attempt to integrate more qualities in educational mathematics games. Therefore, educational games are also considered to pursue an exciting and interesting investigation area to assess students' engagement, specifically in mathematics.

Educational (Digital) Games

Beginning in 2001 and growing massively in 2008, educational game research has received timely attention from learning scientists, educational researchers, and instructional designers and technologists. Since 2008, the National Science Foundation (NSF) has awarded more than 15 educational game related projects and allocated more

than 25 million dollars for those projects (NSF, 2011). These numbers might indicate that the US government also believes in the importance of the emergence of using educational games as a research area in educational settings to increase students' engagement and achievement. As clarified in the introduction, educational games have been described in this study as any type of instructional game that can be played with computerized systems, such as video games, computer games, and/or mobile games to foster learners' academic and psychological growth (such as learning gains, skills, experiences, motivation, and engagement). Game is an interactive problem-solving activity that has goal(s), conflict(s), rule(s), challenge(s) to engage players (Schell, 2008). Among the published work on educational games containing keywords such as "games", "educational games", "digital games", "computer games", and "mobile games" in top journals, it is noted that the number of studies on educational games has increased.

There may be various reasons for this trend, but one might be that today's *Net Generation* or *digital natives* do not seem to be engaged and do not perform well with the current instructional strategies (Gee, 2007; Hirumi, 2010). A second factor might be the increased popularity of video games (van Eck, 2006). In 2010 alone, consumers spent $15.9 billion on video games and $9.23 billion on game hardware and accessories (Entertainment Software Association [ESA], 2011). More importantly and recently, instructional games have recently been seen as one of the most effective tools for learning and instruction (Kebritchi, 2008; Kebritchi & Hirumi, 2008). A report published by the Federation of American Scientists (FAS) (2006) suggested incorporating games into schools would be beneficial and stated that, "people acquire new knowledge and complex skills from game play, suggesting gaming could help address one of the nation's most

pressing needs – strengthening our system of education and preparing workers for 21st century jobs" (p. 3). This emphasizes the necessity of integrating educational games in the American system of education to be able to develop better and more qualified students for the future.

The number of research studies on educational games increase in accordance with the video game industry. Various types of educational games and media have been used to conduct educational research. Although many educational games have been used in various research studies for years, they have been tested in different platforms including video games, mobile games, and virtual manipulative games, with the purpose of improving students' engagement within the specific content, such as mathematics social sciences, language arts, or science. In addition to using various platforms for educational games, research on a variety of learning outcomes and skills such as problem-solving (Dempsey et al., 1993), knowledge transfer (Barab et al., 2009), and drill and practice (Liu & Chu, 2010; Papastergiou, 2009) have been conducted. Nevertheless, selected researchers have rightfully questioned some of the positive claims about educational games due to insufficient empirical support (Randel et al., 1992).Other researchers have asserted that educational games have been found to improve engagement (Annetta, Mangrum, et al., 2009; Huizenga, Admiraal, Akkerman, & ten Dam, 2009), achievement (Ke & Grabowski, 2007; Tuzun, Yilmaz-Soylu, Karakus, Inal, & Kizilkaya, 2009; Yip & Kwan, 2006) and resulted in significantly higher levels of motivation (Ebner & Holzinger, 2007; Ke, 2008a; 2008b).

According to the literature, there are important gaps to be filled with empirical research in the target area to evaluate the use of educational games in terms of

engagement. In the engagement section, it is made clear that engagement and achievement have a significant relationship. While presenting the literature reviews, the researcher wanted to direct readers' attention to the point between engagement and learning. Therefore, the relationship between engagement and educational games is presented first and the relationship between learning and educational games is presented later. Although researchers have found that engagement is the most important predictor for learning gains (Appleton et al., 2008; Bodovski & Farkas, 2007), it is still a question that needs to be answered for educational game research studies. As there are mixed results in different literature reviews, in this section, important literature reviews by researchers interested in educational game research are presented and discussed in chronological order. One reason for presenting the literature reviews from the earliest to the most recent is to highlight differences evoked by the period, the technology used, and the referent learning theories.

Pierfy (1977) conducted the first literature review on educational games. In his work, Pierfy (1977) showed that students demonstrated high interest in game activities based on results comparing 22 educational game studies. However, the researcher's general findings suggested that students' learning with educational games was not more effective than traditional classroom instruction. Another literature review conducted by Randel et al. (1992) concluded that, in 12 of 14 studies, students showed more interest in educational games than in traditional classroom instruction. However, they also found that, among 68 studies on games covering 28 years, 38 (56%) showed no differences between games and traditional instruction, 27 (38%) favored games, and only 3 (4%) favored classroom instruction (Randel et al., 1992).

Dempsey et al. (1993) reviewed 51 journal articles on gaming literature. As mentioned in the introduction, educational games were used mainly for drills and practice; therefore, one of the interesting findings from their study was that most games were used to teach new skills (23%) and practice existing ones (21%). For some papers, they could not determine this (14%) because the articles were not clear enough to understand the game functions. Another important finding concerned the learning outcomes of the studies; they found that games were used mostly for problem-solving (23%), followed by *attitude* (13%) (Dempsey et al., 1993). According to their literature review, one might also conclude that some game research studies were not properly explained to get enough information about the studies.

Hays (2005) found no evidence to indicate that educational games were a preferred method of instruction in all situations based on a review of 48 empirical studies. In addition, he concluded that empirical research on the effectiveness of educational games was fragmented and filled with ill-defined terms and methodological flaws (Hays, 2005). This might be one reason of finding no significant difference in educational game research. Randel et al. (1992) commented on the methodological weaknesses in most of the studies they examined as well. Hays (2005) concluded that, even though educational games support effective learning for different types of students, areas, and tasks such as mathematics, attitudes, electronics, and economics, it is not known whether it is best to use an educational game for a specific instructional task. He stated, “We should not generalize from research on the effectiveness of one game in one learning area for one group of learners to all games in all learning areas for all learners” (Hays, 2005, p. 6).

In the most recent literature review, Kebritchi et al. (2010) found that educational games promoted students' motivation in 4 of 16 studies, improved students' achievement in 9 of 16 studies, and made no difference in students' achievement or motivation in 5 of 16 studies. Their literature review indicated that educational games are not always effective learning tools. Prensky (2010) agreed that educational games cannot solve all our current educational and instructional problems, of course, but he stated that they could help as an instructional tool "to help reach and teach the currently unreached and untaught" (p. 8).

Based on the literature reviews done so far, one conclusion is that there are still mixed findings in terms of the effectiveness of educational games. As shown in the first two literature reviews on educational games, although students showed more interest in educational games, no difference was found between traditional instruction and educational games. However, there has been an increasing trend in educational game research toward more positive results, starting with *no difference* studies and continuing with more *positive differences* research on educational games. Although, earlier literature reviews showed no relationship between achievement and educational games, recent literature reviews have proven the opposite. Possible reasons for finding mixed results in the literature reviews of educational game research might be that the researchers have not limited their literature reviews by a) highly-cited journals, b) robust studies, and c) time. Furthermore, methodological flaws in empirical studies related to educational games are important factors that prevent researchers from drawing conclusions about the effects of educational games on engagement and learning (Kebritchi, 2008; Randel et al., 1992). Moreover, in current research on educational games, new technologies and learning

theories have been used; limiting the educational game research studies by time might be a better way to analyze the literature. In addition to focusing on educational game research studies published recently, researchers need to rely on better quality journals to get results that are more reliable from their literature reviews.

Therefore, a very detailed and up-to-date literature review is needed to point out the current situation of the educational games research clearly. The gaps need to be filled in order to improve the quality of educational game research and contribute to the educational game literature. Therefore, the research papers on educational games and their impact on *engagement* published in the top journals according to Social Science Citation Index (SSCI) database from 2001 to 2011 have been investigated to see the existing situation of the educational game studies in the last decade. *Australasian Journal of Educational Technology(AJET), The British Journal of Educational Technology (BJET), Computer Assisted Language Learning (CALL), Computers and Education (C&E), Educational Technology & Society (ETS), Educational Technology Research & Development (ETR&D), International Journal of Computer-Supported Collaborative Learning (IJCSCL), International Journal of Science Education (IJSE), Journal of Computer Assisted Learning (JCAL), Journal of Science Education and Technology (JSET),* and *Innovations in Education and Teaching International (IETI)* were selected for analyzing the related research on educational games. The main reason for selecting those journals is that they have been widely accessed and are recognized to having high impact factors as released by the Institute for Scientific Information (ISI) Journal Citation Reports.

For this purpose, among hundreds of the articles published in those journals, only research studies conducted with an educational game within a context to increase students' *engagement and motivation* are chosen for this literature review. The reason motivational studies are added to the literature review is that two concepts -engagement and motivation- are used interchangeably in some studies (Fredricks et al., 2004). Studies on students' attitudes have also been added to the literature review is because some attitudes involve the qualities of engagement described in this study, such as value and enjoyment (Ke & Grabowski, 2007). All other kinds of articles such as book reviews, letters, and editorial sections were excluded. After a thorough analysis and filtering the papers, the articles suitable with the purpose were selected to do a literature review. A total of 31 articles related to educational games to increase student engagement, motivation, and attitudes were found among hundreds of articles.

Results of the literature review showed that there is an increase in the number of the empirical research in educational games and their use in enhancing engagement. The most number of educational game research studies have been published in this year (n=10). 2009 (n=7) and 2010 (n=5) were also very productive in terms of educational game research on engagement, motivation, and attitudes. The increased number of research studies on educational games might be a result of the interest in educational games and the funding opportunities provided by the government stated above. Among 31 articles reviewed, 35% of the *target group of students or participants* in the articles (n=11) published in top journals is elementary school students -between 6-11 years old/from first grade to fifth grade students-. The ease and feasibility of doing research with elementary school students and their increased interest in games might be the two

most important reasons why that age group is the most targeted sample groups in educational game research studies. Actually, this is also true for other studies in education because elementary school students are in the same class and it is easier to do experimental research with them. Another reason might be to detect and solve the learning problems starting from the beginning with elementary schools. This finding has showed the potential benefit for this research to define the target group of students to study because when the literature is examined, there is a need for more research studies to prove the effectiveness of using educational games in mathematics with elementary school students to improve engagement.

As the researcher has to study a specific *content* using educational games to analyze engagement, research studies on engagement and the courses used in those studies have been investigated. Mathematics is found to be one of the most researched areas as it has been argued in the literature. There are problems in learning and teaching mathematics starting from primary schools and researchers in education try to focus more on mathematics in their research (n=7) (Ke & Grabowski, 2007). Furthermore, 85% of the mathematics research on educational games was done in primary/elementary school students (6 out of 7 studies). In response to this finding, the research questions of this study are drawn because it is also stated in many research studies that although there are research on mathematics using educational games, there only small number of rigorous studies (Shin, Sutherland, Norris, & Soloway, 2011). In addition, there are only four studies focused specifically on engagement and no studies have been conducted on engagement by using mathematics as target content. Although there are many studies on

primary school mathematics, what is missing in educational game research studies is an analysis of elementary school students' engagement in mathematics.

In summary, according to the literature review on educational games published in the top journals in the area of educational technology, there is a growing body of research on educational games. As discussed previously, today's students are growing up with more technology than before and there are more technological tools in classrooms. Educational games are only one of them. According to the literature reviews, educational games are used primarily in elementary schools for mathematics course although there are no studies examined students' engagement. Therefore, an empirical research study on educational games to see their impact on students' engagement is expected to make an essential contribution to the literature. The next section will provide more details about whether using educational games might have an effect on students' engagement.

Research on educational games and engagement. Although a theoretical definition made above, one can easily understand the definition of engagement while kids are playing video or computer games. In commercial games, there are many physical (i.e. shaking the controller), visual (specific details) and auditory (sounds, screaming) elements in the screen in order to be able to direct players' attention easily. During the game play, kids do not even listen to what is told, as they are focused on the happenings in the gameplay. In one study, where the brain activities of game players were examined, researchers created a stressful environment for the players, but they were so engaged by the game that they did not respond to the discomfort and noise (Johnson, 2007). Sometimes they were startled, scared, and mad when they lost the game as they made a deep connection with the game. They also had the opposite feelings such as happiness,

success, and confidence when they won. The pleasure they received from the game experience such as cheerfulness and satisfaction is another emotional engagement predictor (Chou & Ting, 2003). Replaying/Restarting the same level of the game repeatedly is only one example of their behavioral engagement for a game (Hoffman & Nadelson, 2010). Thinking strategically in order to finish the game with more points is an example of the cognitive engagement that researchers can leverage to measure another predictor.

According to the definition of engagement provided before, it is expected from educational games research to measure the qualities of such an engagement in order to identify the game attributes to buckle students up for learning. This is what educational researchers should attempt to achieve as teachers and parents complain about their kids not paying enough attention and not focusing well enough. Therefore, there have been research studies conducted on using educational games with students and how it affects their engagement (e.g. Amory, 2010; van der Spek et al., 2011; Watson, Mong, & Harris, 2011).

Charles et al. (2009) state that educational games can improve student engagement for learning and this will increase the students' achievement and allow students to encounter rewarding experiences. However, there are also mixed results in terms of the effect of educational games on engagement when the literature is examined. Huizenga et al. (2009) concluded from their observational data that the students had strong active engagement in the assignments done with the educational game. In addition, Annetta, Minogue, et al. (2009) found similar results indicating that students who played educational games were more engaged in the content. In another study, Annetta,

Mangrum, et al.'s (2009) observational data analysis suggested high student engagement during the educational game play. As understood, most of the research studies on educational games have focused on engagement in general rather than breaking engagement into domains. Therefore, these findings reinforce the critical need for further research aimed at isolating and documenting the behavioral, cognitive, and emotional impact of using educational games (Annetta, Minogue, et al., 2009).

Skoric, Teo, and Neo (2009), in their study, found that game engagement has no significant negative influence on academic achievement in elementary school children. Thus, students who are engaged in playing games do not differ in terms of achievement (Skoric et al., 2009). Unlike the general tendency that students who are playing games are unsuccessful at school subjects, the research showed no significant difference between game playing and achievement at school. However, when the literature on engagement is examined, one of the most important anchors is the studies proved that engagement is the most important predictor for achievement (Appleton et al., 2008; Bodovski & Farkas, 2007). Therefore, more research is needed to understand if engagement yields academic achievement in educational games as well.

In another study, Kiili (2005) used flow theory as a framework to engage students in learning to maximize the impact of educational game environments. In his study, 18 university level students studied through an educational game, IT-Emperor. He also studied on the factors that have an influence on flow experience by collecting data from questionnaires and interviews. Positive connection between flow and learning was found in this study. The results indicated that educational game provided an environment for students to experience flow. One inference might be that, as it was mentioned in the

emotional engagement section, when qualities of flow theory are taken into account while choosing the most appropriate educational game (as it is done in this study), it is expected to increase students' emotional engagement. It is also supported by Hoffman and Nadelson (2010) that gaming is a very suitable environment to do research on emotional engagement as it increases players' intrinsic motivation, positive affect, and many aspects of the flow experiences mentioned earlier.

When examining the current educational games research literature specifically on engagement, 15 studies were identified on engagement. Eleven of them found significant or positive difference while four of them found no difference or no positive effects. In other words, 73.3% of the studies related to the effect of educational games on engagement found that students were engaged during the game-play in the target content area. However, as mentioned before, more research studies on different domains of engagement is needed to understand the causes of engagement to increase students' achievement. One important inference from the educational game studies is that most of the researchers have not used an instrument to assess students' engagement; instead, they preferred to use observational data, recordings, and interviews (Annetta, Mangrum, et al., 2009; Echeverria et al., 2011). Besides, those qualitative observations need to be verified through an experimental investigation (Ke, 2008a). This result shows an important gap to be filled for future educational games research. Therefore, founding the research on an underlying theory for engagement and creating a valid and well-founded instrument to assess students' engagement will contribute to the educational game literature.

When the educational game literature specifically focused on engagement is examined in regards to the learning theories, most of the games are not supported by a

theory or theories framing their use to increase engagement. In some, there seems to be a theory behind the game, but the theory and the game are not matched very well in terms of their individual attributes. For example, in the current literature review of 31 articles published in the top journals between the years 2001 and 2011 on engagement, at least in 6 articles, no sign of theory related to engagement was found. Even sometimes, learning or a teaching strategy behind the game is not found. This gap was also found by Hays (2005) in his literature review. Aside from the engagement theories such as flow theory or self-regulation theory, in some studies, researchers think that they use game-based learning as a background theory; however, the researchers are not aware that game-based learning is not actually a theory but a strategy to enhance learning and teaching. Therefore, in this study, the definition of engagement bases the research to examine the underlying qualities of students' behavioral, cognitive, and emotional engagement. Leveraging from the attributes of virtual manipulatives and educational games is expected to establish a relationship with various qualities of engagement mentioned previously.

Main Attributes of Virtual Manipulatives and Educational Games

According to the related literature review, there are some elements need to be placed to design an effective instruction and educational games. Since Malone's (1981) investigation on game attributes, number of researchers has suggested using games to engage them towards subjects (Sedighian & Sedighian, 1996). The researcher presents and evaluates more features in general by using two different scales while describing the educational games used in this study in chapter 3. However, c*lear goals* every step of the way, *immediate feedback* to one's actions, balance between *challenges and skills* are the

fundamentals that this study is focused by using virtual manipulatives and educational games (Atkinson & Hirumi, 2010; Bowman, 1982; Csikzentmihalyi, 1996; Gee, 2007, 2010a, 2010b; Kiili, 2005; Prensky, 2001, 2010; Sedighian & Sedighian, 1996; Squire, 2003; Wilson et al. 2009). Bowman (1982) explains that:

> The power of video games lies in the fact that they are action systems where skills and challenges are progressively balanced, goals are clear, feedback is immediate, and unambiguous and relevant stimuli can be differentiated from irrelevant stimuli. Together, this combination contributes to the formation of a flow experience (p.15).

Based on Sedighian and Sedighian's (1996) suggestion, the researcher attempted to investigate attributes of learning environments such as educational games and virtual manipulatives and how they might have an effect on students' engagement. When good games are analyzed in depth, one can see that these three features –clear and achievable goals, immediate feedback, and balance between challenges and skills are the common features in all good games and they are tied together or dynamically integrated in most games and other learning environments. Therefore, following sections discuss about these three features in detail.

Goal. When we talk about games, oftentimes finishing or beating the game is the ultimate goal but there might be some intermediate goals in the game (Sedighian & Sedighian, 1996). However, if a game does not provide a clear goal to the player to pursue, the player will not know what to do next and how to proceed in the game. Same applies to any type of learning environment such as virtual manipulatives. If students are not given a clear goal, they will not know what they need to do. If the goal is challenging

for them, it will become engaging. Most of the researchers clearly state that games should provide clear goal(s) for students, as they know what to do next and what they are going to achieve at the end (Bowman, 1982; Charles et al., 2009; Garris et al., 2002; Gee, 2010a, 2010b; Hirumi, Appelman, Rieber, & van Eck, 2010; Hoffman & Nadelson, 2010). Additionally, goals are tied with the rules and mechanics of the learning environments. When games are taken as example, they present the goal at the beginning and they tell how players can reach that goal by introducing the game elements such as how to play the game. When clear goals are presented, players start working to reach that goal and many of them show persistence to achieve the goal. Based on the description and qualities of a goal, it is considered as addressing the behavioral part of the engagement. This type of classification might help researcher to establish a connection between game attributes and domains of engagement.

According to Garris et al. (2002), meaningful game contexts that provide various and hierarchical goal structures do increase achievement. Besides, multiple level educational games are considered to provide high levels of engagement (Gee, 2003). As understood, goals and challenges are interrelated within game environment. Many researchers (e.g. Bottino et al. 2007; Ke & Grabowski, 2007) used educational games that have multiple levels so that players can finish one level by reaching the objectives for each level. This feature also helps researchers and teachers let students play the game according to students' potential (Bottino et al. 2007).Therefore, setting achievable and challenging goals that are on the edge of the students' skills (zone of proximal development-ZPD) will provide engaging environment for students to play game and to keep them play. Garris et al. (2002) also state that clear and specific goals enable players

to understand the relationship between goal and feedback, which are the essential elements in triggering greater attention and motivation. Besides educational games that have clear, challenging, and specific goals suitable with target students' skills enhance students' performance (Shin et al., 2011). In Kebritchi et al.'s (2010) study, students stated that educational games were effective as they challenged them to learn mathematics.

Feedback. As a part of the assessment, most of the games and online learning environments in the market provide *immediate feedback* if the students are doing something right or especially wrong. Prensky (2008) also argues that knowing to do right or wrong will increase students' engagement. In addition to this, feedback can help students to understand the errors made (Werts, Caldwell, & Wolery, 2003). In educational games, students should also know what they are doing and how they are doing, so the games should be designed to give *constant*, *immediate*, and *unambiguous feedback* to the players/students (Csikzentmihalyi, 1996; Malone, 1981; Sedighian & Sedighian, 1996; Wilson et al., 2009). Many researchers confirmed that some activities of virtual manipulatives provide immediate and corrective feedback (Reimer & Moyer 2005; Suh & Moyer 2005).

Feedback on students' performance keeps them progress toward the main goal according to Garris et al. (2002). Becker (2007) states that there should be sufficient positive feedback for correct actions and it must be continuous during the whole game; but it can also be a final evaluation at the end of each stage/level. Moreover, it can be presented in various forms such as verbal, visual, or score (Wilson et al., 2009). According to Gee (2007), one of the reasons why video games are so motivating and

engaging is because of their ability to provide "explicit information both on-demand and just-in-time, when the student needs it or just at the point where the information can best be understood and used in practice" (p. 138). In addition, Delacruz (2010) state that using feedback in educational games to engage students in learning is a noticeable gap in related literature. Moyer et al. (2002) also suggested doing research on the attribute of feedback with virtual manipulatives.

As can be understood, feedback might provide students self-regulatory strategies such as regulating, monitoring, and evaluating as students adjust their thinking or strategy based on the feedback they receive. Furthermore, they try different ways to figure out the problem when they received a feedback indicating that they are doing wrong. When they understand that they are doing right based on the feedback, they continue to think in the same way or use the same strategy. Checking their knowledge is considered as a regulating activity (Pintrich et al., 1991). Based on the description and qualities of feedback, it is considered as addressing the cognitive part of the engagement. This classification of attributes is also consistent with the engagement survey designed for this research.

Challenge. Malone (1981) and Malone and Lepper (1987) mention challenge as an integral feature of games and they argue that challenge makes educational games more engaging. In any type of educational game, there should be balance between challenges and skills so that the students should not get bored (when the challenge is too easy for their skills) or frustrated (when the challenge is too hard for their skills) (Malone, 1981; Garris et al., 2002; Wilson et al., 2009). Therefore, an optimal level of difficulty is required (Malone, 1981; Garris et al., 2002). Challenges in the game play need to be

directly related to the goal(s) of the game and players' skill(s). As Csikzentmihalyi (1996) states, "In a really enjoyable game, the players are balanced on the fine line between boredom and anxiety" (p.111). Besides, Malone (1981) believes that there should be multiple levels of difficulty to adjust the game difficulty for students by providing skill levels. These difficulty levels should be progressive according to Garris et al. (2002) and Sedighian and Sedighian (1996). According to Becker (2007) people enjoy games and learn from games when they can achieve the goal but not very easy.

Challenge is mainly related to the emotional part of engagement as it "adds fun and competition by creating barriers between current state and goal state" (Wilson et al., 2009, p. 230). Sedighian and Sedighian's (1996) interviews with students also revealed that challenge means not to be bored for almost all students. As described previously, there is a thin line between boredom and anxiety and these qualities of challenge demonstrate that it is directly associated with emotional engagement.

Summary. Indeed, there are tens of learning environment and/or educational game attributes in the literature. However, little attention has been given to the manipulation of these attributes in learning environments with respect to their impacts on student engagement with different domains. In their article, Wilson et al. (2009) attempted to categorize sources of various game features with specific learning outcomes in three domains as skill-based, cognitive, and affective. This study expects to contribute to the literature on three game features by categorizing them with specific engagement domains. Although these attributes of educational games have not been categorized as triggering behavioral, cognitive, and emotional domains of engagement, the researcher has begun attempts to classify them based on their qualities explained previously in the

literature (Figure 3). Similar to the three domains of engagement with their sub-domains, these three game features are also interrelated with each other. It is very hard to differentiate them in terms of triggering the engagement. Although scholars might argue about the specified domains of these attributes, it is essential to make it clear once again that these are mainly game features as described in the previous paragraphs. However, based on the literature, this type of classification with more qualities might let researchers take a step further to create more engaging learning environments addressing behavioral, cognitive, and emotional domains.

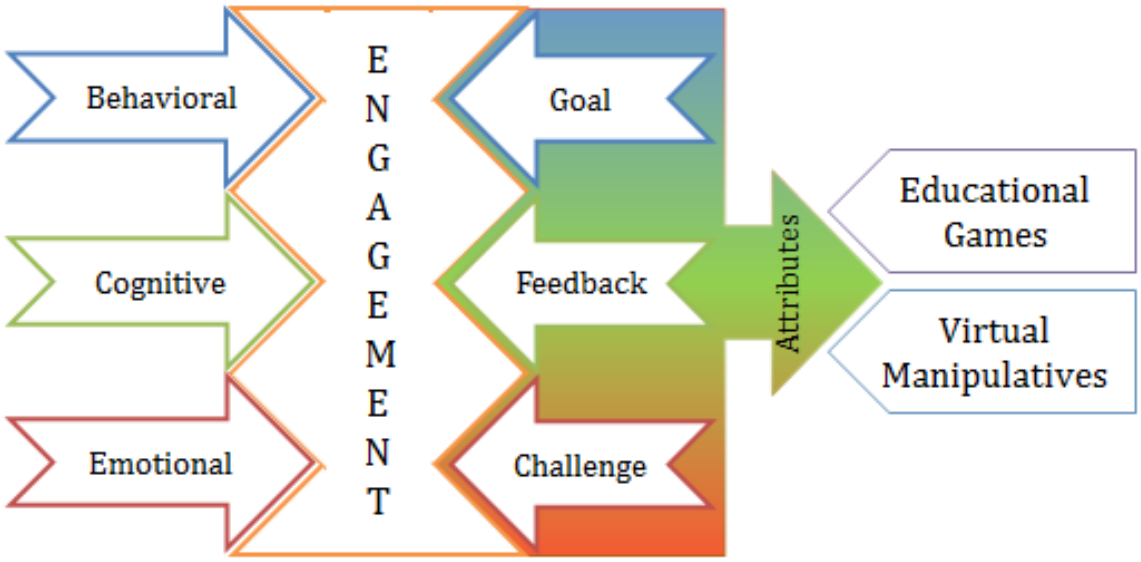

Figure 3. Matching game attributes with three domains of engagement.

Research Purpose and Questions

As evidenced in this chapter, late elementary early middle school students are performing poorly in mathematics, especially in fractions. Research shows that educational games and virtual manipulatives are used to engage students more into the content. Therefore, employing a pre-and-post-test control-group design, the purpose of this dissertation study is to design and develop an engagement instrument with three

domains and measure fifth grade students' mathematics engagement using educational games and virtual manipulatives as experimental groups by leveraging their unique attributes in comparison to paper-and-pencil drills as a control group.

Based on the preceding review of literature, three research questions have been appeared concerning the research on educational games and virtual manipulatives and their effect on engagement. More specifically, the following research questions were identified and provided the basis for the subsequent study:

1. Do experimental group students demonstrate significant difference in terms of their engagement than control group students?
    a. If yes, do experimental group students demonstrate significant difference in terms of their behavioral, cognitive, and emotional engagement than control group students?
2. Do students playing educational games demonstrate significant difference in terms of their engagement than control group students?
    a. If yes, do educational games group students demonstrate significant difference in terms of their behavioral, cognitive, and emotional engagement than control group students?
3. Do students using virtual manipulatives demonstrate significant difference in terms of their engagement than control group students?
    a. If yes, do virtual manipulatives group students demonstrate significant difference in terms of their behavioral, cognitive, and emotional engagement than control group students?

Hypotheses

The research questions given above were explored by conducting a quasi-experimental research study that investigated the use of educational games and virtual manipulatives with the experimental groups and paper-and-pencil drills with control group. As educational games and virtual manipulatives allow students to have more interactive and enhanced learning environments, the target participants might be differently engaged after the game playing, virtual manipulatives, or paper-and-pencil drills. Based on the review of the literature concerning the educational games, virtual manipulatives, engagement, and mathematics, the following hypotheses were proposed:

1. Students who are in experimental groups will score significantly higher on the engagement survey than the students in control group.
    a. Students who are in experimental groups will score significantly higher on the engagement survey in three domains (behavioral, cognitive, and emotional) than the students in control group.
2. Students who play the educational games in the experimental groups will score significantly higher on the engagement survey than participants who do the paper-and-pencil drills in the control group.
    a. Students who play the educational games in the experimental groups will score significantly higher on engagement survey in three domains (behavioral, cognitive, and emotional) than participants who do the paper-and-pencil drills in the control group.

3. Students who do activities with virtual manipulatives in the experimental group will score significantly higher on the engagement survey than participants who do the paper-and-pencil drills in the control groups.
    a. Students who do the activities of virtual manipulatives in the experimental group will score significantly higher on engagement survey in three domains (behavioral, cognitive, and emotional) than participants who do the paper-and-pencil drills in the control group.

As evidenced in the hypotheses, it is expected that there will be significant differences in the engagement post-test survey between the participants in the experimental groups when they are exposed to the educational mathematics games and virtual manipulatives related to fractions and the participants in the control groups when they do the paper-and-pencil drills. Chapter 3 details the study design, participants, instruments, pilot study and results, data collection procedures, and data analysis techniques related to the methodological approach to be undertaken to answer posited research questions.

Chapter 3: Methodology

This chapter details the methods and design that have been developed to address the research questions for this study and describes the participants, instruments, pilot study, data collection procedures, and data analysis techniques. The purpose of this study is to measure fifth grade students' mathematics engagement in the context of using educational games and virtual manipulatives as compared to the control group students who use paper-and-pencil drills. The findings of this study provide insights into the theoretical and practical implications for applying educational games and virtual manipulatives within the actual classroom environment. Game researchers, educators, parents, and policymakers might use this study as a reference on important issues related to educational games, virtual manipulatives, and these new media forms because new media have changed how youth socialize and learn by creating a new set of issues (Ito et al., 2008).

Study Design

Randel et al. (1992) pointed out in their literature review on educational games that more experimental design for game research studies were needed. It was also suggested that confusing variables needed to be removed from experimental designs (Randel et al., 1992). Moreover, using tests right and using the right tests were also suggested because they are the researchers' essential data sources for good research because researchers need to more carefully measure what they want to measure with the instrument.

Therefore, considering these suggestions, by employing a pre-test-post-test quasi-experimental design, this study attempts to measure the effects of engagement in the

context of using educational games, virtual manipulatives, and paper-and-pencil drills on mathematics. In quasi-experimental studies, "the investigator uses control and experimental groups but does not randomly assign participants to the groups" (Creswell, 2003, p.167). In this study, the researcher used each classroom as an intact group as either experimental or control group. The groups were selected by the school board based on their discretion. Students' engagement is the outcome variable. The four groups -two educational game, one virtual manipulative, and one control- are the predictor variables. In this between-subject design, the researcher compared the experimental groups -educational games and virtual manipulatives- with control group -paper-and-pencil drill- in terms of students' engagement in general and in three domains. The participants' engagement measured by the engagement survey as a self-report (Appendix B) serves as the dependent variable in this study. The engagement survey was designed by the researcher and it was validated through expert views, pilot testing, and item analysis. The reliability results are presented in chapter 4.

The research took place in four classrooms in four different public elementary schools in southwest Virginia during regular school hours. Students participated in the study during their regularly scheduled mathematics class periods. Of these four classrooms, one classroom was assigned as control group (paper-and-pencil drills group), one classroom as first experimental group in which students played an educational game called Candy Factory (X1), one classroom as second experimental group in which students played another game called Pearl Diver (X2), and one classroom as the third experimental group in which students did activities with virtual manipulatives (X3), and one classroom was assigned as control group (paper-and-pencil drill group) (X4) (Table

1). The educational games, virtual manipulatives, and paper-and-pencil drills that students used during the study were all about the same topic, fractions. As each classroom was in a different school and each group had a different mathematics teacher. Using different teachers in each group might affect validity of the treatments due to classroom and teacher differences but administration of the treatment conditions was consistent because the researcher provided scripts and step-by-step guides for each teacher to follow from the beginning of the study until the end. In addition, during the whole treatment process, a researcher or an instructional technologist was in place to ensure the treatment fidelity. At the beginning and at the end of the two-week study, the engagement survey (O2) was distributed to all of the groups to measure the effect of treatments (X1, X2, X3, and X4) on engagement and compared the results of the control group. Further, the learner characteristics survey (O1) was given to the students to collect demographics, game-playing conditions, computer skills, and parental information. Also, the game features survey (O3) was distributed to the educational game group students to be able to describe three game features mentioned previously in the literature review section. Figure 4 illustrates the research design of this study by providing a classic notation system.

Group A (Experimental Groups)	O _____ X _____ O

Group B (Control Groups)	O _____ O

Figure 4. Nonequivalent (pre-test and post-test) control-group design (Creswell, 2003)

The research design of the experimental and control groups with instruments and treatments is demonstrated in Table 1.

Table 1

The research design of the experimental and control groups with instruments and treatments

Groups	Number of the classrooms	Day 1	Day 2 Day 6	Day 3 Day 7	Day 4 Day 8	Day 5 Day 9	Day 10
Treatment (educational game – Pearl Diver)	1	O1O2	X1	X1	X1	X1	O2O3
Treatment (educational game – Candy Factory)	1	O1O2	X2	X2	X2	X2	O2O3
Treatment (virtual manipulatives)	1	O1O2	X3	X3	X3	X3	O2
Control group (paper-and-pencil drills)	1	O1O2	X4	X4	X4	X4	O2

X1= Experimental Group (Educational game – Pearl Diver game)
X2= Experimental Group (Educational game – Candy Factory game)
X3= Experimental Group (Virtual manipulatives)
X4= Control Group (Paper-and-pencil drills)
O1= Learner characteristics survey
O2= Engagement survey
O3= Game features survey

During the researcher's visits to classrooms, the researcher observed students, took notes, helped students and teachers. Yet, unstructured observations and field notes were not analyzed to make interpretations. There were no anticipated risks, compensation, or other direct benefits. The participants knew that they were free to withdraw their consent and discontinue participation at any time without any consequence. Each participant was identified by a code number provided by the school board. The sheet chart matching participants to identification numbers was kept by the teachers.

Participants

The county that the research was conducted has 162 fifth grade students in seven classrooms in four schools. It is located in southwest Virginia in the United States of

America. In the county. there are five Hispanic, two Black, 145 White, and eight multiple race students in those four schools according to the statistics retrieved from Virginia Department of Education (VDOE) (2011). Students varied in gender: 47% were female and 53% were male. According to the 2010-2011 Standards of Learning (SOL) student descriptives, there were 74 economically disadvantaged and 80 economically not disadvantaged fourth grade students in those four schools. Hence, the researcher might state that this study was done in urban area where almost half of the students were economically disadvantaged. In terms of measuring the engagement effect using the educational games and virtual manipulatives, studies have neglected to include students who have lower levels of skills, knowledge, and socio-economic status. There were no migrants or homeless students in those schools (VDOE, 2011). All of the students were proficient in English and all four schools have met the required objectives set by the No Child Left Behind program in mathematics (VDOE, 2011).

However, only four classrooms out of seven were consisted the sample to collect data for this study. In four classrooms, there were 92 students according to the numbers given by the school board. Among these students, six students did not want to participate in the study or did not bring their parental consent forms; therefore, they were excluded from the study. As a result, 86 students participated in this study (N=86) (Table 2).

Table 2

Frequencies table for groups

Classes	Groups	N
Pearl Diver Game Group	Treatment 1	19
Candy Factory Game Group	Treatment 2	17
Virtual Manipulatives Group	Treatment 3	23
Paper-and-Pencil Drill Group	Control	27
	Total	86

There were multiple reasons why fifth grade students were chosen as target participants for this study. According to the Virginia Department of Education, the fifth grade classes at the four participating schools have had failure rates of 12%, 7%, and 5% in the last three years on the Standards of Learning (SOL) tests (VDOE, 2011). Percentages of the last two years were above the state level. However, according to the fourth grade SOL mathematics results, there was 18% of fail rate in all schools last year. Therefore, there was a request from the school board to increase their achievement percentages in mathematics because the fourth graders of last year were the fifth graders of the current year. As mentioned in the engagement section in the literature review, engagement is the most important predictor of achievement (Appleton et al., 2008).

Second, as it was mentioned previously, the chosen topic, fractions is important at this stage of their mathematics learning. According to SOL in mathematics, late elementary and early middle school students should be able to recognize and name commonly used fractions in their equivalent decimal form and vice versa. Third, fifth grade students are together in one class and it is feasible for the researcher to create groups and collect data. Finally, according to mathematics SOL for fifth grade students, the students at this stage are required to use engaging concrete materials and appropriate technologies, therefore the game application and virtual manipulatives on fractions to be used in the classroom setting was considered appropriate for fifth grade students. Participation in the study was voluntary and students were informed that they could leave the study whenever they desired. Yet, all participants were expected to participate in the pre-test, treatment, and post-test processes. The students who did not participate were guided by the teacher and did other activities or worksheets at the teachers' discretion.

The researcher, teachers, and students developed positive relationships with each other during the two-week treatment process as they were interested in using educational games and virtual manipulatives as assisting tools of teaching and learning.

Instrumentation and Materials

Learner characteristics survey (Appendix A), the engagement survey (Appendix B), and game features survey (Appendix D and E) were the instruments to collect and analyze data for this study. In addition to these instruments, the Candy Factory game and the Pearl Diver game were used as materials in each experimental group separately. Applets from the National Library of virtual manipulatives designed by Utah State University were used for the other experimental group. The control group students used paper-and-pencil drills designed by the researcher. All of the instruments and materials used in the study are explained in the following paragraphs. Besides, the researcher developed scripts, step-by-step guides (Appendix O, Appendix Q, Appendix S, and Appendix U) and walkthroughs (Appendix P, Appendix R, and Appendix T) for each experimental and control group teachers to guarantee that students in all groups received enough explanation and direction for all of the activities and steps during the study.

Learner characteristics survey. The students' background information such as their gender, age, experiences with technology, parental controls, and game conditions were collected with this describe to understand students' demographics. Descriptive statistics are presented in chapter 4. Although they might have had an influence on students' engagement, they were not used as variables to analyze in this study.

Engagement survey. In regards to engagement survey, the items based on the survey items and studies of Annetta, Minogue, et al. (2009); Arici (2008); Blumenfeld

and Meece (1988); Brockmyer et al. (2009); Chou and Ting (2003); Connell and Wellborn (1991); Cretchley (2008); Finn (1993); Finn et al. (1995); Fredricks et al. (2005); Fu, Su, and Yu (2009); Hoffman and Nadelson (2010); IRRE (1998); Kong et al. (2003); Marks (2000); Pierce, Stacey, and Barkatsas (2007); Pintrich and De Groot (1990); Pintrich et al. (1991); Shapka and Keating (2003); Skinner and Belmont (1993); Sweetser and Wyeth (2005); Connell and Wellborn (1991). The items were used to identify probable variables affecting student engagement in three domains (See Appendix C for more detailed information about the engagement survey).

Developed from previous research studies on engagement, *The Students' Engagement Survey* consisted of 33 items involving three domains (11 behavioral, 11 cognitive, and 11 emotional items). All items employed a 4-point Likert scale (1= Strongly disagree, 2=Somewhat disagree, 3=Somewhat agree, and 4= Strongly agree) after each item was revised in terms of wording and grammar to make the items appropriate for the fifth grade students. In the engagement survey, some of the items were designed more generic in terms of mathematics engagement; however, some items were created to measure on-task engagement considering the fractions tasks that students did during the treatment. Therefore, the researcher attempted to examine the change between students' responses on pre-and-post engagement survey. For example, students' responses to the items such as "Learning fractions is fun" are examined to see if there is any difference in students' emotional engagement before and after the treatment. The researcher tried to focus on the fraction activities that students did during the two-week treatment (educational games, virtual manipulatives, and paper-and-pencil drills).

Validity. In terms of *face validity*, self-reports or surveys are considered as reasonable way of collecting data on engagement, as literature suggests that it is hard to define students' cognitive and emotional engagement as they are inferred (Oncu, 2007). Experts stated that the engagement survey seemed to be well designed. To ensure *construct validity* of the engagement survey, first theoretical relationships were specified in chapter 2. Second, empirical relationships between the items and concepts were examined to check if items are measuring what they need to measure (Appendix C). To ensure *content validity*, experts in education and psychology were asked to provide feedback on each item. Individual items, their domains (behavioral, cognitive, and emotional), and their relationships with engagement in general discussed with experts in the field based on the literature review in chapter 2. Next, the engagement survey went through three-phase pilot study to revise, edit, and validate the items. The items in the survey were designed as task-specific because of the definition of engagement made for this study. Therefore, the engagement survey was expected to contribute to the instructional technology literature especially when researchers would like to analyze participants' engagement in three domains. The reliability analysis of the survey is presented in chapter 4.

Game features survey. Game features survey was designed to present what students thought about the three game attributes that the researcher focused on this study. The researcher would compare the statistics of game features survey and the engagement survey to see if they corroborated with each other. Therefore the question is, will students' engagement scores in the educational game groups support the game features survey statistics? In order to answer this question, three similar game features surveys

have been used to design the survey (Fu, Su, & Yu, 2009; Hays, 2010; Sweetser & Wyeth, 2005) (Appendix D and E). The original items of these researchers' scales are consisted of various heuristics on usability, playability, instructional issues, game mechanics, and attributes. They are described in detail in the following section. As described in the literature review section, students were asked about only the three game features –goals, feedback, and challenge-. The researcher expected to match these attributes to the results of the engagement survey. The reason behind why the researcher applied the game features survey to only educational game group students was that it was designed based on the survey items and studies of Fu et al. (2009), Hays (2010), and Sweetser and Wyeth (2005). Their surveys were designed to evaluate the game features with various criteria. However, the researcher could not find an instrument to measure the features of virtual manipulatives to base the survey. Because of the validity issues that may arise, the researcher did not revise the original items to make them suitable with the activities of virtual manipulatives as they were designed to measure what they meant to measure –educational game features-. The survey consists of 13 items in three domains. There are three items for goals (items 1, 2, and 3), four items for feedback (items 5, 6, 11, and 13), and six items for challenge (4, 7, 8, 9, 10, and 12). The items were put on a 4-point Likert scale (1= Strongly disagree, 2=Somewhat disagree, 3=Somewhat agree, and 4= Strongly agree). Each item was revised in terms of wording and grammar. The game features survey was shared with the experts in the field of education and educational game design to be able to get feedback for each item. Next, the game features survey was implemented for pilot study to revise, edit, and validate the items, similar to the engagement survey. According to Cronbach's alpha reliability analysis, the reliability of

the game features survey was found 0.716 that indicated a normal level of internal consistency for the survey with this specific sample of students. When the researcher deeply looked at the item-total statistics table, removal of item 12 would result in Cronbach's alpha to be 0.743 but the researcher did not delete the item because of the small sample of the students.

Educational games. Two educational games were used for this study -Candy Factory and Pearl Diver games-. The most important features of these two games are that they enable clear goals, provide feedback, and present multiple levels of difficulty for students. Before gameplay, students were explicitly provided with important instructional goals that were aligned with students competencies in terms of challenges and these attributes were essential in educational game research studies, as they resulted in more engaged learning (Hoffman & Nadelson, 2010; Ke, 2008a). Especially, multiple-level educational games are characterized as providing high levels of engagement (Gee, 2007). Therefore, the educational games that have more than one level were used in this research to analyze students' engagement.

In addition to considering having multiple levels as an important feature of the games, Hays' (2010) *Instructional game evaluation scale* (Appendix F) and Sweetser and Wyeth's (2005) *GameFlow criteria for player enjoyment in games* were used to choose the most appropriate and effective games to be used in this study (Appendix G). As mentioned in the previous section, they were also used to create game features survey to collect data on students' thoughts about the game features focused in this study. The researcher utilized criteria from the instructional game evaluation scale and GameFlow scales. The instructional game evaluation addresses instructional quality, playability, and

technical quality (Hays, 2010). The game flow criteria include concentration, challenge, player skills, control, clear goals, feedback, immersion, and social interaction (Sweetser & Wyeth, 2005). The researcher wanted to provide proof for why these instructional games were used for this study. To evaluate these two educational games, the researcher used 5-point Likert type evaluation for both games as it was suggested by the authors (Hays, 2010; Sweetser & Wyeth, 2005).

Hays' (2010) instructional game evaluation scale addresses three main issues with 14 criteria for a good instructional game. For instructional issues, the scale provides items such as "game activities increase in difficulty as learners' performances improve", for technical issues "there are no sensory conflicts in the game", and for playability issues; it provides items such as "game screens are aesthetically pleasing." In addition to support the Hays' (2010) instructional game evaluation scale, one of the criteria of playability (criteria number 14) specifically focusing on engagement "game activities are fun and engaging (attract and maintain learner attention)" is important for this study.

As engagement is the main variable of the study, the researcher also used GameFlow scale. Sweetser and Wyeth (2005) designed the scale to evaluate player enjoyment in games (Appendix G). Hence, the Candy Factory and the Pearl Diver games were evaluated to see if these two educational games had difference in mean scores. Hays (2010) also suggested using this type of additional, stand-alone criteria for engagement. While Hays' (2010) scale focuses on the instructional game elements, Sweetser and Wyeth's (2005) scale focuses on qualities of players' engagement from the perspective of the three domains mentioned in the engagement section. For example, an item related to concentration is, "game quickly grabs the players' attention and maintain their focus

throughout the game", as for challenge, "challenges in games match the players' skill levels", for player skills, "players are rewarded appropriately for their effort and skill development", for control, "players feel a sense of control over the game shell (starting, stopping, saving, etc.)", for clear goals, "overriding goals are clear and presented early", for feedback, "players receive feedback on progress toward their goals", for immersion, "players become less aware of their surroundings", and for social interaction, "game supports competition and cooperation between players."

Most of these items are based on the studies of Csikzentmihalyi (1996), Malone and Lepper (1987), and Sweetser and Wyeth (2005). They all analyzed engagement and come up with the ideas, qualities, and items of engagement, therefore, after a thorough examination of the existing games related to the target topic (fractions), the researcher analyzed the games according to these two scales and found the mean scores of each (Candy Factory Game *M*=3.58; Pearl Diver Game *M*=4.64).

Candy Factory. The Candy Factory game was designed by the Virginia Tech Learning Transformation Research Group. This game was selected after all the fraction games that were designed for the Apple iOS platform (i.e., iPod Touch, iPad) were inspected. Although the mean scores of the Candy Factory game was found lower than the other educational game, the game met many of the game flow criteria for player enjoyment in games designed by Sweetser and Wyeth (2005) (*M*=3.8 out of 5) (see Appendix G) in addition to the Hays' (2010) instructional game evaluation scale (*M*=3.57 out of 5) (see Appendix F). Scales were aligned with research questions of the study and the content of the proposed research study.

The Candy Factory game has three levels, starting from the easy tasks and continuing with hard tasks. The players receive a customer order as if they were the owner of the candy factory in specific chocolate bar and they try to produce the exact size of the customer order by partitioning and iterating the chocolate bar. When they think that they have the correct amount of chocolate bar, they measure the bar and ship it for the customer. The students receive feedback at the end of the game by explaining the proper fractions. The first level is easier because it gives partitioned candy bars, but in the subsequent levels, customer orders are received as whole chocolate bars without partitions. Therefore, it becomes more challenging for the students. When students practice their skills in Level 1, they can go to Level 2 and continue to play the game. Current version (v1.0) of the Candy Factory game reflects an application between an educational game and a virtual manipulative. That was one of the reasons that the Candy Factory game was selected for this study. In Appendix H, some screen shots from the gameplay are presented to show the game.

Based on the observations in the pilot study, the researcher realized that after some time playing the Candy Factory game, students were getting bored. Therefore, the researcher set some goals for each day for the Candy Factory game levels in order not to bore students during this two-week study and to provide a challenging atmosphere for the students. For example, for day 3, the objective for students was to ship at least 10 correct orders in 15 min in Level 1, and to ship 3 correct orders in 5 minutes in Level 2. For the last day of the treatment, students needed to write down a guess for what fraction the customer order is of the whole before choosing a number of partitions. After they shipped the candy bar, they needed to compare their first guess with the correct order, using the

symbols (<, >, =). For the last day, they needed to ship at least 12 correct orders in 5 min for Level 1, 7 correct orders in Level 2 in 5 minutes, and another 7 correct orders in Level 3 in 10 minutes (Appendix O).

Pearl Diver. The Pearl Diver game was selected after all the fraction games that were designed for the Apple iOS platform (i.e., iPod Touch) were inspected in terms of their usability and playability according to the GameFlow Criteria for Player Enjoyment in Games (*M*=4.45 out of 5) by Sweetser and Wyeth (2005). The game has met most of the criteria designed suitably with the flow theory (Appendix G); therefore, those criteria serve the best for selecting the game to measure student engagement. The researcher used the instructional game evaluation scale designed by Hays (2010) to analyze its appropriateness for the classroom use (Appendix F). Overall it was found better than the Candy Factory game based on Hays' scale (*M*=4.83 out of 5).

The Pearl Diver is a number line math game designed by New Mexico State University (NMSU) Learning Games Lab. The game helps students learn the number line while diving for pearls amidst shipwrecks and sunken ruins. It is suitable for grades 3-8. The game has clear instructional objective for students. The Pearl Diver game addresses number and operations standards - such as number line sense, whole numbers, decimals, mixed numbers, and fractions. It has nine levels in it, starting from the easy ones and continuing to the hard ones. Players are challenged in each level so that they try harder after they lose the game. Players need to have the pearl diver dive in the correct number line to take out the minimum number of pearls within the limited time. If players dive into the wrong number line, they lose time and cannot get pearls in the given time. They can also see the correct number, fraction, or decimal when they dive in the wrong spot.

This is also considered as immediate feedback for the players. Players need to collect at least four pearls in each level. There is also an electric eel passing by the diver. Thus, players have to be careful about diving at the appropriate pace when the electric eel is not under the diver. If they touch the electric eel, they lose one of their three lives given for each gameplay. The electric eel also provides another challenge for players. At the end of each level, the game provides feedback by providing the scoring system. In Appendix I, some screen shots from the gameplay are presented to show the game. Besides, the researcher got the necessary permission from the NMSU Learning Games Lab team to be able to use the game in this research study (Please see the Appendix V).

Similar to the Candy Factory game, students had some goals set for each day to reach. Again, the reason behind this was to engage students more into the game play that students might get bored after third or fourth time of playing the same game without an objective. For example, students needed to finish Level 3 at least four times in 20 minutes on the second day. On the last day of treatment, students were expected to finish the whole game (Level 9) twice in 20 minutes. Those goals were set for classroom management purposes because teachers would have hard time dealing with the students after the first week of treatment when some of the students got bored playing the same game every day. Therefore, the researcher also needed to think the fidelity of the research in advance.

Virtual manipulatives. During the virtual manipulative treatments, students in one classroom used computers and internet to work on the website called the National Library of Virtual Manipulatives (http://nlvm.usu.edu/en/nav/vlibrary.html). The students worked specifically with the "Fractions – Adding", "Fractions – Comparing", "Fractions

– Equivalent", "Fractions – Naming", and “Fractions – Visualizing” applets in the grade 3-5 Number and Operation section. There are two reasons for choosing these 5 specific applets for this study. First of all, they are all related to fractions, and second, each applet has constructed activities for students to follow. Each applet has its own instructional objective and goal for students to accomplish. However, there are some other applets in National Library of Virtual Manipulatives where students can freely drag and drop the fraction pieces and color them without any instruction given but students in the virtual manipulatives group did not work with those activities.

To give examples, “Fractions – Adding” applet illustrates what it means to find a common denominator for two different fractions and add these two fractions (Appendix J). Students are presented with two fraction circles or squares that have different denominators. The computer asks students to rename the two fractions so that they have the common denominator. Students click on arrow buttons below the whole unit to change the number of parts. When they see that the lines and the colors match for both fractions with the same number, it means that they have found a common denominator. When a common denominator has been identified, students can type the names of the equivalent fractions into the appropriate boxes. They check their answers by clicking the check button that provides them immediate feedback on their actions. If the answer is wrong, either the applet gives directions to the students or it tells students that it is wrong. If their answer is correct, the computer takes them to the next step, where students need to add the two fractions either by combining fraction representations by dragging the fraction pieces into the white spot on the upper right corner of the screen called the sum circle or sum square or by typing the answer to the problem without dragging and

dropping the pieces. This applet has also difficulty level to challenge students more. It has three levels of difficulty (easier, harder, and hardest), students worked with all of them starting with the easier and continuing to the harder and hardest levels during the treatment (See Appendix S).

The “Fractions-Comparing” applet is the one that students need to judge the size of fractions and plot them on a number line. It is similar to fractions adding in terms of finding the common denominator. At the beginning, students need to find a common denominator for both fractions by increasing or decreasing the arrows. Similar to the fractions-adding applet, it provides feedback. When their answer is correct, in the next stage students are asked to find these two fractions in the number line. When they correctly locate the fractions, they are asked to find a fraction between these two fractions.

The “Fractions-Equivalent” applet illustrates the relationship between equivalent fractions, students are shown one fraction circle or square that they are asked to rename at least three different ways. Using the arrow key, students can divide the fraction into multiple parts, name the fraction, and check their answer. Feedback is provided for students’ actions. When students answer correctly, the applet asks students to name one more fraction for the same example. When wrong answer is given, the applet gives direction to the students to fix their answer.

In the “Fractions-Naming” applet, students write the fraction corresponding to the highlighted portion of a shape and simply check their answers. “Fractions-Visualizing” illustrates a fraction by dividing a shape and highlighting the appropriate parts. Similar to the “Fractions-Equivalent” applet, these two applets have integrated feedback system.

The researcher also got the approval from one of the principal investigator of the National Library of Virtual Manipulatives to be able to use them in this research (Appendix W).

As mentioned previously, all of the applets used in this study have clear instructional goals given by the applets and all of these applets were also designed in a way to challenge students every day. The researcher set goals for each day for students to reach. For example, in a given amount of time, students were asked to provide 20 correct answers in "Fractions-Naming" in 10 minutes for the first day and on the last day, it was 40 correct answers in 10 minutes. For each applet, students were challenged by accuracy and time during the two-week study (Appendix S).

Paper-and-pencil drills. While the students in the experimental groups did activities on fractions, students in the control group did paper-and-pencil drills on the same topic. The drills were designed according to the current fifth grade mathematics textbook that teachers and students were using. In addition to the textbook, the Candy Factory game, the Pearl Diver game, and the virtual manipulative activities were used as guides to design the drills because the control group students need to practice fractions similar with the experimental group students. The students in paper-and-pencil drills group also completed eight sessions with worksheets on fractions for 20 minutes in each session. Students were asked to hand in the worksheets as quickly and as correctly as possible. One sample example of paper-and-pencil drills is shown in the Appendix K. Similar types of questions were used for each session.

Pilot Study

In order to test the effectiveness of engagement survey, a pilot study was conducted in the Fall of 2011. The pilot study was expected to further the development

and design of the engagement instrument through gathering feedback on the suitability of the questions, levels of the questions, time spent on the questions, survey processes, structure, grammar usage, and term ambiguity. The pilot study helped refining the individual questions and procedures for the newly created instruments. The pilot study consisted of three phases. The first phase was focused on the testing the accuracy and clarity of the engagement survey with college and graduate students. The second phase of the pilot study was focused on testing the engagement survey and educational game with fifth grade students in the actual classroom setting. Finally, the last phase of the pilot study focused on retesting the revised survey, determining accuracy, and assessing the clarity of the instruments with elementary school students and graduate students.

In the first phase of the pilot study, a total of 30 college and graduate students answered the pre-and-post-tests of engagement survey. Each participant was asked to answer the survey to give feedback to the researcher in terms of clarity and grammar to see whether they were able to understand the items in the survey. In addition to providing sample data for each question in the engagement survey, participants were expected to provide unrestricted feedback on all aspects of the instrument including recommendations on how it could be improved. The researcher took notes while the participants were answering the survey items. This process was expected to provide a basis for refining the survey items. The results were important for items in the engagement survey as it expected to move it toward the next phase of the pilot study with fifth grade students. According to their feedback and the data analysis, weak items were removed from the engagement survey to increase the Cronbach Alpha reliability. No treatment was planned for the first phase of the study.

In the second phase of the pilot study, after making the required arrangements, making an informative session about the study, having meetings with the school board and the teachers, listening to their concerns, and answering the questions, official permission from the school was received so that Virginia Tech Institutional Review Board (IRB) could approve the pilot study. Once the teacher agreed to participate in the study, the teacher chose one of her classes to participate in the pilot. The students were recruited after their parents signed the *Parent/Guardian Permission Forms.* On the first day of the pilot study, students were informed by their teacher about the research that was going to be done in their classroom and asked whether they would like to participate in the study. Students were also informed that they could stop anytime when they felt frustrated or uncomfortable. Any student who wanted to withdraw from the study was going to do different activities guided by the teacher and rest of the students read and signed the *Student Assent Form* in the classroom. Student assent forms were signed and witnessed by the researchers and the teachers as well. Second, students were given an identifier (ID) in order not to use their personal information. Third, students were given the engagement survey with demographics information and they answered both instruments in 10 minutes. Finally students who were done with the instruments picked a number from the bag which contains number 1 (experimental group – educational game) and number 2 (control group – paper-and-pencil drills) to be assigned randomly to one of these two groups. The number of the students in each group was equal or close to equal. The first day of the pilot study ended with pre-test data collection.

On the next day of the pilot study, students were separated into two classrooms because of the confusion that might arise in the classroom. In the educational game

group, students were informed about the study and watched a video on how to play the game for approximately three minutes. Next, students were given iPod Touch and allowed to play the game for 20 minutes. The researcher took unstructured notes about what was working and what was not working while students were playing the game. After 20 minutes of game play, students were given the engagement survey again to answer in 10 minutes.

In the control group, the paper-and-pencil drills designed by the researcher by were distributed to the students. The students answered the practice questions in the paper-and-pencil drills for about 20 minutes and they were given the engagement survey that they answered in 10 minutes. The second phase of the pilot study took two days for approximately one hour in total.

Data analysis was done right after the pilot study with the fifth grade students. First of all, the reliability score of the mathematics engagement survey were found (Cronbach Alpha reliability index score was found 0.8149). The researcher found a score higher than 0.80 suggesting a reliable instrument. Analysis was done to find out which items showed high engagement level across students (Item 8 and 13) and which items showed low engagement level across students (Item 10) in order to take the precautions for those items. Besides, item analysis was done to increase the reliability of the engagement survey if an item deleted (If item 16 is deleted, Cronbach Alpha = 0.84). Findings helped to identify the items that had a low in reliability score and to refine the wording of the engagement survey items to serve fifth grade students better. More importantly, the researcher was able to experience how the technologies that were used in

the study would work with the students. Therefore, important insights were gained from the pilot study in order to realize a better treatment with fewer problems.

In the third phase of the pilot study, the researcher revised the instruments and applied them to different 10 elementary and middle school students and 10 graduate students again. The researcher focused on the timing of the instruments, vocabulary used in the instruments, and how they responded to the instruments. The final version of the instrument was given shape after the three phase pilot study.

Data Collection Procedures

The data collection procedure began in the spring term of 2011-2012 academic year. First of all, the researchers had meetings with the teachers and school board separately to inform all of the teachers about the study. Then, the dates were decided with the teachers to do the treatments in four schools and four classrooms. After getting official approval letters from the teachers and schools to do the research, approval from the Virginia Tech Institutional Review Board (IRB) to conduct the study was received (Appendix L).

The data collection procedure was done in three phases: 1) collecting consent forms and pre-test data from all participants, 2) 8 days of treatment in four different groups, and 3) post-test data collection on engagement from all participants. In the first phase, after distributing all of the parent consent forms (Appendix M) and getting them back, the classrooms were assigned to one of the four groups by the discretion of the school board. There were three treatment classrooms and one control classroom. Before the researcher gave students the Student Assent Form (Appendix N) and let them signed the forms and turned them back, the students were given an identifier by the school board

so that any information about the students was kept confidential. Second, the background information form, which has the demographic information about the students and pre-test for engagement survey, were distributed to all of the students in each group on the first day.

In the second phase, treatment was conducted starting from the second day until the last day for 8 consecutive days. One class of students played the Candy Factory game, the students in another classroom played the Pearl Diver game, and the students in the last classroom did the activities with virtual manipulatives eight times for 20 minutes. In total, students did the tasks for two hours and 40 minutes. Another challenge encountered in the literature is related to duration of the gameplay, most studies have not examined an individual game over a long period, or they have not let students play the game repeatedly. According to Randel et al. (1992), evaluators are required to spend enough time for students to become familiarized with the game in order to get the true results, especially if the game is complex. Each student played the game alone but the students had right to ask for help when needed during the treatment. Either the teacher or the researcher led the 20-minute sessions in each classroom based on the teachers' script and step-by-step guide provided by the researcher (Appendix O, Appendix Q, Appendix S, and Appendix U). The third phase of the treatment was the post-test data collection. The same engagement survey was distributed and collected at the end of the eight-day treatment.

As for the control group, students used paper-and-pencil drills for the same amount of time that each of the experimental groups spent on game play (Appendix K). According to the literature, another challenge was to allow the control group students to

have equivalent classroom time on the same subject, because the increase in engagement could be assumed due to the games or extra time that students spend on the subject matter. The same engagement instrument was distributed to and collected from the control group in the same manner as it was in the experimental groups (at the beginning and at the end of the study). The students in the control group could also ask for help and feedback from the teacher when necessary. The paper-and-pencil drills were designed to take about 20 minutes by the researcher.

Each engagement pre-test and post-test was designed to take approximately 10-15 minutes to answer and participants were informed about the time before each test. Therefore, the complete study took place within two weeks for approximately three to four hours. As this study was done in an actual school and classroom setting, there were naturally some constraints in terms of time, space, and resources; therefore, all of these conditions were considered to do the most effective treatment within these constraints.

Data Analysis Techniques

This study analyzed the students' engagement for each domain (behavioral, cognitive, and emotional) separately. Descriptive statistics were used to describe the students' general information, characteristics, and game features survey. Descriptive statistics provide a way to organize and describe the data in a meaningful way that helps to summarize the characteristics of the sample (Creswell, 2003). Descriptive data is not only useful for developing an understanding of the characteristics of the sample; it is also the starting point that supports other methods of statistical analysis that explore variable comparisons and relationships (Howell, 2007). In addition to the descriptive statistics, comparison of means, analysis of variance (ANOVA), Bonferroni, and Tukey HSD Post

Hoc analysis were applied to the pre-test and post-test data sets. The participants' responses to the engagement survey address three main domain of engagement, which are behavioral, cognitive, and emotional domains. Therefore, each domain was analyzed separately to understand the main causes of engagement for experimental and control groups by using the analyses mentioned above.

The items that form each domain of engagement were collapsed for each student so that a mean score was obtained. There were also reverse items in the survey and they were transformed into same variables where 1 changed to 4, 2 to 3, 3 to 2, and 4 to 1. The Coefficient Alpha reliability of the engagement survey items were analyzed and reported in the results section.

Each hypothesis was tested by using mean scores, standard deviation, and analysis of covariance (ANCOVA). The dependent variable of this study included: (a) the engagement pre-test (Engagement1) and (b) the engagement post-test (Engagement2). The engagement post-test was analyzed by using ANCOVA with LSD and Bonferroni Post Hoc analysis were applied by using the SPSS software program designed to examine the effect of treatment after controlling for the pre-test. ANCOVA is, "an extremely useful tool for analyzing experimental data" (Howell, 2007, p. 575). In order to see whether the difference of post-test results between control and experimental group stem from the treatment, engagement pre-test data (Engagement1) was taken into analysis as a covariate to place more control into the experiment because the researcher expects considerable variability in the pre-test activity. ANCOVA is more powerful than the corresponding one-way or two-way ANOVA adjusted by the linear regression. The inclusion of covariates in the model reduces unexplained variation and thus, it increases

the power of statistical analysis. In the analysis, .05 was regarded as the significance level.

Assumptions and Limitations of the Study

This study confines itself to conducting treatment and collecting survey data from the fifth grade elementary school students in a southwest Virginia in the academic year of 2011-2012. The results of this study were indications of effects of the Candy Factory, Pearl Diver games, virtual manipulatives, and paper-and-pencil drills on students' engagement. A limitation created by the nature of quasi-experimental studies, the assignment of classrooms by school board to either control or experimental groups decreases the generalizability of findings. The major assumption of this study was that students assigned to experimental or control groups were equal in terms of their engagement. None of these four schools used ability groups; therefore, it might be assumed that students were randomly placed in each classroom before the study. Therefore, the findings of this study are not intended to be generalizable to the population of all fifth grade students in United States. The generalization of the results is limited to the similar population using the same instruments and same educational games and virtual manipulatives for the same topic. A description of the games, virtual manipulatives, and the sample population have been provided in this chapter and chapter 2 to make it possible to use the results of this study in other similar situations. Besides, in this quantitative study, the findings can be subject to other interpretations.

In addition, the duration of the study, the number of the participants, and the teacher effect were other limitations of this study. Although the duration of the treatment seems to be short, a longer-length treatment does not seem feasible for this study as

teachers and students in the participated schools have limited amount of time that they can devote to use educational games, virtual manipulatives, and paper-and-pencil drills during their classroom time. Moreover, this study aimed to find a difference on students' immediate engagement towards mathematics because students' engagement post-test scores were collected 11 days later than the engagement pre-test. Therefore, the researcher expected to find a short-term significance on students' mathematics engagement. Clearly, a larger sample of students might have yielded more reliable results with more powerful statistical analyses. The way the teacher teaches, treat students, interact with students, and the teachers' approach towards students might also have an effect on students' engagement; therefore, teacher characteristics might also be considered as another limitation of this study.

The researcher assumes that students gave honest responses to the engagement survey. The researcher did not know what students were thinking while they were answering the engagement survey because some items were more generic compared to some specific items. The engagement survey was assumed to be valid measure of engagement after the content and construct validity analysis were established. Finally, novelty and the Hawthorne effect were two of the other limitations of this study because students know that they were on a research study. As the four schools are located in a rural part of Southwest Virginia, students are not used to seeing researchers from universities in their classrooms. Therefore, students might have improved or modified their behavior in response to the fact that it was a research study and students' interest might have increased because of the new technologies used in the classrooms. Despite

these limitations, this study is expected to make an important contribution to the body of knowledge regarding the effect of educational games on engagement in mathematics.

Chapter 4: Results

Chapter 4 presents the results of testing the research hypotheses through quantitative methods from the participated students. The quantitative data include the results of the statistical and descriptive analyses of the pre-and-post-tests. Tables and figures are included to provide descriptive and statistical information on quantitative data. The chapter is divided into six main sections including: (a) introduction, (b) the descriptive statistics on participants' demographics, (c) reliability analysis of the engagement survey, (d) data analysis, (e) testing research hypotheses, and (f) further analyses on students' engagement in terms of three domains.

Introduction

The following two research hypotheses were proposed in this study:

1. Students who are in experimental groups will score significantly higher on the engagement survey than the students in control group.
    a. Students who are in experimental groups will score significantly higher on the engagement survey in three domains (behavioral, cognitive, and emotional) than the students in control group
2. Students who play the educational games in the experimental groups will score significantly higher on the engagement survey than participants who do the paper-and-pencil drills in the control group.
    a. Students who play the educational games in the experimental groups will score significantly higher on engagement survey in three domains (behavioral, cognitive, and emotional) than participants who do the paper-and-pencil drills in the control group.

3. Students who do activities with virtual manipulatives in the experimental group will score significantly higher on the engagement survey than participants who do the paper-and-pencil drills in the control groups.
    a. Students who do the activities of virtual manipulatives in the experimental group will score significantly higher on engagement survey in three domains (behavioral, cognitive, and emotional) than participants who do the paper-and-pencil drills in the control group.

A quasi-experimental study was conducted using the design described in chapter 3 and depicted in Table 1 to test these hypotheses. As shown in Table 1, form of student demographics was used at the beginning of the 2 week period and two sets of survey including the engagement survey was used at the beginning (pre-test) and end of (post-test) the 2 weeks school period.

Descriptive Statistics

The total population for this study was 162 students and 4 teachers from the four elementary schools in the southwest of the Virginia in United States of America. The total sample for this study was 86 students (*N*=86) from four classrooms in four elementary schools (Table 3). The sample of 86 cases was input into SPSS. Of 86 cases, the total of 86 cases had valid data on all the engagement survey and 2 cases had one or more missing data on the learner characteristics survey. The two dependent variables of this study included: (a) the engagement pre-test (Engagement1), (b) the engagement post-test (Engagement2). The engagement pre-test was considered as covariate.

Table 3

The number of participants and their gender for each group (N=86)

Groups	N	Gender			
		Male	%	Female	%
Pearl Diver Game Group (Treatment1)	19	8	42.1	11	57.9
Candy Factory Game Group (Treatment2)	17	9	52.9	8	47.1
Virtual Manipulatives Group (Treatment3)	23	10	43.4	13	56.6
Paper-and-pencil Drills Group (Control)	27	12	44.4	15	55.6
Total	86	39	45.3	47	54.7

Despite there are few missing data, their distribution and effects on the dependent variables were analyzed using descriptive and correlation tests (Howell, 2007). The descriptive test was used to find a possible missing pattern based on the participants' demographic variables including teacher, gender, age, computer skills, and game playing conditions. The descriptive analysis indicated that the missing data were randomly distributed among all aforementioned criteria.

Descriptive statistics of learner characteristics survey. The demographics of the 86 research participants on their gender, age, and game playing conditions are provided in Table 4. The information about gender, age, and game playing conditions were obtained from the learner characteristics survey.

Table 4

Learner characteristics of the participated students (n=86)

Items	Characteristic	N	Percent
Gender	Male	39	45.3
	Female	47	54.7
Age	10	33	38.4
	11	52	60.5
	12	1	1.2
How would you describe yourself as a game player?	Gamer	29	33.7
	Proficient	39	45.3
	Novice	18	20.9

	Non-gamer	0	0
How often do you play digital games?	Everyday	32	37.2
	2-3 times a week	36	41.9
	Once a week	14	16.3
	Once a month	4	4.7
	Once or twice a year	0	0
	Never	0	0
How long do you usually play when you play digital games?	Less than 15 min	8	9.3
	Longer than 15 minutes but less than 30 minutes	20	23.3
	Longer than 30 minutes but less than 1 hour	29	33.7
	Longer than 1 hour but less than 2 hour	13	15.1
	Longer than 2 hours	16	18.6
Do you have a computer at home?	Yes	78	90.7
	No	8	9.3
Do you have the Internet at home?	Yes	75	87.2
	No	11	12.8
I play digital games more than my friends do.	Yes	26	30.2
	No	60	69.8
I often play digital games	Yes	67	77.9
	No	19	22.1
I learn math digital games fast.	Strongly disagree	0	0
	Somewhat disagree	5	5.8
	Somewhat agree	46	53.5
	Strongly agree	35	40.7
It is easy for me to learn math digital games.	Strongly disagree	1	1.2
	Somewhat disagree	8	9.3
	Somewhat agree	31	36
	Strongly agree	46	53.5
If I use digital games to learn math, I can get a better math grade.	Strongly disagree	7	8.1
	Somewhat disagree	10	11.6
	Somewhat agree	35	40.7
	Strongly agree	34	39.5
Digital games are good educational tools to help me to learn math.	Strongly disagree	2	2.3
	Somewhat disagree	9	10.5
	Somewhat agree	29	33.7
	Strongly agree	46	53.5
My parents make rules on my digital game playing.	Strongly disagree	44	51.2
	Somewhat disagree	14	16.3
	Somewhat agree	17	19.8
	Strongly agree	10	11.6
My parents check the content of my digital games	Strongly disagree	40	46.5
	Somewhat disagree	14	16.3
	Somewhat agree	16	18.6

	Strongly agree	14	16.3
My parents tell me which digital games are good ones.	Strongly disagree	34	39.5
	Somewhat disagree	15	17.4
	Somewhat agree	20	23.3
	Strongly agree	16	18.6
My parents play digital games with me.	Strongly disagree	38	44.2
	Somewhat disagree	12	14
	Somewhat agree	27	31.4
	Strongly agree	8	9.3

Descriptive statistics of game features survey. The game features survey based on the three attributes of educational games was applied to the educational game group students (*n*=37) and descriptive statistics are demonstrated in Table 5.

Table 5

Descriptive statistics of game features survey for each group (n=37)

Items	Answer	PDG		CFG	
		N	Percent	N	Percent
1. The goal of the game was clear. Goal	Strongly disagree	1	5	0	0
	Somewhat disagree	1	5	1	5.9
	Somewhat agree	3	15	6	35.3
	Strongly agree	15	75	10	58.8
2. Game guided me well how to play the game. Goal	Strongly disagree	0	0	1	5.9
	Somewhat disagree	1	5	4	23.5
	Somewhat agree	5	25	4	23.5
	Strongly agree	14	70	8	47.1
3. Game was not easy to understand how to play. (R) Goal	Strongly disagree	17	80	6	35.3
	Somewhat disagree	1	5	6	35.3
	Somewhat agree	1	5	3	17.6
	Strongly agree	1	5	2	11.8
4. The first level was easier than the next levels. Challenge	Strongly disagree	2	10	0	0
	Somewhat disagree	1	5	1	5.9
	Somewhat agree	0	0	2	11.8
	Strongly agree	17	85	14	82.4
5. Game helped me learn from my mistakes. Feedback	Strongly disagree	3	15	3	17.6
	Somewhat disagree	3	15	3	17.6
	Somewhat agree	4	20	5	29.4
	Strongly agree	10	50	6	35.3
6. Game gave me information on my score and level.	Strongly disagree	1	5	2	11.8
	Somewhat disagree	3	15	3	17.6
	Somewhat agree	6	30	5	29.4

Feedback	Strongly agree	10	50	7	41.2
7. Game was neither too difficult nor too easy. Challenge	Strongly disagree	3	15	1	5.9
	Somewhat disagree	0	0	2	11.8
	Somewhat agree	4	20	5	29.4
	Strongly agree	13	65	9	52.9
8. Game became boring after some time of playing. (R) Challenge	Strongly disagree	10	50	3	17.6
	Somewhat disagree	3	15	3	17.6
	Somewhat agree	6	30	8	47.1
	Strongly agree	1	5	3	17.6
9. Game provided important tasks for me. Challenge	Strongly disagree	5	25	1	5.9
	Somewhat disagree	4	20	7	41.2
	Somewhat agree	7	35	7	41.2
	Strongly agree	4	20	2	11.8
10. Game was fun to play. Challenge	Strongly disagree	1	5	3	17.6
	Somewhat disagree	0	0	3	17.6
	Somewhat agree	2	10	5	29.4
	Strongly agree	17	85	6	35.3
11. Game provided immediate feedback on my actions. Feedback	Strongly disagree	3	15	1	5.9
	Somewhat disagree	1	5	5	29.4
	Somewhat agree	6	30	6	35.3
	Strongly agree	10	50	5	29.4
12. Game was very easy to finish. (R) Challenge	Strongly disagree	2	10	1	5.9
	Somewhat disagree	3	15	3	17.6
	Somewhat agree	2	10	9	52.9
	Strongly agree	13	65	4	23.5
13. Game did not provide me enough feedback on math. (R) Feedback	Strongly disagree	12	60	5	29.4
	Somewhat disagree	4	20	7	41.2
	Somewhat agree	2	10	4	23.5
	Strongly agree	2	10	1	5.9

Reliability Analyses of the Engagement Survey

Before analyzing the results of the engagement test, the researcher did reliability analysis for the engagement test itself. Cronbach's alpha is the most common measure for reliability analysis as the researcher used multiple Likert-type of questions in the engagement survey. According to Cronbach's alpha reliability analysis, the reliability of the engagement survey was found *0.892* for pre-engagement survey and 0.917 was found for post-engagement survey that indicated a very high level of internal consistency for the survey with this specific sample of students (Table 6). When the researcher deeply looked

at the item-total statistics table, removal of any item except from item number 10, 11, 18, 20, 23, and 29 would result in lower Cronbach's alpha. However, the researcher would not want to remove these items. Removal of those items would lead to a small improvement in Cronbach's alpha and it was seen that the "Corrected Item-Total Correlation" values were low for these items. The total scale and all of the subscales with 33 items met the requirement of higher than .7 cut-off point suggested by Nunnally (1978).

Table 6

The reliability of the engagement survey with 33 items

			Reliability (pre-test)		Reliability (post-test)	
		Number of Items	Cronbach's alpha (α)	N	Cronbach's alpha (α)	N
Total Scale		33	0.892	86	0.917	82
Subscale	Behavioral	11	0.712	86	0.806	84
	Cognitive	11	0.774	86	0.820	83
	Emotional	11	0.817	86	0.833	83

Data Analysis

In this section, the data analysis always starts from general to more specific. For each case, the researcher first analyzes the difference between control and experimental groups, and then analysis made for each group separately. In terms of the three domains of the engagement survey, the difference between control and experimental groups are presented first and the differences in each group are presented for three domains. Table 7 shows the analyses conducted to describe the results from the pre-and-post-test engagement.

Table 7

Analyses conducted for engagement pre-and-post-test

Groups	Engagement	Analyses
Experimental vs. Control	General	Mean and standard deviation analysis, ANOVA for engagement pre-test, ANCOVA
	Three domains	
All groups	General	Mean and standard deviation analysis, ANOVA for engagement pre-test
	Three domains	
Educational games vs. Control	General	ANCOVA
	Three domains	
Virtual manipulatives vs. Control	General	
	Three domains	
Candy Factory game vs. Control	General	
	Three domains	
Pearl Diver game vs. Control	General	
	Three domains	
Educational games vs. Virtual manipulatives	General	
	Three domains	

The following analyses were conducted to examine the data on engagement:

1) Mean and standard deviation analyses
    a. Mean and standard deviation results of pre-and-post engagement survey for experimental and control groups
    b. Mean and standard deviation results of pre-and-post engagement survey for experimental and control groups in terms of three domains
    c. Mean and standard deviation results of pre-and-post engagement survey for all groups
    d. Mean and standard deviation results of pre-and-post engagement survey for all groups in terms of three domains
2) Analyses of variance (ANOVA) for pre-engagement survey
    a. The results of ANOVA for pre-engagement survey between experimental and control groups

b. The results of ANOVA for pre-engagement survey between experimental and control groups in terms of three domains
c. The results of ANOVA for pre-engagement survey among all groups
d. The results of ANOVA for pre-engagement survey among all groups in terms of three domains

3) Research questions analyses using analysis of co-variance (ANCOVA)
    a. The results of ANCOVA for post-engagement survey between experimental and control groups
        i. The results of ANCOVA for post-engagement survey between experimental and control groups in terms of three domains
    b. The results of ANCOVA for post-engagement survey between educational game and control groups
        i. The results of ANCOVA for post-engagement survey between educational game and control groups in terms of three domains
    c. The results of ANCOVA for post-engagement survey between virtual manipulatives and control groups
        i. The results of ANCOVA for post-engagement survey between virtual manipulatives and control groups in terms of three domains
4) Further ANCOVA on individual groups
    a. The results of ANCOVA for post-engagement survey between the Candy Factory game group and control group

b. The results of ANCOVA for post-engagement survey between the Candy Factory game group and control group in three domains
c. The results of ANCOVA for post-engagement survey between the Pearl Diver game group and control group
d. The results of ANCOVA for post-engagement survey between the Candy Factory game group and control group in three domains
e. The results of ANCOVA for post-engagement survey between the virtual manipulatives group and educational games group
f. The results of ANCOVA for post-engagement survey between the virtual manipulatives group and educational games group in three domains

The mean and standard deviation results of the engagement survey in general. To begin the data analysis for this study, first of all, the mean and standard deviation of scores of two dependent variables (pre-test and post-test) for the three groups of experimental and one group of control are provided in Table 8.

Table 8

The mean and standard deviation of engagement pre-test and post-test for experimental and control groups (N=86)

	Experimental		Control	
	Pre-test	Post-test	Pre-test	Post-test
Mean	88.59	93.76	89.96	82.88
Std Dev.	16.30	16.15	16.02	19.66

The mean and standard deviation results of the engagement survey in three domains. As the researcher used three domains engagement survey (behavioral,

cognitive, and emotional), the mean and standard deviation results of each pre-and-post-test engagement based on the control and experimental groups were presented in Table 9.

Table 9

The mean and standard deviation of behavioral, cognitive, and emotional engagement pre-and-post test results for experimental and control groups (N=86)

Domains		Experimental		Control	
		Pre-test	Post-test	Pre-test	Post-test
Behavioral	Mean	34.4237	34.7627	33.8148	31.1111
	N	59	59	27	27
	Std Dev.	5.18686	5.10692	5.61617	7.13784
Cognitive	Mean	28.8475	30.7797	27.8889	26.3333
	N	59	59	27	27
	Std Dev.	6.80723	6.81547	5.91825	6.66218
Emotional	Mean	25.3220	28.4915	28.2593	25.4444
	N	59	59	27	27
	Std Dev.	6.59791	6.61340	7.52735	8.28499

Table 9 shows the mean scores of each engagement domain between experimental and control groups. As seen, different qualities of engagement have different mean score values between groups. To be able to interpret the results for all groups in a more detailed way, the researcher run through separate analysis to show the mean scores and standard deviation of two dependent variables for all groups separately in terms of their pre-and-post engagement survey results in Table 10.

Table 10

The mean and standard deviation of engagement pre-test and post-test for all groups separately (N=86)

	CFG		PDG		VM		P&P	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Mean	99.17	98.12	85.21	93.27	83.56	91.00	89.96	82.88
Std Dev.	14.70	19.58	16.78	12.05	13.78	16.39	16.02	19.66

CFG=Candy Factory game group
PDG=Pearl Diver game group
VM=Virtual Manipulatives group
P&P=Paper-and-pencil drills group (Control group)

In order to see mean scores among all groups in terms of the three domains, the mean and standard deviation results of engagement pre-test and post-test of each group and each domain were presented in Table 11.

Table 11

The mean and standard deviation of behavioral, cognitive, and emotional engagement pre-test and post-test results for all groups separately

		CFG		PDG		VM		P&P	
Domains		Pre	Post	Pre	Post	Pre	Post	Pre	Post
Behavioral	Mean	36.94	36.94	33.73	33.90	33.13	33.86	33.81	31.11
	N	17	17	19	20	23	22	27	27
	SD	4.656	5.921	5.237	4.327	5.065	4.793	5.616	7.137
Cognitive	Mean	32.35	32.11	27.68	30.75	27.21	29.77	27.88	26.33
	N	17	17	19	20	23	22	27	27
	SD	6.518	8.268	7.203	4.314	5.946	7.539	5.918	6.662
Emotional	Mean	29.88	29.64	23.78	28.75	23.21	27.36	28.25	25.44
	N	17	17	19	20	23	22	27	27
	SD	5.765	7.017	6.078	6.163	6.134	6.814	7.527	8.284

When Table 11 is examined in detail, students' behavioral, cognitive, and emotional engagement mean scores in the Pearl Diver game and the virtual manipulatives groups have increased. The post-test mean scores of other groups did not improve compared to their pre-test mean scores. In order to analyze if these differences in engagement pre-test scores among groups are meaningful or not, a set of analysis of variance (ANOVA) was conducted in the next section.

ANOVA results for pre-engagement survey. Before testing the research hypotheses, the engagement pre-test survey scores needed to be analyzed to see if there was any significant difference between experimental and control groups in terms of

students' engagement in general. Therefore, Table 12 shows ANOVA results for the mathematics engagement pre-test to see if there is any significant difference between experimental and control groups.

Table 12

The results of ANOVA for engagement pre-test between experimental and control groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	34.753	1	34.753	.132	.717
Within Groups	22097.200	84	263.062		
Total	22131.953	85			

According to Table 12, ANOVA results show that the different mean scores in experimental and control groups are not significantly different from each other, F (1,84)= .132, p=.717. Therefore, the researcher might say that the conditions for the treatment were equal or close to equal in terms of students' general mathematics engagement before the treatment.

The mean score analysis of engagement survey (pre-test) with three domains separately. Another analysis was made to see if there is any significant difference between control and experimental group students' behavioral, cognitive, and emotional engagement before testing the research hypotheses. As the researcher expected to see a difference after the treatment, the ANOVA analysis for each domain was made in Table 13.

Table 13

ANOVA results for each domain of engagement (behavioral, cognitive, and emotional) in control and experimental groups

		Sum of Squares	df	Mean Square	F	Sig.
Behavioral Engagement (Pre-test)	Between Groups	6.868	1	6.868	.242	.624
	Within Groups	2380.481	84	28.339		
	Total	2387.349	85			
Cognitive Engagement (Pre-test)	Between Groups	17.020	1	17.020	.397	.530
	Within Groups	3598.294	84	42.837		
	Total	3615.314	85			
Emotional Engagement (Pre-test)	Between Groups	159.806	1	159.806	3.358	.070
	Within Groups	3998.067	84	47.596		
	Total	4157.872	85			

As seen in Table 13, there is no significant difference between experimental and control groups in terms of students' behavioral, cognitive, and emotional engagement before the study with an $F_{\text{behavioral}}$ score of .242 (p=.624), $F_{\text{cognitive}}$ score of .397 (p=.530), and $F_{\text{emotional}}$ score of 3.358 (p=.070),.

To get more detailed results for all of the groups, the researcher run through a separate analysis to see if there is any difference between all groups in terms of their engagement in Table 14.

Table 14

The results of ANOVA for engagement pre-test between all groups separately

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2737.710	3	912.570	3.858	.012*
Within Groups	19394.244	82	236.515		
Total	22131.953	85			

* $p < .05$.

According to Table 14, ANOVA results show that the different mean scores in four groups (3 treatment and 1 control) are significantly different from each other with an *F* score of 3.858 (p=.012). Therefore, post hoc analysis was conducted to see which group created the difference among four groups. Table 15 shows the means for groups in homogenous subsets.

Table 15

Post hoc results from Tukey HSD for the differences between all groups

Classes	N	Subset for alpha = .05	
		1	2
Virtual Manipulatives Group	23	83.56	
Pearl Diver Game Group	19	85.21	
Paper-and-Pencil Drills (Control) Group	27	89.96	89.96
Candy Factory Game Group	17		99.17
Sig.		.539	.222

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 20.837.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

As we have seen from the means of groups in homogenous subsets (Table 15), one group is consisting the upper subset (Candy Factory game group) and two groups are consisting lower subset (Virtual manipulatives group and the Pearl Diver game group) meaning that the upper group is different from the lower groups in terms of their engagement pre-test mean scores and they are significantly different from these two lower level groups. The control group, which is the paper-and-pencil drill group, is not significantly different from the virtual manipulatives group, the Pearl Diver game group, and Candy Factory game group. Also, according to Bonferroni test results; there are significant differences only between the Pearl Diver game group and Candy Factory

game group; the virtual manipulatives group and Candy Factory game group. Paper-and-pencil drill group is not different from other groups according to Bonferroni test results.

One last analysis was conducted to see if there is any difference between all groups in terms of their behavioral, emotional, and cognitive engagement. Table 16 presents the pre-test results of ANOVA for each engagement domain for each group.

Table 16

ANOVA results for each domain of pre-engagement (behavioral, cognitive, and emotional) in all groups

		Sum of Squares	df	Mean Square	F	Sig.
Behavioral Engagement (Pre-test)	Between Groups	162.041	3	54.014	1.990	.122
	Within Groups	2225.308	82	27.138		
	Total	2387.349	85			
Cognitive Engagement (Pre-test)	Between Groups	312.747	3	104.249	2.588	.058
	Within Groups	3302.567	82	40.275		
	Total	3615.314	85			
Emotional Engagement (Pre-test)	Between Groups	659.851	3	219.950	5.156	.003*
	Within Groups	3498.021	82	42.659		
	Total	4157.872	85			

* $p < .01$.

As seen in Table 16, while there is no difference among all four groups in terms of their behavioral and cognitive engagement with an $F_{\text{behavioral}}$ score of 1.990 (p=.122), $F_{\text{cognitive}}$ score of 2.588 (p=.058), there is a significant difference in students' emotional engagement among all four groups with an $F_{\text{emotional}}$ score of 5.156 (p=.003). Emotional engagement was also analyzed to see which classes were different from each other in terms of their emotional engagement in Table 17.

Table 17

Post hoc results from Tukey HSD for the differences in emotional engagement pre-test between all groups

Classes	N	Subset for alpha = .05	
		1	2
Virtual Manipulatives Group	23	23.21	
Pearl Diver Game Group	19	23.78	
Paper-and-Pencil Drills (Control) Group	27	28.25	28.25
Candy Factory Game Group	17		29.88
Sig.		.069	.853

Means for groups in homogeneous subsets are displayed.
Uses Harmonic Mean Sample Size = 20.837.
The group sizes are unequal.
The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

As we have seen from the means of groups in homogenous subsets (Table 17), one group is consisting the upper subset (Candy Factory game group) and two groups are consisting lower subset (Virtual manipulatives group and the Pearl Diver game group) meaning that the upper group is different from the lower groups in terms of their *emotional engagement mean scores* and they are significantly different from these two lower level groups. The control group is not significantly different from the virtual manipulatives group, the Pearl Diver game group, and Candy Factory game group. Also, according to Bonferroni test results; there are significant differences only between the Pearl Diver game group and Candy Factory game group; the virtual manipulatives group and Candy Factory game group. Paper-and-pencil drill group is not different from other groups according to Bonferroni test results.

Testing the Research Hypotheses

To test the research hypotheses, an analysis of covariance (ANCOVA) was conducted to determine the effect of the educational games and virtual manipulatives on

the participants' mathematics engagement. ANCOVA is a useful test to compare two or more groups when there is a covariate and a dependent variable and independent variable. Four ANCOVA tests were run separately. The first ANCOVA tested the first hypothesis, the second ANCOVA tested the second hypothesis, and the third and the fourth ANCOVA tested if there is any difference between educational games. All tests for significance were set at the .05 level.

The first research hypotheses. To test the first hypotheses on the effect of experimental groups (Candy Factory game, Pearl Diver game, and virtual manipulatives) on students' engagement, ANCOVA was conducted and results were shown in Table 18. The students' engagement was measured using mathematics engagement post-test, used as a dependent variable. The pre-test scores of engagement survey were considered as covariate.

Table 18

The ANCOVA results of the engagement post-test survey according to experimental and control group

Source	SS	df	MS	F	Sig.
Engagement Pre-test (cov.)	9007.589	1	9007.589	46.789	.000
Group (Treatment vs. Control)	2226.977	1	2226.977	11.568	.001*
Error	15401.059	80	192.513		
Total	26564.651	82			

a Computed using alpha = .05
b R Squared = .420 (Adjusted R Squared = ,406)
* $p < .01$.

An ANCOVA was conducted to explore the relationship between pre-and-post-test scores on experimental and control group students' engagement. There was a statistically significant interaction for post-test, $F(1, 80)= 11.568$, $p=.001$. When the

experimental and control groups were compared with post-test results, there was a meaningful difference on behalf of the engagement of experimental groups. The effect size was reported, η^2=0.126. The η^2 = 0.126 indicated 12% of variance of the dependent variable was associated with the group factor. The partial η^2 value is the proportion of variance of the dependent variables related to the group factor where 0.126 is considered medium effect size (Howell, 2007). As for the sub-question for the first research hypothesis, another ANCOVA was conducted and results were shown in Table 19.

Table 19

The ANCOVA results of the experimental and control group post-test survey in terms of behavioral, cognitive, and emotional engagement

Source	SS	df	MS	F	Sig.
Behavioral Engagement Pre-test (cov.)	1147.405	1	1147.405	58.042	.000
Group (Treatment vs. Control)	149.819	1	149.819	7.579	.007**
Error	1581.476	80	19.768		
Total	96208.000	83			
Source	SS	df	MS	F	Sig.
Cognitive Engagement Pre-test (cov.)	933.413	1	933.413	26.115	.000
Group (Treatment vs. Control)	222.532	1	222.532	6.226	.015*
Error	2859.444	80	35.743		
Total	4131.181	82			
Source	SS	df	MS	F	Sig.
Emotional Engagement Pre-test (cov.)	1137.892	1	1137.892	29.378	.000
Group (Treatment vs. Control)	349.857	1	349.857	9.033	.004**
Error	3098.614	80	38.733		
Total	4400.675	82			

* $p < .05$. ** $p < .01$.

According to Table 19, students in experimental and control groups showed significant difference in terms of their behavioral, $F(1, 80)= 7.579$, $p=.007$, cognitive

$F(1, 80)= 6.226$, $p=.015$, and emotional $F(1, 80)= 9.033$, $p=.004$ engagement on behalf of the experimental groups.

The second research hypotheses. To test the second hypotheses on effect of the educational games on students' engagement, ANCOVA was conducted and results were shown in Table 20.

Table 20

The ANCOVA results of the engagement post-test survey according to educational games groups and control group

Source	SS	df	MS	F	Sig.
Engagement Pre-test (cov.)	7285.680	1	7285.680	37.738	.000
Group (Games vs. Control)	1714.964	1	1714.964	8.883	.004*
Error	11197.369	58	193.058		
Total	20898.852	60			

* $p < .01$.

An ANCOVA was conducted to explore the relationship between pre-and-post-test scores on educational game groups and control group students' engagement. There was a statistically significant interaction for post-test, $F(1, 58)= 8.883$, $p=.004$. The effect size $\eta^2= .133$ indicated 13% of variance of the dependent variable was associated with educational games. When the educational games groups and control groups were compared with post-test results, there was a meaningful difference on behalf of the educational games groups. As for the sub-question for the second research hypothesis, another ANCOVA was conducted and results were shown in Table 21.

Table 21

The ANCOVA results of the educational games group and control group post-test survey in terms of behavioral, cognitive, and emotional engagement

Source	SS	df	MS	F	Sig.
Behavioral Engagement Pre-test (cov.)	845.587	1	845.587	35.626	.000
Group (Educational Games vs. Control)	116.511	1	116.511	4.909	.031*
Error	1376.638	58	23.735		
Total	2474.557	60			

Source	SS	df	MS	F	Sig.
Cognitive Engagement Pre-test (cov.)	757.339	1	757.339	24.212	.000
Group (Educational Games vs. Control)	177.311	1	177.311	5.669	.021*
Error	1814.220	58	31.280		
Total	2928.852	60			

Source	SS	df	MS	F	Sig.
Emotional Engagement Pre-test (cov.)	1055.393	1	1055.393	28.293	.000
Group (Educational Games vs. Control)	305.053	1	305.053	8.178	.006**
Error	2163.539	58	37.302		
Total	3425.246	60			

* $p < .05$. ** $p < .01$.

According to Table 21, students in educational games groups scored significantly higher in terms of behavioral, $F(1, 58)= 4.909$, $p=.031$, cognitive engagement, $F(1, 58)= 5.669$, $p=.021$, and emotional $F(1, 58)= 8.178$, $p=.006$, than the students in control group.

The third research hypotheses. To test the third research hypotheses on the effect of the virtual manipulatives on students' engagement, ANCOVA was conducted and results were shown in Table 22.

Table 22

The ANCOVA results of the engagement post-test survey according to the virtual manipulatives group and control group

Source	SS	df	MS	F	Sig.
Engagement Pre-test (cov.)	5871.473	1	5871.473	27.467	.000
Group (VM vs. Control)	1703.101	1	1703.101	7.967	.007*
Error	9833.193	46	213.765		
Total	16502.204	48			

* $p < .01$.

An ANCOVA was conducted to explore the relationship between pre-and-post-test scores on virtual manipulatives and control group students' engagement (Table 22). There was a statistically significant interaction for post-test $F(1, 46)= 7.967$, $p=.007$. The effect size $\eta^2= .148$ indicated 14% of variance of the dependent variable was associated with virtual manipulatives. When the virtual manipulatives and control groups were compared with post-test results, there was a meaningful difference on behalf of the virtual manipulatives group. As for the sub-question for the third research hypothesis, another ANCOVA was conducted and results were shown in Table 23.

Table 23

The ANCOVA results of the virtual manipulatives group and control group post-test survey in terms of behavioral, cognitive, and emotional engagement

Source	SS	df	MS	F	Sig.
Behavioral Engagement Pre-test (cov.)	731.597	1	731.597	31.286	.000
Group (Virtual Manipulatives vs. Control)	108.081	1	108.081	4.622	.037*
Error	1075.661	46	23.384		
Total	1899.102	48			

Source	SS	df	MS	F	Sig.
Cognitive Engagement Pre-test (cov.)	330.662	1	330.662	7.540	.009
Group (Virtual Manipulatives vs. Control)	147.921	1	147.921	3.373	.073

Error	2017.201	46	43.852		
Total	2491.265	48			

Source	SS	df	MS	F	Sig.
Emotional Engagement Pre-test (cov.)	912.146	1	912.146	22.710	.000
Group (Virtual Manipulatives vs. Control)	262.319	1	262.319	6.531	.014*
Error	1847.611	46	40.165		
Total	2804.408	48			

* $p < .05$.

According to Table 23, students in the virtual manipulatives group scored significantly higher in terms of behavioral, $F(1, 46)= 4.622$, $p=.037$, and emotional, $F(1, 46)= 6.531$, $p=.014$, engagement than the students in control group. However, there was no significant difference in terms of their cognitive engagement, $F(1, 46)= 3.373$, $p=.073$, when compared to control group students, although the result is close to alpha level ($p=.073$).

Further Analyses

The following questions were proposed in order to examine the results of the study further and to reach better conclusions about the study.

1. Did participants who played the Candy Factory game demonstrate greater increase in the engagement survey than participants who did paper-and-pencil drills?
2. Did participants who played the Candy Factory game demonstrate greater increase in terms of behavioral, cognitive, and emotional engagement as measured by the engagement survey than participants who did paper-and-pencil drills?

3. Did participants who played the Pearl Diver game demonstrate greater increase in the engagement survey than participants who did paper-and-pencil drills?
4. Did participants who played the Pearl Diver game demonstrate greater increase in terms of behavioral, cognitive, and emotional engagement as measured by the engagement survey than participants who did paper-and-pencil drills?
5. Did participants who did activities with virtual manipulatives demonstrate greater increase in the engagement survey than participants who played the Candy Factory game in one class and the Pearl Diver game in another class?
6. Did participants who did activities with virtual manipulatives demonstrate greater increase in terms of behavioral, cognitive, and emotional engagement as measured by the engagement survey than participants who played the Candy Factory game in one class and the Pearl Diver game in another class?

In order to answer these questions, ANCOVA was conducted to see if there is any meaningful difference on students' engagement post-test (engagement post-test) when the engagement pre-test scores were taken as a covariate (engagement pre-test).

In order to answer the first question, ANCOVA was conducted to see if there is difference between the Candy Factory game group and paper-and-pencil group in terms of their engagement in general (Table 24).

Table 24

The ANCOVA results of the Candy Factory game group in terms of their engagement in general compared to control group

Source	SS	df	MS	F	Sig.
Engagement Pre-test (cov.)	9152.209	1	9152.209	54.967	.000
Group (CFG vs. Control)	295.257	1	295.257	1.773	.191
Error	6660.207	40	166.505		
Total	18144,605	42			

As seen in Table 24, no significant difference was found between the Candy Factory game group students' engagement and paper-and-pencil drill group students' engagement, $F(1, 42)=1.773$, $p=.191$. The effect size $\eta^2= .042$ indicated 4% of variance of the dependent variable was associated with the Candy Factory game. In order to answer the question 2, ANCOVA was conducted to see if there is difference between the Candy Factory game group and paper-and-pencil group in terms of their engagement in three domains (Table 25).

Table 25

The ANCOVA results of the Candy Factory game group in terms of their engagement in three domains compared to control group

Source	SS	df	MS	F	Sig.
Behavioral Engagement Pre-test (cov.)	844.033	1	844.033	34.149	.000
Group (Candy Factory Game vs. Control)	60.248	1	60.248	2.438	.126
Error	988.633	40	24.716		
Total	2124.419	42			
Source	SS	df	MS	F	Sig.
Cognitive Engagement Pre-test (cov.)	838.841	1	838.841	23.815	.000
Group (Candy Factory Game vs. Control)	47.707	1	47.707	1.354	.251
Error	1408.909	40	35.223		
Total	2584.744	42			
Source	SS	df	MS	F	Sig.

Emotional Engagement Pre-test (cov.)	1502.063	1	1502.063	56.436	.000
Group (Candy Factory Game vs. Control)	55.662	1	55.662	2.091	.156
Error	1064.604	40	26.615		
Total	2731.907	42			

According to Table 25, three domains of engagement were presented comparing the control group with Candy Factory game group. There was no statistically difference in terms of students' behavioral, $F(1, 42)=2.438$, $p=.126$; cognitive engagement, $F(1, 42)=1.354$, $p=.251$; and emotional, $F(1, 42)=2.091$, $p=.156$, compared to control group. To answer the third question, ANCOVA was conducted to see if there is any significant difference between the Pearl Diver game group and control group. Results were presented in Table 26.

Table 26

The ANCOVA results of the Pearl Diver game group in terms of their engagement in general compared to control group

Source	SS	df	MS	F	Sig.
Engagement Pre-test (cov.)	3387.889	1	3387.889	15.567	.000
Group (Pearl Diver vs. Control)	1607.436	1	1607.436	7.386	.010
Error	9140.388	42	217.628		
Total	13693.911	44			

* $p < .05$.

According to Table 26, the Pearl Diver game group and control group students' engagement scores were found significantly different from each other, $F(1,42)=7.386$, $p=.010$. The effect size $\eta^2= .15$ indicated 15% of variance of the dependent variable was associated with the Pearl Diver game. In order to see the specific domains that create the difference and to answer the fourth question, ANCOVA was conducted for each domain and presented in Table 27.

Table 27

The ANCOVA results of the Pearl Diver game group in terms of their engagement in three domains compared to control group

Source	SS	df	MS	F	Sig.
Behavioral Engagement Pre-test (cov.)	443.254	1	443.254	15.255	.000
Group (Pearl Diver Game vs. Control)	78.629	1	78.629	2.706	.107
Error	1220.358	42	29.056		
Total	1757.244	44			
Source	SS	df	MS	F	Sig.
Cognitive Engagement Pre-test (cov.)	192.806	1	192.806	6.430	.015
Group (Pearl Diver Game vs. Control)	162.821	1	162.821	5.430	.025*
Error	1259.472	42	29.987		
Total	1629.911	44			
Source	SS	df	MS	F	Sig.
Emotional Engagement Pre-test (cov.)	661.138	1	661.138	15.670	.000
Group (Pearl Diver Game vs. Control)	331.144	1	331.144	7.849	.008**
Error	1772.029	42	42.191		
Total	2557.200	44			

* $p < .05$. ** $p < .01$.

According to Table 27, the Pearl Diver game group students' emotional and cognitive engagement scores were found statistically different from the control group students, $F_{emotional}(1,42)=7.849$, $p=.008$ and $F_{cognitive}(1,42)=5.430$, $p=.025$. However, no significant difference was found in terms of students' behavioral engagement between the Pearl Diver and control group students, $F_{behavioral}(1,42)=2.706$, $p=.107$.

As for the questions 5 and 6, no significant difference found between educational games groups and virtual manipulatives group in terms of their engagement in general, $F(1, 53)=.003$, $p=.954$, $\eta^2= .00$ and their behavioral $F(1, 53)=.021$, $p=.885$, cognitive engagement, $F(1, 53)=.002$, $p=.963$, and emotional, $F(1, 53)=.091$, $p=.764$, separately. Furthermore, the relationships among all of the experimental groups were found close to 1.

Chapter 5: Discussion

Chapter 5 discusses the research findings presented in chapter 4. The purpose of this study was to measure students' engagement within three domains -behavioral, cognitive, and emotional- in the context of using educational games and virtual manipulatives. Four 5th grade classrooms with total number of 86 students from four different schools participated in this study (N=86). Three of the classrooms constituted the experimental group and one classroom constituted the control group. The control group students did paper-and-pencil drills on fractions for a 20-minute period per day for eight days. Of the experimental groups, one played the Candy Factory game, one played the Pearl Diver game, and the other one did activities with virtual manipulatives for the same amount of time on the same topic as the other two treatment groups. Initially, a pre-test was administered to all of the students to analyze students' previous mathematics engagement scores. After the eight-day treatment in two weeks, students were asked to fill in the engagement survey again to collect the post-engagement data. Differences in engagement within its behavioral, cognitive, and emotional domains were investigated. In addition to the engagement survey, students in educational game groups responded the game features survey. Chapter 5 discusses the results of the learner characteristics survey, data analyses, three research hypotheses with further analyses, and the three game attributes. Finally, this chapter presents the conclusions and suggests what remains to be explored with future research.

Learner Characteristics

A total of 86 fifth grade students from four different schools in southwest Virginia, USA participated in this study (N=86). Three classrooms constituted the

experimental groups and one classroom constituted the control group. While 45.3% of students were male, 54.7% of the students were female. 98.9% of the students were 10 and 11 years old. In terms of students' game playing experiences, 79% of the students described themselves as either a gamer or a proficient game player. This percentage was confirmed by another item in the demographics survey in which students were asked if they often play games and 77.9% of the students responded "yes". In addition to this, 79.1% of the students reported playing digital games every day or at least 2-3 times a week and 67.4% of the students reported playing more than 30 minutes when they start to play a game. Interestingly, 69.8% of the students thought that they did not play digital games as frequently as their friends did. The researcher can assert that the students participating in this study were familiar with digital games and that most of them often play games.

As for the parent-student-digital game triangle, 67.5% of the students indicated that their parents do not make rules on their digital game playing. Interestingly, the report of ESA (2011) found that 80% of parents limit their kids' game playing time. In addition, 62.8% of the students reported that their parents do not check the content of their digital games and 56.9% reported that their parents do not tell them which digital games are good ones. These results are not consistent with the report of ESA (2011) which states "9 out of 10 parents pay attention to the content of the games their children play" (p. 5). However, one consistent result with the report of ESA (2011) was that 58.2% of the students' parents in this study do not play digital games with them (55% in the report of ESA).

In terms of their approach to learning with the help of digital games, 94.2% of the students think that they can learn mathematics digital games quickly and 89.5% of the students agree that it is easy for them to learn mathematics games. Moreover, 80.2% of the students think that they can get better mathematics grade if they use digital games to learn mathematics. Again, 87.2% of the students think that digital games are good educational tools to learn mathematics. Therefore, the researcher might state that students' attitudes towards learning mathematics with games are highly positive.

Data Analyses Results

Before the treatment started, students' engagement pre-test data were analyzed to see if there was any significant difference between experimental and control groups. The ANOVA results showed that experimental and control groups were not significantly different from each other with an F score of 0.132 (p=.717). Although groups were not randomly assigned at the beginning, groups were found to be almost equal before the treatment, the researcher may credit changes to the media and their attributes. When ANOVA results of engagement pre-test survey in all groups were analyzed, there was a significant difference between the Candy Factory game group and the other two experimental groups -the Pearl Diver game group and the virtual manipulatives group-. Although there was no significant difference between the control and experimental groups, the difference might stem from the following reason. When the researcher did the pilot study with the students, they played Candy Factory game. In addition to this, during the pilot study, the students were separated into ability groups where successful students were put in the same classroom by the school board. When the researcher talked to the teacher right before the treatment, she stated that they were not using ability groups

anymore. Students were distributed to the classes randomly by the school board before the study. Therefore, some of the students in the Candy Factory game group were already exposed to the game in the pilot study that might have affected their engagement towards mathematics.

The researcher expected to see a difference between the control and the experimental groups after the experiment in terms of the students' engagement in three domains; however, there was no difference in terms of students' engagement pre-test scores in the three domains. Although students' emotional engagement was found to be significantly different between experimental groups -the Candy Factory game group versus the virtual manipulatives and the Pearl Diver game groups-, there was no significant difference between the experimental and the control groups.

Research Hypotheses

According to the mean analyses, the total mean scores of control and experimental groups showed that the control group students' engagement was found higher before the treatment ($M_{control}$=89.96) than after the treatment ($M_{control}$=82.88). The control group students' engagement in mathematics decreased after the treatment. On the other hand, students' engagement scores in the experimental group increased and most importantly sustained after the treatment ($M_{treatment\ before}$= 88.59 and $M_{treatment\ after}$= 93.76). Figure 5 presents the total mean scores of pre-test and post-test for each group. Analyses were conducted to determine if these mean scores are significant when compared to control group and engagement pre-test survey results.

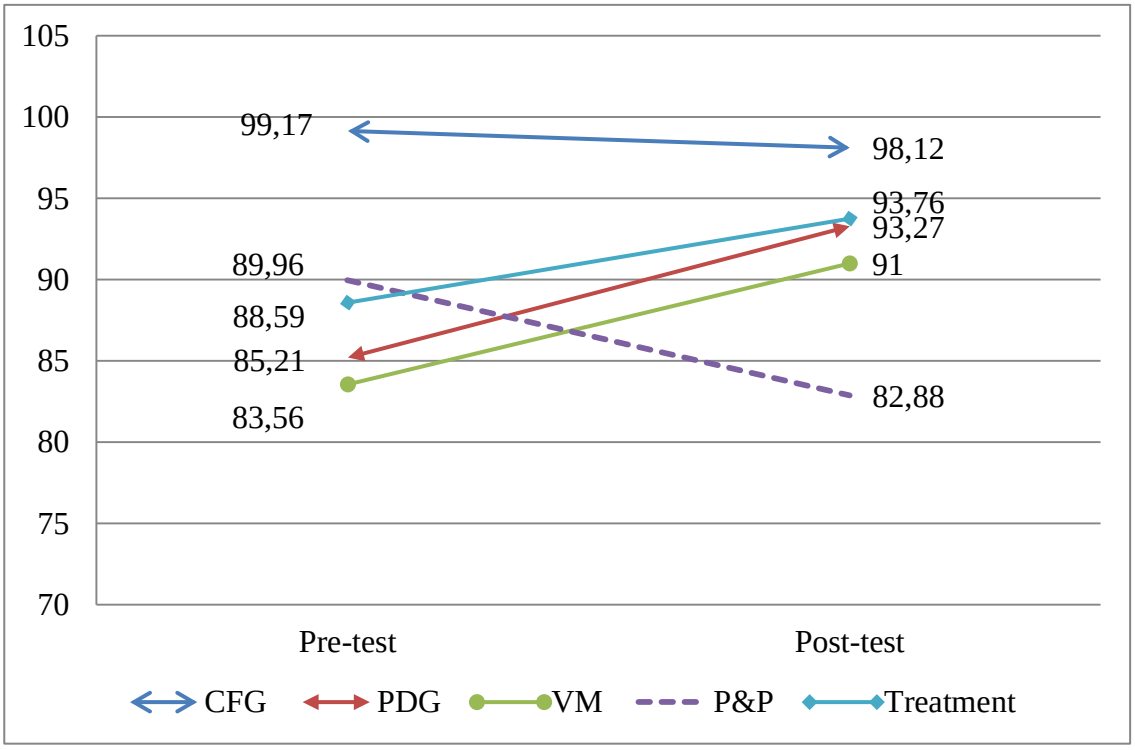

Figure 5. Mean scores of pre-and-post engagement survey results for each group.

The researcher cannot generalize results, as the non-random sampling cause reduced external validity. Still, the researcher expected to find a difference between students' pre-test and post-test engagement after the treatment. Hence, the results of the engagement pre-test were taken as a covariate to analyze the engagement post-test results (dependent variable). Therefore, ANCOVA was conducted to test the hypotheses presented in this study.

First research hypothesis. The first research hypothesis suggested that students' engagement in experimental groups (the Candy Factory game group, the Pearl Diver game group, and the virtual manipulatives game group) would score significantly higher than the students in control group (paper-and-pencil drills group) when engagement pre-test scores were used as a covariate. The first research hypothesis was supported by the

ANCOVA results, $F(1, 80)= 11.568$, $p=.001$. Students' engagement in the three experimental groups was found significantly higher than the students' engagement in the control group. The positive results are consistent with the prior empirical research on the effects of educational games on engagement, including those reported by Akkerman, Admiraal, and Huizenga (2009), Annetta, Minogue et al. (2009), Clark et al. (2011), Echeverria et al. (2011), Huizenga et al. (2009), Kim (1993), Reimer and Moyer (2005), Smith (2006), and van der Spek et al. (2011), suggesting that educational games and virtual manipulatives improve students' engagement.

The sub-hypothesis of the first research hypothesis was formed to suggest that the students who were in experimental groups would score significantly higher on the engagement survey in three domains (behavioral, cognitive, and emotional) than the students in the control group. This sub-hypothesis on the three domains of engagement was also supported according to the results of ANCOVA. Results showed significant differences in three domains of engagement between experimental and control groups, behavioral, $F(1, 80)= 7.579$, $p=.007$, emotional $F(1, 80)= 9.033$, $p=.004$, and cognitive engagement $F(1, 80)= 6.226$, $p=.015$. Students in the Candy Factory game, the Pearl Diver game, and the virtual manipulatives groups showed statistically higher behavioral, cognitive, and emotional engagement scores than the students in the paper-and-pencil drills group.

Second research hypothesis. As for the second research hypothesis, students who played the educational games in the experimental groups would score significantly higher on the engagement survey than participants who did the paper-and-pencil drills in the control group. The second research hypothesis was also supported by the ANCOVA

results, $F(1, 58)= 8.883$, $p=.004$. Students who played the Candy Factory game in one group and the Pearl Diver game in another group showed significantly higher engagement than students who did paper-and-pencil drills in the control group. This result is consistent with the premise that educational games are more engaging than traditional classroom activities (Malone, 1981; Rieber, 1996). This positive result was also supported by Charles et al. (2009) stating that educational games can improve students' engagement in learning and they added that this improvement could increase students' performance and allow them to have more satisfying experiences. Annetta, Minogue et al. (2009) also found similar results asserting that students who played educational games were more engaged in the content than control group students who did paper and pencil drills. NRC (2009) also reports that when educational games are well integrated into the lesson plans, they increase students' engagement. In addition, Echeverria et al. (2011) and van der Spek et al. (2011) found promising results in terms of the effect of educational games on students' engagement. Although for some researchers, it is hard to integrate the educational games in the formal schooling system, the researcher tried to overcome this issue during the research study (Brom et al., 2011).

The sub-hypothesis was formed in terms of the second research hypothesis to determine that students who played the educational games in the experimental groups would score significantly higher on engagement survey in three domains (behavioral, cognitive, and emotional) than participants who did the paper-and-pencil drills in the control group. The sub-hypothesis on three domains of engagement was also supported by the ANCOVA results in all three domains, behavioral, $F(1, 58)= 4.909$, $p=.031$, emotional $F(1, 58)= 8.178$, $p=.006$, and cognitive engagement, $F(1, 58)= 5.669$, $p=.021$.

Deeper analysis on engagement revealed that students who played the Candy Factory game in one group and the Pearl Diver game in another group showed significantly greater behavioral, cognitive, and emotional engagement than students who did paper-and-pencil drills in the control group. The results are consistent with Oncu's (2007) study in which the author reports that games contribute an increase in students' behavioral engagement. These results are also consistent with Wilson et al.'s (2009) literature review in which researchers state that educational games can lead to greater behavioral, cognitive, and emotional outcomes. In regards to emotional engagement, the result was consistent with Pierfy's (1977) and Randel et al.'s (1992) literature reviews presenting that students demonstrated high interest in educational games. In terms of flow theory integration in the engagement survey used in this study, the results were consistent with Chang, Wu, Weng, and Sung's (2012), Kiili's (2005), Wang and Chen's (2010) research studies in which the researchers studied on the qualities of flow. They have found higher flow experience in treatment group students during game playing activity as opposed to the control groups. The results of this study were also found to be consistent with the studies conducted by Kiili (2005) and Inal and Cagiltay (2007), as they reported that educational games provided students to experience flow.

Third research hypothesis. For the third research hypothesis, students who did activities with virtual manipulatives in the experimental group would score significantly higher on the engagement survey than participants who did the paper-and-pencil drills in the control group. The third research hypothesis was also supported by the ANCOVA results, $F(1, 46)= 7.967$, $p=.007$. Students who did activities with virtual manipulatives showed significantly higher engagement than students who did paper-and-pencil drills in

the control group. The virtual manipulatives group showed the second greatest mean difference between pre-and-post engagement survey scores ($M_{\text{VM post-test}} - M_{\text{VM pre-test}} = 7.44$). This result is consistent with McCollister et al. (1986) as they state that computerized environments offer activities that are more engaging than traditional teaching and learning environments. This positive result is also consistent with the prior empirical research studies such as those reported by Kim (1993) and Smith (2006) as they found positive impact of virtual manipulatives on students' engagement. In addition, Reimer and Moyer (2005) found that students were engaged while learning with virtual manipulatives in their study.

The sub-hypothesis was formed in regards to the third research hypothesis to suggest that students who did the activities of virtual manipulatives in the experimental group would report the engagement survey significantly higher in the three domains (behavioral, cognitive, and emotional) than participants who did the paper-and-pencil drills in the control group. ANCOVA results showed statistical difference in behavioral and emotional engagement while the results showed no significant difference in cognitive engagement between virtual manipulatives and control group students, behavioral, $F(1, 46)= 4.622$, $p=.037$, emotional, $F(1, 46)= 6.531$, $p=.014$, and cognitive engagement, $F(1, 46)= 3.373$, $p=.073$. The third sub-research hypothesis was partially supported by the ANCOVA results. When these results were compared to the study done by Drickey (2000), the behavioral engagement qualities, such as students being on task and staying in front of the computer, were corroborated with the findings of this study. The qualities described in Drickey's (2000) study, such as being on-task, were considered as part of behavioral engagement in this study. Similar to this study, students in the virtual

manipulatives group were engaged behaviorally (Drickey, 2000). Smith (2006) and Steen et al. (2006) also found in their study that students who did activities with virtual manipulatives showed increased time-on-task. They found that students showed positive attitudes and increased motivation, consistent with this study in terms of emotional engagement.

Further analyses. To explore the engagement results, further questions were proposed as follows to analyze the three domains of engagement between and among groups:

1. Did participants who played the Candy Factory game demonstrate greater increase in the engagement survey than participants who did paper-and-pencil drills?

The results of ANCOVA showed no significant difference in engagement between the Candy Factory game group and the paper-and-pencil drill group, $F(1, 42)=1.773$, $p=.191$. Although the Candy Factory game group has the highest mean score among experimental groups, their engagement scores were not found statistically significant from the control group students' engagement scores when their engagement pre-test results were taken as a covariate. That was the main reason why the researcher did not leverage from ANOVA, because ANOVA would show a significant difference between the Candy Factory game group and the control group. There is a big difference between the mean scores of the Candy Factory game group and the control group, therefore ANOVA showed a significant difference between these two groups, $F(1,42)=6.892$, $p=.012$. Still, the Candy Factory game group students' engagement pre-test mean scores ($M_{CFG}=99.17$) were found higher than the post-engagement survey mean scores ($M_{CFG}=98.12$). The researcher can argue that students in the Candy Factory game group

sustained their engagement scores based on the results. This result is consistent with the results of the study done by Brom et al. (2011) and Lim, Nonis, and Hedberg (2006). They found that the course with the game was not more engaging than the regular course (Brom et al., 2011). Although their total engagement mean scores were still higher than the other groups, the researcher expected to find a significant increase in their engagement scores. Based on this result, the researcher might state that this is an example of *regression toward the mean* (Nesselroade & Stigler 1980), because students in the Candy Factory game group showed extreme scores on their engagement pre-test and their engagement scores on the post-test regressed toward their average score. Another reason why students' engagement scores were not significantly increased in the Candy Factory game group might stem from the game itself as it provides learning activities between an educational game and a virtual manipulative. As mentioned in chapter three, the Candy Factory game needs some developments in terms of game design because it does not show all of the game elements. On the other hand, it might be considered as more close to the virtual manipulatives activities defined previously.

Finally, the researcher can also argue that the Candy Factory game and its three features focused on this study do not necessarily have to create a big impact on students' engagement. This result is also important because it demonstrates that students' engagement is sustained throughout the treatment process although it is not significantly different from the control group students' engagement.

2. Did participants who played the Candy Factory game demonstrate greater increase in terms of behavioral, cognitive, and emotional engagement as measured by the engagement survey than participants who did paper-and-pencil drills?

According to the ANCOVA results, the Candy Factory game group students' behavioral, cognitive, and emotional engagement scores were not statistically different from the paper-and-pencil drills group students, behavioral, $F(1, 42)=2.438$, $p=.126$; emotional, $F(1, 42)=2.091$, $p=.156$; and cognitive engagement, $F(1, 42)=1.354$, $p=.251$. As Lim et al. (2006) stated, engagement in the game might not necessarily lead to engagement in the learning task, students in the Candy Factory game group might have been engaged during the treatment but it was not enough to engage them more in mathematics than their previous engagement scores.

3. Did participants who played the Pearl Diver game demonstrate greater increase in the engagement survey than participants who did paper-and-pencil drills?

The students' engagement in the Pearl Diver game group scored significantly higher than the control group, $F(1,42)=7.386$, $p=.010$. Based on the total mean differences between engagement pre-test and post-test results, the Pearl Diver game group showed the highest difference between pre-and-post engagement surveys ($M_{\text{PDG post-test}} - M_{\text{PDG pre-test}} = 8.06$). This finding aligns with many other educational game research studies reported that students in the educational game groups were more engaged than the control group students were (Annetta, Minogue et al., 2009; Hays, 2005). Although observations and qualitative focus groups were used to collect data, Annetta, Minogue, et al. (2009) found high student engagement in their study.

4. Did participants who played the Pearl Diver game demonstrate greater increase in terms of behavioral, cognitive, and emotional engagement as measured by the engagement survey than participants who did paper-and-pencil drills?

According to the ANCOVA results, while the Pearl Diver game group students' behavioral engagement was not statistically different from the paper-and-pencil drills group students' behavioral engagement, there was a significant difference in terms of their emotional and cognitive engagement: emotional $F(1,42)=7.849$, $p=.008$; cognitive $F(1,42)=5.430$, $p=.025$; and behavioral $F(1,42)=2.706$, $p=.107$. Therefore, the researcher might state that the Pearl Diver game treatment had an effect on students' emotional and cognitive engagement.

5. Did participants who did activities with virtual manipulatives demonstrate greater increase in the engagement survey than participants who played educational games?

6. Did participants who did activities with virtual manipulatives demonstrate greater increase in terms of behavioral, cognitive, and emotional engagement as measured by the engagement survey than participants who played educational games?

As for the questions 5 and 6, no significant difference was found between educational game groups and the virtual manipulatives group in terms of their engagement in general and in all three domains: engagement in general, $F(1, 53)=.003$, $p=.954$; behavioral, $F(1, 53)=.021$, $p=.885$; emotional, $F(1, 53)=.091$, $p=.764$; and cognitive engagement, $F(1, 53)=.002$, $p=.963$. On the contrary, the relationships among all of the experimental groups were found close to 1 reporting that they were approximately similar in terms of having an effect on engagement. These results might explain the three game attributes focused in each treatment, -goal, feedback, and challenge-. Therefore, the researcher might interpret the results that the attributes of these media did not create significant difference between experimental groups. As all three

experimental groups leveraged from clear goals, immediate feedback, and challenges; it did not create differences between experimental groups. More discussion on the attributes is presented in the next section. Previous qualitative research studies proved that virtual manipulatives provided students a more interesting and engaging learning environment than concrete manipulatives did (Kim, 1993). However, activities of virtual manipulatives have not been compared in terms of students' engagement with educational games in previous research. In addition to this, most of the studies on virtual manipulatives used observational data and they were not supported with quantitative data to analyze students' engagement. Therefore, this current study is expected to fill these gaps by providing an instrument and a sound research in this area.

Fundamental Attributes of Virtual Manipulatives and Educational Games

Based on the discussion between Clark (1983) and Kozma (1991), the researcher reports that it is not the technology itself that creates differences on engagement between groups; it is their unique features and attributes that have the most impact on engagement. The researcher presents three attributes of each technology used in this study. Virtual manipulatives and educational games have unique features such as providing clear goals and immediate feedback to the students in every step. In addition to these, some applets and games provide balance between challenges and skills for students by connecting their various features to create an effective learning environment. Therefore, the main attributes of these technologies constitute the main effect on students' engagement.

Goals. Presenting clear, meaningful, and achievable goals every step of the way is expected to have an impact on students' engagement specifically on behavioral engagement during the treatment. According to the results of the study, the researcher

might state that this aspect of educational games and virtual manipulatives might have had an effect on increasing and sustaining students' engagement in general and behavioral engagement. This result is consistent with Sedighian and Sedighian's (1996) observations and interviews with students in which they state that such goals create a sense of mission to complete in children. The researchers provide students' expressions stating that they try to accomplish that goal and they get excited after they have accomplished it (Sedighian & Sedighian, 1996). As mentioned in the literature review section, these game attributes directly relate with each other.

When educational games were analyzed based on the two scales in terms of providing clear goals (Hays, 2010; Sweetser & Wyeth, 2005), it was seen that they attempted to establish goals clearly for students to describe what they need to do next. When students' responses were analyzed in terms of the goal, 90% of the students who played the Pearl Diver game (PDG) and 94.1% of the students who played the Candy Factory game (CFG) "strongly or somewhat agreed" that the goal of the game was clear. However, the big difference between these two educational games appears in how well the game guided students on how to play it. While 95% of PDG group students responded that the game guided them well on how to play it, it was 70.6% in CFG group. A reverse item on how to play the game attempted to increase the reliability of the survey; while 85% of the students in PDG "strongly disagreed or somewhat disagreed" that the game was easy to understand how to play, it was 70.6% in CFG group. Based on students' responses, one conclusion might be that students should be guided well at the beginning or during the game play or when needed so that they can play the game more efficiently.

If game does not provide enough guidance on how to play the game, students will not understand it and it might create serious issues in terms of engagement.

Feedback. Providing immediate feedback on students' actions was expected to increase students' engagement, their cognitive engagement, in particular. In terms of general engagement, the researcher can assert that feedback might have yielded an impact in students' engagement. In addition, when educational game group students' cognitive engagement scores were compared to control group students', significant difference was found. Therefore, the result is consistent with Sedighian and Sedighian's (1996) conceptual categorization as they classify feedback as a cognitive artifact. Besides, the result is also consistent with Bottino et al.'s (2007) study as they report that feedback supports kids' cognitive processes. When each game was analyzed in terms of their cognitive engagement, statistical difference was discovered in the Pearl Diver game group students although no difference was detected in the Candy Factory game group students compared to control group students. Similar to the Candy Factory game group, students' cognitive engagement in the virtual manipulatives group did not create any difference compared to control group. Therefore, the researcher might assert that the type of feedback that the learning environment provides -visual, auditory, textual, score…etc.- might have had an effect on students' cognitive engagement (Wilson et al., 2009). The Pearl Diver game provided visually aesthetic, immediate, and auditory feedback to the students based on their actions, while the Candy Factory game and virtual manipulatives provided only textual feedback (See Appendix H, I, and J).

When the two scales were analyzed in terms of feedback that each game provided (Hays, 2010; Sweetser & Wyeth, 2005), it was seen that the Pearl Diver game did a better

job of giving feedback to the players. This was proven by the students who responded to the game features survey. 80% of the students in PDG group thought that the game provided them immediate feedback on their actions (64.7% in CFG), the game gave them information on their score and level (70.6% in CFG), and the game provided them enough feedback on mathematics (70.6% in CFG). Finally, 70% of the PDG group students reflected that the game helped them learn from their mistakes while it was 64.7% in CFG group. Therefore, it might be another explanation for the increase of mean scores in the Pearl Diver game group students' engagement. The virtual manipulative group students' significant difference in their engagement compared to control group was consistent with the study conducted by Reimer and Moyer (2005). According to student interviews and attitude surveys, it was indicated that virtual manipulatives helped students learn more about fractions by providing immediate and specific feedback, and it enhanced students' enjoyment in learning mathematics (Reimer & Moyer, 2005).

Challenge. Challenging students with multiple levels and activities that are suitable with their abilities was expected to have an impact on students' engagement particularly on their emotional engagement. When emotional engagement scores were examined in detail, it was found to have the greatest effect on students' engagement. The result is consistent with Sedighian and Sedighian's (1996) interviews with students in which they stated they like challenges as they keep students engaged. It was also observed in their study that students became quickly bored when they do repetitive activities during the gameplay. Similar to this study, in Ke and Grabowski's (2007) study, students in one group did activities on the edge of their skills. The researchers provided them challenging but attainable activities during the treatment and students in that group

had higher emotional outcomes (Ke & Grabowski, 2007). Therefore, the researcher might assert that as an attribute, challenge should be integrated into the learning environment to have a positive impact on students' emotional engagement.

Although two games are close to each other according to the scale items in terms of challenges (Hays, 2010; Sweetser & Wyeth, 2005), it can be asserted that the Pearl Diver game was one-step ahead of the Candy Factory game. Both games provided challenges for students with multiple levels and level of challenges increased as players progressed through the game. However, as it was mentioned previously, the Pearl Diver game provided more levels and more clear goals for students, and this might have resulted in a positive impact in students' engagement when compared to the Candy Factory game group students. When students' responses were analyzed, most of them answered that the first level was easier than the next levels (85% in PDG and 94.2% in CFG). In terms of balancing the challenges with students' skills, 85% of PDG group students answered that the game was neither too difficult nor too easy, similar to CFG group (82.3%). However, around 75% of the students in both groups responded that the game was very easy to finish. In terms of students' emotions towards the game challenges, 95% of the PDG students responded that the game was fun to play, but only 64.7% of CFG students felt that way. Moreover, only 35% of the PDG students replied that the game became boring after some time of playing as opposed to 64.7% of CFG students. However, around 54% of students in each group thought that the game provided important tasks for them.

Garris et al. (2002) asked what factors sustain students' engagement or interest over time. This study might argue that challenge can be the main factor sustaining

students' engagement during the eight days of treatment. Because of their nature, the educational games and virtual manipulatives used in this study were short or mini game type of activities that could not keep students playing or doing them for more than 20 minutes every day. Therefore, the researcher leveraged from challenge in order not to let students' engagement wane over time (Garris et al., 2002). The researcher might argue that challenging them with different goals for each day might have provided higher engagement over eight days of treatment. In summary, the significant difference between experimental and control group students' engagement is corroborated with Malone's (1981) and Malone and Lepper's (1987) arguments stating that challenge is an essential attribute of an educational game to engage students.

The researcher utilized two educational games that had more than one level, and results showed that these multiple level games do sustain students' engagement. Therefore, the significant difference between experimental and control group students' engagement is consistent with Gee's (2007) argument stating that high levels of engagement can be reached by using multiple level educational games. The students' engagement mean scores in the Candy Factory game group did not increase but the Pearl Diver game group students' engagement mean scores increased significantly. Therefore, the researcher could argue that the increase in the Pearl Diver game group might have been based on the more levels that the Pearl Diver game provided (nine levels) than the Candy Factory game did (three levels). When each applet of virtual manipulatives was considered as levels, the researcher could also argue that the source of increase in the virtual manipulatives group might have been the various levels that virtual manipulatives provided.

Summary. As stated in the literature review section, it was not guaranteed that students would be more engaged when they play educational games or do virtual manipulatives activities. However, the researcher could argue that leveraging from media, which had those three game features, might have sustained students' engagement in three domains towards mathematics in these three experimental groups. Csikszentmihalyi's (1996) characteristics of flow activity were as follow: clearly defined goals, challenges suitable with skills, and clear feedback. Hence, the researcher might argue that these three features are the most important elements to ensure students' engagement and flow towards mathematics through educational games and virtual manipulatives based on the results of this study (Figure 6). There are other game features, of course, that might have an impact on students' engagement; however, this study focused only three of them. Ke and Grabowski (2007) and Malone (1981) state that educational games that provide fantasy, contextually relevant information, and challenges can enhance students' engagement and motivation.

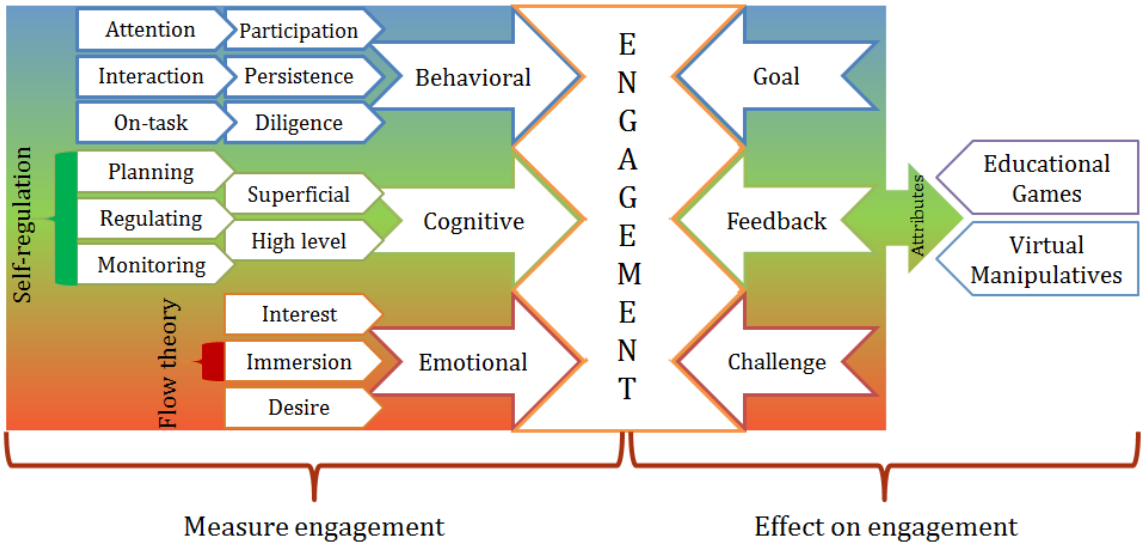

Figure 6. Factors measuring and effecting students' engagement.

Conclusion

First, this dissertation contributes to the field by developing a more refined measure of engagement. The current study also contributes further insights on the existing literature on the effectiveness of educational games on students' engagement. It differs from the previous studies concerning the type of educational games, the research method and design, and the students' level. Additionally, the topic used in this study was specific in virtual manipulatives and educational games groups.

The focus of this dissertation is not to demonstrate the efficacy of educational games and virtual manipulatives, but to take educational game designers' and researchers' attention to their unique features by conducting sound and data-driven research. In addition, this dissertation attempted to design a valid and reliable instrument to measure students' engagement in three domains as a contribution to the field. This study measured engagement effects of recent iOS Mobile platform games that can be used in educational settings while most of the previous research focused on educational games that can only be played with computers. Besides, this study used quantitative data to validate the results while some of the previous research on engagement used qualitative data (Akkerman et al., 2009; Amory, 2010; Watson et al., 2011). In addition, students' engagement was secondary in most research studies with educational games while performance, achievement, or knowledge gains were the main issue. Moreover, the present study focused on elementary school students' mathematics engagement (N=86). These students were from different schools in a rural area of southwest Virginia. There were previous studies that used elementary school students as a sample, but their engagement in mathematics was not analyzed. Annetta, Mangrum, et al. (2009) and

Barab et al. (2007) focused on the effects of educational games on elementary school students' engagement, but in science class. Further, there have been a limited number of empirical educational game studies done in the classroom setting, and this study was conducted during the mathematics periods with fifth grade students' actual mathematics teachers.

Engagement. There can be many factors affecting students' engagement and it is not possible to account for all in one study. This study attempted to measure engagement with three domains. From these results, it can be concluded that students in all three experimental groups were more behaviorally, emotionally, and cognitively engaged to the activities that they did during the treatment than the students in the control group; however, the virtual manipulatives group students did not differ from the control group in terms of cognitive engagement. Effect sizes were found to be moderate. As can be seen from the results, these positive findings echo results seen in many other educational games and virtual manipulatives studies (e.g., Annetta, Mangrum, et al., 2009; Annetta, Minogue, et al., 2009; Clark et al., 2011; Kim, 1993; Reimer & Moyer, 2005; Smith, 2006).

Another interesting result was the engagement scores of the students in the paper-and-pencil drills group as their scores decreased when compared to engagement pre-test results. Clearly, students did not like studying mathematics with paper-and-pencil drills every day for eight days. The researcher can argue that it is the main reason of the decrease in their mathematics engagement. Related literature implies that students who are not engaged present challenges for learning mathematics (Williams & Ivey, 2001). Appleton et al. (2008) stated that engagement is a prerequisite for learning. Bodovski and

Farkas (2007) also stated that student engagement has the most important effect on learning mathematics. The findings of this study confirmed that students' engagement could be increased to get them interested in the course even though the duration of the research study was limited.

Schools have the technology they need and NCTM (2008) wants students to use these technologies for learning mathematics and to engage students more into the content. Therefore, what all teachers need to do is to use them with proper instructional purposes by embedding them in the learning process. NCTM (2008) also suggests integrating technology into lesson plans while teaching mathematics. The main problem was to engage students in mathematics in general. This study proved that there was no difference between experimental and control group students in terms of their desire to attend mathematics classes before the treatment (engagement survey item 13); however, after the treatment, there was a difference between the two groups. As engagement is related to success, educators and policymakers should leverage more from educational games and virtual manipulatives within the curriculum in order to increase students' engagement and achievement respectively. They should also be cautious while choosing the right educational game for the students, because results show that not every educational game increases students' engagement. While some educational games sustain students' engagement, some create a significant difference compared to traditional methods. Although traditional approaches have still been used (Childs et al., 2006), it was demonstrated in this study that they did not provide engaging experiences for mathematics, on the contrary, it hurt students' engagement.

Three domains of engagement. In addition, the current study provided an empirical research covering the three domains of engagement (behavioral, cognitive, and emotional) and their specific qualities. Psychology literature on engagement suggested doing more engagement studies in different domains by stating that there are few research studies on behavioral engagement focusing on involvement in learning and academic activities (Finn et al., 1995). The current study attempted to examine students' engagement on task and on a specific course. Many existing studies collected the engagement data by using qualitative data collection methods such as observing students, taking notes, and doing interviews; however, empirical methods were suggested by researchers to measure engagement precisely (Hoffman & Nadelson, 2010). Therefore, this study expects to add an empirical study to the existing literature, as there are relatively few empirical studies on educational games and virtual manipulatives and their impact on engagement in three domains. The question of which qualities of engagement have the most impact on students' engagement when they use technologies related to mathematics has not been answered. This study showed that three domains of engagement are also interrelated with each other. When students were engaged behaviorally, emotionally, and cognitively to the content, task, or activity, their engagement showed significant improvement. Moreover, further analysis can be done in terms of sub-domains of the engagement survey such as items on behavioral-persistence, emotional-immersion, and cognitive-self-regulation, which can be analyzed separately to see if those specific qualities are significantly increased between groups or not.

Engagement survey. An important gap was stated in the literature: qualitative observations needed to be verified with a quantitative investigation (Ke, 2008a; Kong et

al., 2003). As a result, the current study contributes to the existing literature by providing a reliable and valid instrument on engagement. However, as a limitation, the researcher did not know what students were thinking while they were answering the engagement survey because some items were more generic compared to some specific items. Therefore, those generic items can be eliminated in further studies. Although further research and analyses are needed to verify the instrument and collect more data on it, the current engagement survey can be considered a good start for series of future research on engagement. Furthermore, the students' engagement survey used in this study has been designed in a way that it can be used for other courses such as science, history, etc. Also, the instrument covers three essential domains of engagement with their sub-domains covering flow theory and self-regulation. As explained in chapter three, there are limited empirical studies covering these three domains concurrently and evidently in one study. Although some scholars in psychology or education might naturally want to replace some of the specific items in each domain, the engagement survey, in general, tries to address the main elements of students' engagement. It is clear that these three domains of engagement are interrelated and inseparable from each other (Fredricks et al., 2004). Therefore, some overlaps are inevitable among these three domains because of their multifaceted nature (Annetta, Minogue, et al., 2009; Fredricks et al., 2004; Jimerson et al., 2003).

Mathematics and fractions. This study also tried to present a solution for the targeted students' problem in mathematics, more specifically on fractions. As stated in the literature and confirmed by the teachers, teachers have more trouble with fractions, because fractions are difficult to teach and students find it difficult to understand (Norton

& Wilkins, 2009). The current study provided students with more innovative and sophisticated combinations of instructional strategies by using educational games and virtual manipulatives in order to engage them more into fractions. The results showed a positive effect on students' mathematics engagement in three domains. It is suggested that teachers, instructional designers, and instructional technologists should integrate these types of media focusing their unique features as they engage students more to the content.

Instructional support. This study also has importance in terms of answering Ke's (2008a) question, "Will instructional support features appear so intentional and detached from the game world that they reduce a game's engaging power?" (p. 1619). During the study, there was no instructional support given to the students neither before nor after the treatment. Therefore, there was nothing to interrupt students' game experience and flow during the treatment (van Eck, 2006). Items related with flow theory (emotional-immersion) were integrated to the survey and results showed significant differences between experimental and control groups in terms of emotional engagement.

Future Research

Clearly, this study aimed at finding an immediate difference on students' mathematics engagement because there were only 11 days between pre-test and post-test data collection. Therefore, the results found in this study show students' immediate engagement towards mathematics. A longer-term study might have yielded results that are more different. For example, a future similar study may be conducted with same type of groups but rather than doing the treatment in eight consecutive days, it can be done in eight weeks to see if there will be any different results compared to this study. Moreover,

a delayed post-test (after a month or so) on students' engagement might show different results in terms of students' mathematics engagement. In addition, the number of students participated in the study can be increased to get more reliable results. For each experimental and control group, at least two groups can be used to get more powerful analyses.

The engagement survey designed in this study can be further analyzed in terms of specific sub-domains such as diligence, persistence, interest, immersion, high and superficial levels, and self-regulation strategies. Further analyses might find interesting results for sub-domains between groups. However, the researcher needs more participants to analyze those specific sub-domains. The engagement survey might be used with a different course by rewording the items in order to see if it measures what it means to measure 'engagement'.

It would also be interesting to compare this dissertation study on engagement with Keller's (1987) ARCS (Attention, Relevance, Confidence, and Satisfaction) model in which motivation was investigated in instructional settings. The results of the recent research studies on ARCS model (e.g. Kebritchi et al., 2010) can be analyzed through this study. Comparing the results of these studies, implications can be expanded based on this seminal work, contributions can be made, and finally future research streams can be opened up.

Future study might analyze students' achievement scores in all groups and it might give interesting results in terms of students' mathematics scores in different groups although Annetta, Mangrum, et al. (2009) stated that integrating educational games into classrooms does not necessarily have to increase students' achievement. An important

point for this type of future study should include questions that are studied in all four groups because there are different types of groups doing different activities on the same topic in this study. Therefore, the researcher needs to analyze the content of the activities to prepare an achievement test that can assess students' performance in all groups equally. Furthermore, students' standards of learning (SOL) scores might be analyzed to see if their average SOL scores on fractions have been increased or not after the treatment.

The educational games used in this study were analyzed in terms of their features such as goals, challenge, and feedback; but future research might focus on other specific features. By focusing on different features for each experimental group, the researcher might analyze which feature has the most effect on students' engagement and/or achievement. Moreover, future research needs to focus on connecting the specific tasks with specific game attributes in order to identify which attributes are important to learn which skills (Wilson et al., 2009). In addition, future research might analyze students' engagement by using the same game in different experimental groups but focusing on one or two features of the educational game and determine if those features create any difference between groups.

Furthermore, students' different characteristics can be analyzed to identify if there is any significant difference on, for example, gender, age, socio-economic status (SES), grade point average (GPA), and parental factors. As the number of variables increases, a larger sample size becomes necessary. In future study, teachers' observations can be collected to analyze the potential differences. Their perceptions on how they see their

own students during the treatment and how engaged the students are might be collected as well.

The researcher would want to include more items in the survey for each domain of engagement in order to get results that are more reliable for each domain; however, the researcher and the experts in this area thought that more items would not be convenient for elementary school students considering their short time span on a specific task. Future research might include less survey items but add observation, field notes, and interviews with the students and teachers to cover the missing qualities of engagement and to collect quantitative and qualitative data on students' engagement within three domains. In terms of collecting data, it is suggested that researchers use mobile devices and/or computers to collect survey data for future research as students used those devices during the treatment and they showed their capability to use them effectively.

Summary

Engagement is central to the success of student learning (Charles et al., 2009; Oncu, 2007) and the current research study found that when some educational games and virtual manipulatives are used for a specific topic in mathematics with their unique features, they might have a positive effect on students' engagement. Therefore, students are expected to be more successful in mathematics. This implies that educational games can be effective tools to assist students' engagement or sustain their interest in mathematics learning as long as the educational games are integrated into the mathematics classroom appropriately (Annetta, Mangrum, et al., 2009). The researcher intentionally leveraged from two educational games designed for the same topic to see if they would have different results in terms of students' engagement. As one educational

game was found to demonstrate the three game features less effectively than the other educational game based on the results of the two game features scales, the engagement results of these two educational games were found to be consistent. While the educational game that was found more effective in terms of three game features showed significant differences with control group, no significant difference was found for the other educational game but it was found to sustain students' engagement. Therefore, educators, teachers, and researchers should carefully choose the educational game if they want to increase their students' engagement. However, the generalizability of the findings may be limited to specific settings with similar games, learning environments, same subject, and same grade of students.

Although the number of the participants involved in this research was low, it was expected that the findings of this study might help future researchers by focusing on different attributes to develop more valid and reliable instruments, and applying them within a more robust research design. Although the literature differs in terms of critical game attributes for learning, many researchers support educational games by stating that they help learning and result in greater behavioral, cognitive, and emotional gains (Egenfeldt-Nielsen, 2006). Existing literature is not mature enough to make a connection between game attributes and three domains of student engagement. Therefore, this study focused primarily on addressing that issue. Finally, Hays' (2005) quote needs to be reminded here "we should not generalize from research on the effectiveness of one game in one learning area for one group of learners to all games in all learning areas for all learners" (p. 6).

The implications drawn from these findings should be used with caution, because the game attributes and qualities of behavioral, cognitive, and emotional domains of engagement examined in this study could account for only a small portion of the population in terms of explaining the variation in student engagement scores. It is recommended that the study be replicated based on these results.

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APPENDICES

Appendix A

Learner Characteristics Survey

Study ID:

Learner Characteristics

Please mark your response to following statements by circling one of the options.

		No			Yes
1	I learn math digital games fast.	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
2	It is easy for me to learn math digital games.	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
3	If I use digital games to learn math, I can get a better math grade.	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
4	Digital games are good educational tools to help me to learn math.	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
5	My parents make rules on my digital game playing.	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
6	My parents check the content of my digital games	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
7	My parents tell me which digital games are good ones.	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
8	My parents play digital games with me.	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
9	I often play digital games	Yes		No	
10	I play digital games more than my friends do.	Yes		No	
11	Do you have a computer at home?	Yes		No	
12	Do you have the Internet at home?	Yes		No	
13	How would you describe yourself as a game player?	Gamer (play games a lot)	Proficient (play games regularly)	Novice (play games irregularly)	Non-gamer (never play games at all)
14	How often do you play digital games?	Everyd ay	2-3 times a week	Once a week	Once a month	Once or twice a year
		Never		Others (Please specify):	
15	How long do you usually play when you play digital games?	Less than 15 minutes	Longer than 15 minutes but less than 30 minutes	Longer than 30 minutes but less than 1 hour	Longer than 1 hour but less than 2 hour	Longer than 2 hours
16	What is your gender?	Male		Female		
17	What is your age?	9	10	11	12	13

Appendix B

The Students' Engagement Survey

Study ID:

Math Engagement

Try to reflect on your experience with learning math recently. Please mark your response to following statements by circling one of the options.

		No			Yes
1	I listen to my math teacher carefully while we are doing fractions.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
2	I participate in discussion on fractions.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
3	I get easily distracted from the fraction tasks.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
4	I work hard at fraction tasks.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
5	At home I review fraction problems that I did not understand in school.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
6	When I see difficult fraction problems, I stop working on them.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
7	Sometimes I skip difficult fraction questions.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
8	When I make mistakes in fractions, I work until I correct them.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
9	I follow my teacher's directions on fractions.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
10	I sometimes pretend as if I am studying fractions in math class.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
11	I ask my friends or teachers for a help when I can't solve difficult fraction problems.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
12	I am interested in learning new things in fractions.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
13	I do not like attending math classes.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
14	Learning fractions is fun.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
15	I feel bored when I study fractions.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
16	I feel excited when I study fractions in math class.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
17	I am excited about solving difficult fraction problems.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
18	I like to study other subjects rather than fractions.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
19	Time passes very quickly when I study fractions.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
20	I tend to lose track of where I am when I study fractions.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree

21	I want to spend more time solving fraction problems.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
22	I feel happy when I study fractions.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
23	Sometimes I follow my best guess when I do not know the answer.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
24	When I study fractions, I ask myself questions to make sure I understand it correctly.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
25	I try to connect fractions to real life situations.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
26	I try to think different ways to solve fraction problems.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
27	I try to develop my own strategy when I solve fraction problems.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
28	I set goals for myself when I study fractions.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
29	When I can't solve a fraction problem, I try to change my strategy.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
30	I often think about something else when I study fractions.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
31	At home I think about what I learned about fractions.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
32	I am focused when I study fractions.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
33	I memorize important facts to understand fractions better.	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree

Appendix C

Students' Engagement Survey with Original Items and References

#	Survey Items 11B – 11E – 11C	Domain and Subdomain	Original item in the literature	Author
1	I listen to my math teacher carefully while we are doing fractions.	Behavioral – Attention	I read text as teacher directs; listen to teacher reading	Annetta, Minogue, Holmes, & Cheng (2009)
			I listen to the teacher's instruction attentively.	Kong, Wong, & Lam (2003)
			I pay attention in class.	Fredricks et al. (2005)
2	I participate in discussion on fractions.	Behavioral - Participation	I always take part in the discussion in the mathematics class. & In the discussion of new topics, I take an active part and raise my points.	Kong, Wong, & Lam (2003)
3	I get easily distracted from the fraction tasks. (Reversed)	Behavioral – Student on task	No distraction from the task is highlighted	Fu, Su, & Yu (2009)
			players are not distracted from tasks that they want or need to concentrate on	Sweetser & Wyeth (2005)
4	I work hard at fraction tasks.	Behavioral - Diligence	I work hard in math.	Shapka & Keating (2003)
			In mathematics class, I try as hard as I can.	Marks (2000)
			I work hard at the task.	Arici (2008)
			I work hard to do well in this class even if I don't like what we are doing.	Pintrich et al. (1991) MSLQ
5	At home I review fraction problems that I did not understand in school.	Behavioral - Diligence	I usually make time to check my own working to find and correct errors.	Cretchley (2008)
6	When I see difficult fraction problems, I stop working on them. (Reversed)	Behavioral - Persistence	I persist at the task as I encounter difficulties	Arici (2008)
			When course work is difficult, I give up or only study the easy parts.	Pintrich et al. (1991) MSLQ
			If I cannot solve a problem right away, I will persist in trying different methods until I get the solution.	Kong, Wong, & Lam (2003)
7	Sometimes I skip difficult fraction questions. (Reversed)	Behavioral - Persistence	I persist at the task as I encounter difficulties.	Arici (2008)
8	When I make mistakes in fractions, I work until I correct them.	Behavioral - Persistence	If I cannot solve a problem right away, I will persist in trying different methods until I get the solution.	Kong, Wong, & Lam (2003)
			If I make mistakes, I work until I have corrected them.	Pierce, Stacey, & Barkatsas (2007)

9	I follow my teacher's directions on fractions.	Behavioral – Student on task	I work actively on assigned task, follow directions as given	Annetta, Minogue, Holmes, & Cheng (2009)
10	I sometimes pretend as if I am studying fractions in math class. (Reversed)	Behavioral – Student on task	When I am in class, I just act as if I am working.	Fredricks et al. (2005)
				IRRE RAPS Survey (1998)
11	I ask my friends or teachers for a help when I can't solve difficult fraction problems.	Behavioral – Interaction/ Help	I seek help when it is needed.	Arici (2008)
			When I can't understand the material in this course, I ask another student in this class for help; I ask the instructor to clarify concepts I don't understand well.	Pintrich et al. (1991) MSLQ
12	I am interested in learning new things in fractions.	Emotional - Interest	I am very interested in the content area of this course.	Pintrich et al. (1991) MSLQ
13	I do not like attending math classes. (Reversed)	Emotional - Interest	I do not like attending mathematics classes.	Kong, Wong, & Lam (2003)
14	Learning fractions is fun.	Emotional - Interest	Learning mathematics is enjoyable.	Pierce, Stacey, & Barkatsas (2007)
15	I feel bored when I study fractions. (Reversed)	Emotional - Interest	I feel bored in mathematics class.	Marks (2000)
			I feel bored in school.	Fredricks et al. (2005)
16	I feel excited when I study fractions in math class.	Emotional - Interest	The work is exciting.	Arici (2008)
			I feel excited by my work at school	Fredricks et al. (2005)
17	I am excited about solving difficult fraction problems.	Emotional - Interest	I find mathematics learning pleasurable and I am interested in solving mathematics problems.	Kong, Wong, & Lam (2003)
18	I like to study other subjects rather than fractions. (Reversed)	Emotional - Interest	I wish I were doing something else in math class.	Arici (2008)
19	Time passes very quickly when I study fractions.	Emotional - Immersion	I tend to lose track of time when playing video games	Chou & Ting (2003)
			I lose track of time; Time seems to stand still or stop	Brockmyer et al. (2009)
			Time goes by very quickly when playing video games	Fu, Su, & Yu (2009)
			I forget about time passing while playing the game	Fu, Su, & Yu (2009)
			I experience an altered sense of time	Cho & Ting (2003); Hoffman & Nadelson (2010)
20	I tend to lose track of where I am when I study fractions.	Emotional - Immersion	I lose track of where I am	Brockmyer et al. (2009)
21	I want to spend more time solving fraction problems.	Emotional – Desire	Do students participate in these kinds of activities voluntarily, given free choice?	Arici (2008)

22	I feel happy when I study fractions.	Emotional – Interest	I feel happy (being happy and happiness)	Connell & Wellborn (1991)
			When I'm in class, I feel happy	Skinner & Belmont (1993), Connell & Wellborn (1991)
23	Sometimes I follow my best guess when I do not know the answer.	Cognitive - Superficial	I just made my best guess	Blumenfeld & Meece (1988)
24	When I study fractions, I ask myself questions to make sure I understand it correctly.	Cognitive - Monitoring	I ask myself questions to make sure I understand the material I have been studying in this class.	Pintrich et al. (1991) MSLQ
			I self-check or question to understand mathematical problems.	Arici (2008)
			In learning mathematics, I always try to pose questions to myself and these questions would help me understand the core of mathematics.	Kong, Wong, & Lam (2003)
			When I read a book, I ask myself questions to make sure I understand what it is about.	Fredricks et al. (2005)
25	I try to connect fractions to real life situations.	Cognitive – High level	When I learn mathematics, I would wonder how much the things I have learnt can be applied to real life; I would try to connect what I learned in mathematics with what I encounter in real life or in other subjects.	Kong, Wong, & Lam (2003)
26	I try to think different ways to solve fraction problems.	Cognitive – High level	Whenever I read or hear an assertion or conclusion in this class, I think about possible alternatives.	Pintrich et al. (1991) MSLQ
			If I can't do a problem, I keep trying different ideas.	Pierce, Stacey, & Barkatsas (2007)
			If I don't know what a word means when I am reading, I do something to figure it out.	Fredricks et al. (2005)
27	I try to develop my own strategy when I solve fraction problems.	Cognitive – High level	I treat the course material as a starting point and try to develop my own ideas about it.	Pintrich et al. (1991) MSLQ
			I would solve problems in the same way as the teacher does.	Kong, Wong, & Lam (2003)
28	I set goals for myself when I study fractions.	Cognitive - Planning	When I study for this class, I set goals for myself in order to direct my activities in each study period	Pintrich et al. (1991) MSLQ
29	When I can't solve a fraction problem, I try to change my strategy.	Cognitive - Regulating	If course materials are difficult to understand, I change the way I read the material.	Pintrich et al. (1991) MSLQ
			If I don't know what a word means when I am reading, I do something to figure it out.	Fredricks et al. (2005)

30	I often think about something else when I study fractions. (Reversed)	Cognitive - Monitoring	During class time I often miss important points because I'm thinking of other things.	Pintrich et al. (1991) MSLQ
			I missed some of the things the teacher said because I was thinking about something else	Blumenfeld & Meece (1988)
31	At home I think about what I learned about fractions.	Cognitive - Regulating	I would spend out-of-class time to deepen my understanding of the interesting aspects of mathematics; I would use my spare time to study the topics we have discussed in class.	Kong, Wong, & Lam (2003)
32	I am focused when I study fractions.	Cognitive – High level	Being interested brings cognitive engagement by being focused on it cognitively.	Jones (personal communication, February 15, 2012)
33	I memorize important facts to understand fractions better.	Cognitive - Superficial	I memorize key words to remind me of important concepts in this class.	Pintrich et al. (1991) MSLQ
			In mathematics learning, it is very useful to memorize the methods for solving word problems.	Kong, Wong, & Lam (2003)
			I find working through examples less effective than memorizing given material.	Cretchley (2008)

Appendix D

Game Features Survey for the Candy Factory Game Group

Game Features (Post-test)
Try to reflect on your experience with learning math recently. Please mark your response to following statements by circling one of the options.

			No			Yes
1	The goal of Candy Factory Game was clear.	G	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
2	Candy Factory Game guided me well how to play the game.	G	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
3	Candy Factory Game was not easy to understand how to play. (R)	G	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
4	The first level was easier than the next levels.	C	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
5	Candy Factory Game helped me learn from my mistakes.	F	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
6	Candy Factory Game gave me information on my score and level.	F	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
7	Candy Factory Game was neither too difficult nor too easy.	C	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
8	Candy Factory Game became boring after some time of playing. (R)	C	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
9	Candy Factory Game provided important tasks for me.	C	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
10	Candy Factory Game was fun to play.	C	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
11	Candy Factory Game provided immediate feedback on my actions.	F	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
12	Candy Factory Game was very easy to finish. (R)	C	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
13	Candy Factory Game did not provide me enough feedback on math. (R)	F	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree

Appendix E

Game Features Survey for the Pearl Diver Game Group

Game Features (Post-test)
Try to reflect on your experience with learning math recently. Please mark your response to following statements by circling one of the options.

			No			Yes
1	The goal of Pearl Diver Game was clear.	G	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
2	Pearl Diver Game guided me well how to play the game.	G	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
3	Pearl Diver Game was not easy to understand how to play. (R)	G	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
4	The first level was easier than the next levels.	C	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
5	Pearl Diver Game helped me learn from my mistakes.	F	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
6	Pearl Diver Game gave me information on my score and level.	F	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
7	Pearl Diver Game was neither too difficult nor too easy.	C	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
8	Pearl Diver Game became boring after some time of playing. (R)	C	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
9	Pearl Diver Game provided important tasks for me.	C	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
10	Pearl Diver Game was fun to play.	C	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
11	Pearl Diver Game provided immediate feedback on my actions.	F	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
12	Pearl Diver Game was very easy to finish. (R)	C	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
13	Pearl Diver Game did not provide me enough feedback on math. (R)	F	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree

Appendix F

Instructional Game Evaluation Scale (Hays, 2010, p. 258-263)

Instructional Issues						
1. Instructional goals are clearly stated						
1	2	3	4	5	*CFG	**PD
No instructional goals (or objectives are stated)	Some instructional goals include very general statements (e.g., do not include statements about actions, conditions, and standards)	Some instructional goals include general statements about actions, conditions, and standards	Most instructional goals include specific statements about actions, conditions, and standards	All instructional goals include specific statements about actions, conditions, and standards	4	4
2. Instructions are included on how to play the game						
1	2	3	4	5	CFG	PD
Has no gameplay instructions	Has general gameplay instructions	Has somewhat specific gameplay instructions	Has specific gameplay instructions	Has very specific gameplay instructions	4	5
3. Game activities support instructional goals (or objectives)						
1	2	3	4	5	CFG	PD
No game activities support instructional goals	Few game activities support instructional goals	Some game activities support instructional goals	Most game activities support instructional goals	All game activities support instructional goals	5	5
4. Game activities are realistic (conform to real-world conditions)						
1	2	3	4	5	CFG	PD
Almost all game activities are very different from real-world conditions. Differences are not explained to learners.	Some game activities are different from real-world conditions. Differences are not explained to learners.	Few activities are different from real-world conditions, and differences are explained to learners.	Most activities are realistic (conform to real-world conditions), and differences are explained to learners.	Almost all activities are realistic (conform to real-world conditions), and differences are explained to learners.	3	4
5. Game activities increase in difficulty as learners' performances improve						

1	2	3	4	5	CFG	PD
All game activities have a constant level of difficulty	A few of the game activities increase in difficulty as learners' improve their performances	About half of the game activities increase in difficulty as learners improve their performance s	Most game activities increase in difficulty as learners improve their performance s	All game activities increase in difficulty as learners improve their performance s	5	5
6. Game includes assessments of learners' actions						
1	2	3	4	5	CFG	PD
Has no assessments of game activities	Has few assessments of game activities	Has assessments of about half of game activities	Has assessments of most game activities	Has assessments of all game activities	3	5
7. Game provides feedback on learners' actions						
1	2	3	4	5	CFG	PD
No feedback provided	Very general feedback provided on overall result of game	General feedback provided on some learner actions	General feedback provided on all learner actions	Specific feedback provided on all learner actions	2	5
					3.71	**4.71**
Technical Issues						
8. Game graphics are clear and sharp						
1	2	3	4	5	CFG	PD
None of the graphics are clear and sharp	Few of the graphics are clear and sharp	Some of the graphics are clear and sharp	Most of the graphics are clear and sharp	All of the graphics are clear and sharp	3	5
9. Game audio is clear and sharp						
1	2	3	4	5	CFG	PD
None of the audio is clear and sharp	Little of the audio is clear and sharp	Some of the audio is clear and sharp	Most of the audio is clear and sharp	All of the audio is clear and sharp	4	5
10. Game video is clear and sharp						
1	2	3	4	5	CFG	PD
None of the video is clear and sharp	Little of the video is clear and sharp	Some of the video is clear and sharp	Most of the video is clear and sharp	All of the video is clear and sharp	4	5
11. There are no sensory conflicts in the game						
1	2	3	4	5	CFG	PD
Different/conflicting	Different/conflicting	Different/conflicting	Different/conflicting	Different/conflicting	5	5

information is always presented simultaneously in two or more modalities	information is often presented simultaneously in two or more modalities	information is sometimes presented simultaneously in two or more modalities	information is seldom presented simultaneously in two or more modalities	information is never presented simultaneously in two or more modalities		
12. Game installation is easy or not required						
1	2	3	4	5	CFG	PD
Game requires very difficult installation	Game requires difficult installation	Game requires somewhat easy installation	Game requires easy installation	Game does not require installation, or installation is very easy	4	4
					4.0	**4.8**
Playability issues						
13. Game screens are aesthetically pleasing						
1	2	3	4	5	CFG	PD
None of the game screens are aesthetically pleasing	Few of the game screens are aesthetically pleasing	Some of the game screens are aesthetically pleasing	Most of the game screens are aesthetically pleasing	All of the game screens are aesthetically pleasing	3	5
14. Game activities are fun and engaging (attract and maintain learner attention)						
1	2	3	4	5	CFG	PD
None of the activities are engaging	Few of the activities are engaging	Some of the activities are engaging	Most of the activities are engaging	All of the activities are engaging	3	5
					3.0	**5.0**
				Overall	**3.57**	**4.83**

Appendix G

GameFlow Criteria for Player Enjoyment in Games by Sweetser and Wyeth (2005) for the game Candy Factory and Pearl Diver

Elements		**Criteria**	Candy Factory	Pearl Diver
Concentration Games should require concentration and the player should be able to concentrate on the game	1.	- game provides a lot of stimuli from different sources	4	5
	2.	- game provides stimuli that are worth attending to	4	5
	3.	- game quickly grabs the players' attention and maintain their focus throughout the game	3	5
	4.	- game does not burden players with tasks that doesn't feel important	4	5
	5.	- game has a high workload, while still being appropriate for the players' perceptual, cognitive, and memory limits	4	5
	6.	- players are not distracted from tasks that they want or need to concentrate on	5	5
		Mean	**4**	**5**
Challenge Games should be sufficiently challenging and match the player's skill level	7.	- challenges in games match the players' skill levels	5	5
	8.	- game provides different levels of challenge for different players	5	5
	9.	- the level of challenge increases as the player progresses through the game and increases their skill level	5	5
	10.	- game provides new challenges at an appropriate pace	5	5
		Mean	**5**	**5**
Player Skills Games must support player skill development and mastery	11.	- players are able to start playing the game without reading the manual	1	1
	12.	- learning the game is not boring, but it is part of the fun	3	4
	13.	- game includes online help so that players don't need to exit the game	5	5
	14.	- players are taught to play the game through tutorials or initial levels that feel like playing the game	1	1
	15.	- game increases the players' skills at an appropriate pace as they progress through the game	5	5

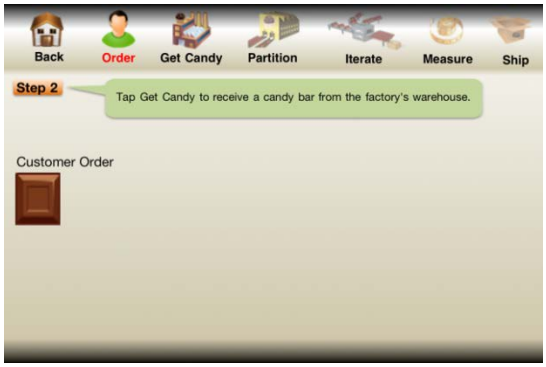
	16.	- players are rewarded appropriately for their effort and skill development	3	5
	17.	- game interfaces and mechanics are easy to learn and use	3	5
		Mean	**3**	**3.71**
Control Players should feel a sense of control over their actions in the game	18.	- players feel a sense of control over their characters or units and their movements and interactions in the game world	4	5
	19.	- players feel a sense of control over the game interface and input devices	5	5
	20.	- players feel a sense of control over the game shell (starting, stopping, saving, etc.)	5	5
	21.	- players are not able to make errors that are detrimental to the game and are supported in recovering from errors	5	5
	22.	- players feel a sense of control and impact onto the game world (like their actions matter and they are shaping the game world)	5	5
	23.	- players feel a sense of control over the actions that they take and the strategies that they use and that they are free to play the game the way that they want (not simply discovering actions and strategies planned by the game developers)	1	1
		Mean	**4.16**	**4.3**
Clear Goals Games should provide the player with clear goals at appropriate times	24.	- overriding goals are clear and presented early	3	4
	25.	- intermediate goals are clear and presented at appropriate times	3	4
		Mean	**3**	**4**
Feedback Players must receive appropriate feedback at appropriate times	26.	- players receive feedback on progress toward their goals	4	5
	27.	- players receive immediate feedback on their actions	3	5
	28.	- players always know their status or score	2	5
		Mean	**3**	**5**
Immersion Players should experience deep but effortless	29.	- players become less aware of their surroundings	3	4
	30.	- players become less self-aware and less worried about everyday life or self	3	3

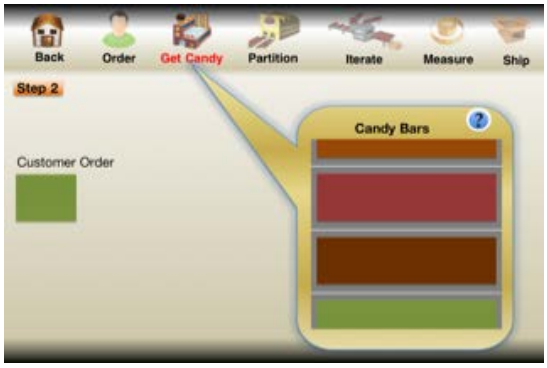
involvement in the game	31.	- players experience an altered sense of time	4	4
	32.	- players feel emotionally involved in the game	3	5
	33.	- players feel viscerally involved in the game	3	4
		Mean	**3.2**	**4**
Social Interaction Games should support and create opportunities for social interaction	34.	- game supports competition and cooperation between players	3	5
	35.	- game supports social interaction between players (chat, etc.)	3	5
	36.	- game supports social communities inside and outside the game	1	4
		Mean	**2.33**	**4.66**
		Overall	3.46	4.45

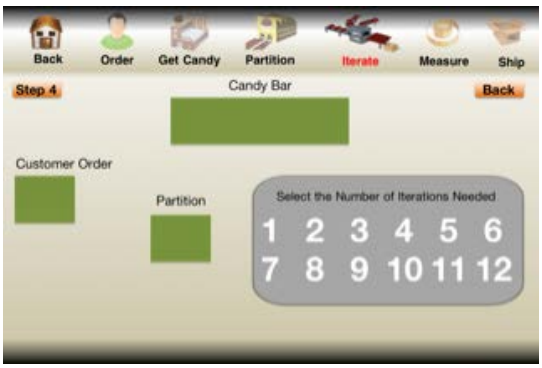
0 – N/A, 1 – not at all, 2 – below average, 3 – average, 4 – above average, 5 – well done

Appendix H

Screen Shots of the Candy Factory Game

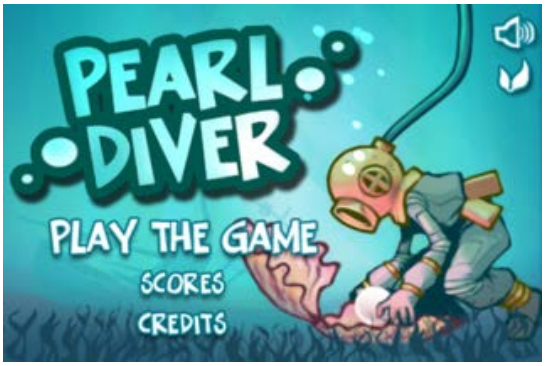


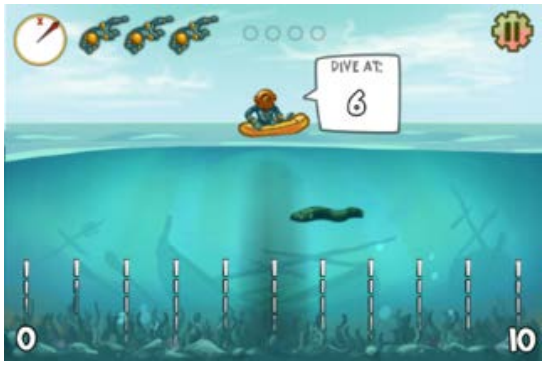




Appendix I

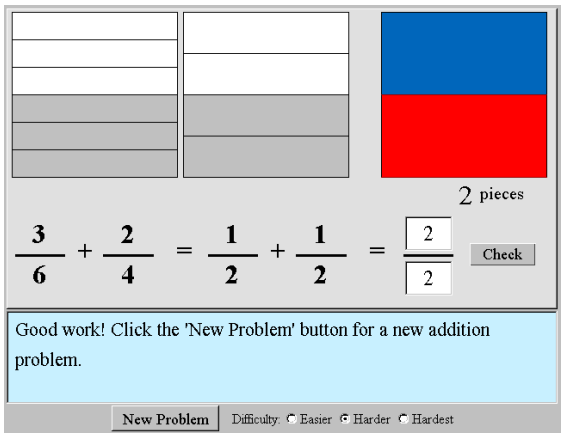
Screen Shots of the Pearl Diver Game

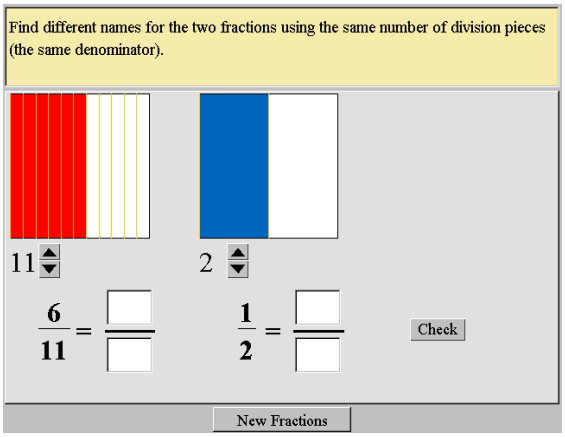


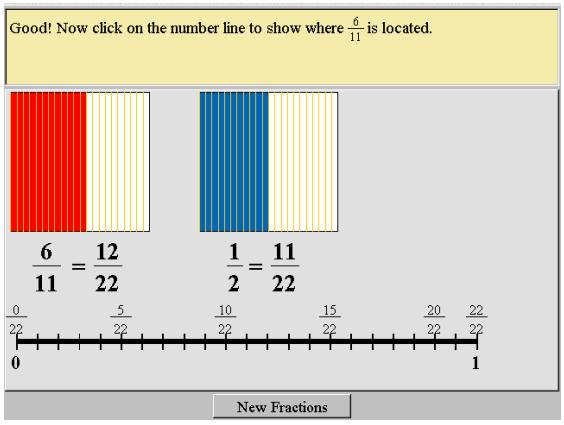


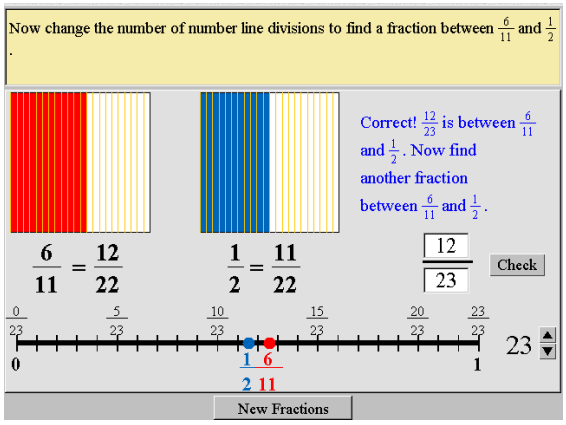
Appendix J

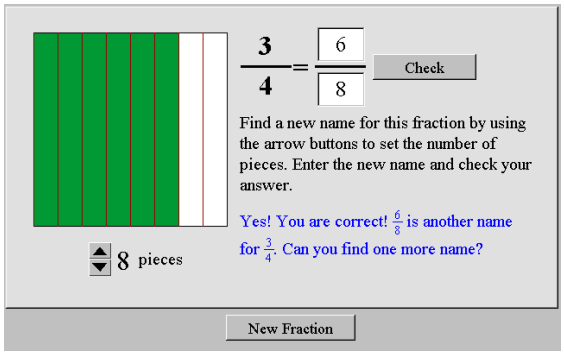
Example of an Activity with Virtual Manipulatives

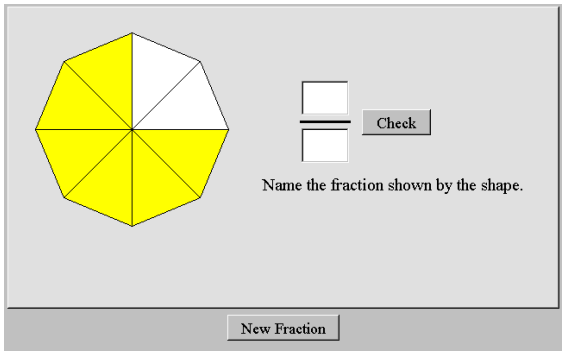












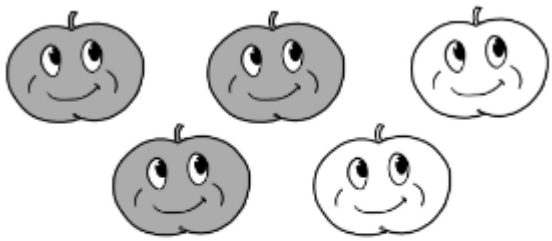
Appendix K

An Example of Paper-and-pencil Drill

Exercises - 1

Please do the exercises below.

1. What is the equivalent fraction shown below:



$\frac{3}{5}$ $\frac{1}{5}$ $\frac{2}{5}$

2. Circle TRUE or FALSE

$\frac{1}{3} > \frac{2}{5}$ TRUE FALSE

$\frac{5}{3} < \frac{2}{5}$ TRUE FALSE

$\frac{8}{12} = \frac{2}{3}$ TRUE FALSE

3. Circle the equivalent fraction according to the first one.

$\frac{1}{2}$	$\frac{5}{10}$	$\frac{3}{9}$	$\frac{3}{2}$	$\frac{4}{2}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{6}{8}$	$\frac{4}{8}$	$\frac{2}{4}$
$\frac{1}{3}$	$\frac{2}{4}$	$\frac{3}{9}$	$\frac{4}{6}$	$\frac{4}{2}$	$\frac{2}{3}$	$\frac{6}{9}$	$\frac{6}{8}$	$\frac{1}{2}$	$\frac{1}{5}$

4. Fill in the empty fraction lines with the equivalent fraction numbers

1) $\frac{1}{2} = \frac{\quad}{6}$ 2) $\frac{1}{4} = \frac{\quad}{8}$ 3) $\frac{1}{3} = \frac{\quad}{6}$ 4) $\frac{1}{4} = \frac{\quad}{12}$

5. Fill in the empty fraction lines with the equivalent fraction numbers

$\frac{2}{3} = \frac{\quad}{9}$ $\frac{2}{5} = \frac{\quad}{15}$ $\frac{1}{7} = \frac{\quad}{14}$ $\frac{3}{3} = \frac{\quad}{9}$

$\frac{2}{\quad} = \frac{4}{18}$ $\frac{3}{\quad} = \frac{9}{15}$

6. Put <, > or = symbols according to the relationship of the two fractions.

$\frac{3}{7} \square \frac{10}{14}$ $\frac{2}{3} \square \frac{8}{15}$

$\frac{4}{10} \square \frac{9}{12}$ $\frac{1}{6} \square \frac{2}{10}$

7. You had this amount of chocolate shown below:

But you ate most of it and you have this amount of chocolate left:

How much chocolate did you eat?

a) $\frac{4}{5}$ b) $\frac{3}{6}$ c) $\frac{1}{3}$ d) $\frac{1}{2}$

8. If this chocolate shown below is 1.

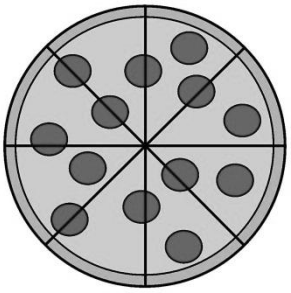
What is the fraction of this chocolate shown below?

a) $\frac{1}{2}$ b) $\frac{1}{3}$ c) $\frac{1}{4}$ d) $\frac{1}{6}$

9. In Amanda's birthday party, her mother cut her birthday cake into 16 equal pieces. 12 pieces were eaten at her birthday party. What fraction of the cake is left now?

a) $\frac{7}{16}$ b) $\frac{1}{4}$ c) $\frac{4}{12}$ d) $\frac{3}{4}$

10. Mike and his three friends ordered a pizza. How many slices should they eat if they want to eat equally?



a) Each person can eat 2.5 slices
b) Each person can eat $\frac{1}{2}$ slices
c) Each person can eat $2\frac{1}{2}$
d) Each person can eat 2 slices

11. Ashley baked 36 cookies and she wants to bring $\frac{3}{9}$ to school. How many will she bring to school?

a) 3 b) 9 c) 6 d) 12

12. Jennifer had a pizza that was divided into 12 equal slices. She ate 3 of them. David has a pizza that is the same size, but his is divided into 4 equal slices. He ate 3 slices of his pizza. Who ate more pizza?

a) Jennifer b) David

13. Order the numbers from least to greatest.

$\frac{6}{8}$ $\frac{3}{5}$ $\frac{7}{9}$ $\frac{4}{9}$ $\frac{6}{12}$ $\frac{7}{7}$ $\frac{2}{9}$ $\frac{6}{9}$ $\frac{2}{6}$ $\frac{3}{8}$ $\frac{1}{12}$ $\frac{5}{6}$

___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

Appendix L

Virginia Tech IRB Approval Letter

VirginiaTech

Office of Research Compliance
Institutional Review Board
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, Virginia 24060
540/231-4606 Fax 540/231-0959
e-mail irb@vt.edu
Website: www.irb.vt.edu

MEMORANDUM

DATE: February 23, 2012

TO: Mido Chang, Michael Evans, Yavuz Samur, Sunha Kim, Kirby Deater-Deckard, Anderson Norton

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires May 31, 2014)

PROTOCOL TITLE: GAMES - Floyd

IRB NUMBER: 12-162

Effective February 23, 2012, the Virginia Tech IRB Chair, Dr. David M. Moore, approved the new protocol for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at http://www.irb.vt.edu/pages/responsibilities.htm (please review before the commencement of your research).

PROTOCOL INFORMATION:
Approved as: **Expedited, under 45 CFR 46.110 category(ies) 7**
Protocol Approval Date: **2/23/2012**
Protocol Expiration Date: **2/22/2013**
Continuing Review Due Date*: **2/8/2013**
*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:
Per federally regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals / work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Appendix M

Parent/Guardian Permission Form

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERISTY

Parent/Guardian Permission Form

Title of Project: **Gateways to Algebraic Motivation, Engagement and Success (GAMES)**

Investigators: **Mido Chang and Michael A. Evans**

I. Purpose of this Research Project

This study is to investigate whether an educational mathematics game can be used to promote 5th grade students' mathematics proficiency and engagement. An iPod Touch game and a paper-and pencil practice sheet designed to help students learn fractions will be provided for 5th grade mathematics classes of the Floyd County Public Schools.

II. Procedures

Students will participate in the ten sessions of the project activities which will be held for ten separate days in the Floyd County Public Schools. In the first session, students will answer fraction questions and engagement survey questions for 40 minutes. During the second session, students will practice fractions with or without digital games for 20 minutes. During the subsequent seven sessions, students will practice fractions for 20 minutes for each session. In the tenth session, students will be asked to respond to engagement surveys and fraction problems for 40 minutes. Investigators will collaborate with center administrators, teachers, and parents to minimize the disruption. Researchers will work with the teachers to install the proper app(s) and provide all paper-based materials.

III. Risks

The data on students' performance on fractions and their engagement survey answers will be collected. This research poses no more than minimal risk.

IV. Benefits

Investigators and teachers will gain better understanding of the effects of educational games on students' academic performance and mathematical engagement. Results are intended to be used to develop the materials, tests, and survey. Findings will be provided to the design of future instructional strategies and technologies to better serve teachers and students in the elementary mathematics classroom. No promise or guarantee of benefits has been made to encourage you to participate. You are encouraged to contact the investigators at a later time for a summary of the research results and investigators will schedule regular updates to keep parents informed of research progress.

V. Extent of Anonymity and Confidentiality

In the process of the research, the investigators will protect and/or disguise your child's identity when using the data. The data gathered from the students will be maintained in a locked filing cabinet in the office of the investigator (Dr. Evans). You have the right to review the data taken as a part of the research to determine whether they should be edited or erased in whole or in part.

The investigators and graduate research assistants will analyze the data collected from the fraction tests, and engagement survey items. Any data gathered from your child will be identified by a numbered code only,

preserving anonymity and confidentiality. Only the aggregated forms of the data will be used in reported results, protecting confidentiality.

VI. Compensation

No compensation will be earned by participating in this research project.

VII. Freedom to Withdraw

You may withdraw your child from the research project at any time and for any reason. Your child is free not to answer any questions or respond to experimental situations without penalty. To withdraw please inform child's teacher, or one of the persons listed at the bottom of this form.

VIII. Parent or Guardian's Permission

I have read and understand the Permission Form and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

_____Date_____
Child's name (please print)

_____Date_____
Parent or guardian signature

Should I have any pertinent questions about this research or its conduct, and research participants' rights, and whom to contact in the event of a research-related injury to my child, I may contact:

Dr. Mido Chang _____ 540-231-9727/mchang@vt.edu
Investigator Telephone/e-mail

Dr. Michael A. Evans _____ 540-231-3743/mae@vt.edu
Investigator Telephone/e-mail

David Moore _____ 540-231-4991/moored@vt.edu
Chair, Virginia Tech Institutional Review Board for the Protection of Human Subjects
Office of Research Compliance
2000 Kraft Drive, Suite 2000,
Blacksburg, VA 24061 Telephone/e-mail

Virginia Tech Institutional Review Board Project No. 12-162
Approved February 23, 2012 to February 22, 2013

Appendix N

Informed Assent from Student

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERISTY

Informed Assent from Student

Title of Project: **Gateways to Algebraic Motivation, Engagement and Success (GAMES)**

Investigators: **Mido Chang and Michael A. Evans**

You are invited to participate in research on how students learn fractions.

If you decide to join, you will be asked to complete surveys asking about your experiences learning math. Also, you will be asked to solve fraction problems. Then, you will be asked to practice fractions in an in-class exercise. Afterward, you will be asked to respond to surveys on learning math and fraction questions.

If you become frustrated by a question, you can choose not to answer. Also, you can choose whether to join the study or not. Please discuss the idea with your parents, and feel free to ask questions. If you decide to join, you can change your mind at any time by informing your teacher that you want to stop.

I have read the above (or I have had it read to me) and I understand what I am being asked to do. I have had all of my questions answered and I understand that I can stop at any time.

I would like to participate in this project.

Student Name: _____
(Please print)

Student Signature: _____
(Please write cursive)

Date: _____

Witness Name: _____
(Please print)

Witness Signature: _____

Virginia Tech Institutional Review Board Project No. 12-162
Approved February 23, 2012 to February 22, 2013

Appendix O

Candy Factory Game Group Step-by-step Guide and Script

Candy Factory Game Group Day-by-day Step-by-step Guide
1st day (03/19/2012) Monday – Pre-test data collection

Things To-Do	***Script* (in italics) and Related Explanation**
Explain the project	*This is a two week project that professors and graduate students from Virginia Tech are doing. In this project, you will be asked to fill the surveys and solve some fraction problems for today. Until next Friday, you will be playing an iPod Touch game called Candy Factory every day for about 20 minutes. The Candy Factory game has three levels and it is about fractions. During the gameplay you are expected to ship as many chocolates as you can. On Friday next week, you will be asked to fill out some surveys and solve fractions problems again. Participation will not affect your grade in this course in any manner. If you do not want to participate, that's fine, just please let us know. But we would like to have you in our study. If you would like to participate, would you please read and sign the Student Assent Form and give it back.*
Give students the "**Informed Assent from Student Form**"	*Please read the form and if you agree, write your name, date and sign it. Then, please give it back to me.*
	Please and let them read, write their name, date, and sign the student assent form. And then, please fill the Witness name as your name and sign it. Please collect all of the Student Assent forms
Give each student an **IDENTIFIER**	An ID is given to each student according to their teacher's order list to keep their information confidential. This key is needed to make sure that we will link the questionnaire responses on the first day and the last day from the same student. For example, the first student in the top of the teacher's list might get "1" as an identifier for that student. The students need to fill the "Study ID" with the ID that is given. Each student needs to write same ID in each test/survey.
Give students the **learner characteristics and math engagement pre-test (10 min)** and tell students	*Please answer each question carefully and be honest with your answers. Please also try to fill all of the survey items without leaving blank answers. Your answers are truly important for researchers. If you do not understand a word, phrase, or sentence, please let me know so that I can help you with that.*
	*The term "digital games" in the learner characteristics survey refers to any kind of game that can be played with computerized devices such as computer games, video games (PS3, Xbox, PS, Wii, Nintendo…etc.), iPhone, iPad, iTouch games, and online games. *How do they answer survey questions? For example, in Learner Characteristics survey question #1, if students think that they learn math digital games fast, they should choose "I strongly agree", if they think that they do not learn math digital games fast, they should choose

	"I strongly disagree". If they are not sure what they want to say, they can choose "I am not sure".
Give students the **Fractions 1 test (20 min)** and tell students	*You have 20 minutes to solve this multiple choice test. Please try to answer each question carefully. If you have any questions, please let me know. You are NOT allowed to use a rule during the test. You can use any space on the paper, you can use any type of pen/pencil as long as the right answer is visible. Do not forget that you are not going to be graded for this test.*
	After 20 minutes, please collect the tests, while collecting please take a look if there is any problems in the test (ex. multiple answer in one question, not clear which answer…etc.)

Candy Factory Game Group Day-by-day Step-by-step Guide
2nd day (03/20/2012) Tuesday – First Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
Installation @Researcher & @Tech person	Before the second day of treatment, please make sure that all of the iPod Touches have the Candy Factory game installed, if not please install the game from AppStore to the uninstalled iPod Touches.
Bring the iPod Touch to the classroom, hand-out @Teacher	Please take the iPod Touches and hand one to each of your students. This is going to be 20 minute session for students. It is up to teacher when they want to let students play the game. It can be at the beginning or in the middle of the course.
Showing the video	*As this is the first day of the project, you are going to watch the video on how to play the game. Please watch the video carefully so that you can understand how to play the Candy Factory Game.*
	Students can watch the walkthrough in three ways: 1. Go to this link: http://www.youtube.com/watch?v=W-fdHqUYU6A 2. They need to click on YouTube from the applications, tap search from the bottom, tap the bar in the top of the screen and write "Candy Factory Virginia Tech" and tap the first video in results and let them watch the walkthrough. 3. Teacher can show the video from his/her computer/laptop to the students through projector/screen. If this option is more suitable, then please open YouTube from your browser, in the search box write "Candy Factory Virginia Tech" and click on the video named "Candy Factory Demo" and let students watch the video.
Open the game and give instruction	*Please now open the Candy Factory game among the applications. If you want to change the settings you can tap the settings icon under Level 3.You have 15 minutes to play the game,* ***but please try to play only the Level 1 for today.***
	You can help students if they have any questions or concerns related with the game. Try to help them understand how to play the game and

	let them ship as many orders as they can in Level 1. *Level 1:* Teaches proper fractions as part-whole concept. A *proper fraction* is a fraction in which the numerator is smaller than the denominator. The whole-part concept candy is displayed with a fraction less than a whole (e.g., 5/8).
Finish	*Time's up. Please close the game and give the iPod Touches back.*

Candy Factory Game Group Day-by-day Step-by-step Guide
3rd day (03/21/2012) Wednesday – Second Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
Open the game and give the instruction for Level 1	*You are going to play the Level 1 for 15 minutes and this time I want you to count how many correct orders you ship in Level 1. Try to ship* ***10 correct orders in 15 minutes in Level 1.***
	You can help students if they have any questions or concerns related with the game. Some students can exceed the goal and some cannot. These goals are flexible. As a teacher, you can adjust the goals for individual students so that they can be successful. For example, it might be better for X student to focus on getting 5 right on level 1 even on day 5 because on the prior days he has not achieved that many correct.
Level 2	*Ok, now I want you to play Level 2 for the rest of the 5 minutes and I want you to count how many correct orders you ship in Level 2.* ***Try to ship 3 correct orders in 5 minutes in Level 2.***
	You can apply the same explanation for Level 2. *Level 2:* Teaches proper fractions as whole concept. The continuous candy bar is displayed with a fraction less than a whole (e.g., 6/11).
Finish	*Time's up. Please close the game and give the iPod Touches back.*

Candy Factory Game Group Day-by-day Step-by-step Guide
4th day (03/22/2012) Thursday – Third Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
Open the game and give the instruction for Level 1	*You are going to play the Level 1 for 10 minutes and again I want you to count how many correct orders you ship in Level 1.* ***Try to ship 13 correct orders in 10 minutes in Level 1.***
	You can help students if they have any questions or concerns related with the game. Some students can exceed the goal and some cannot. These goals are flexible. As a teacher, you can adjust the goals for individual students so that they can be successful.
Level 2	*Ok, now I want you to play Level 2 for the rest of the 10 minutes and I want you to count how many correct orders you ship in Level 2.* ***Try to ship 6 correct orders in 10 minutes in Level 2.***
	You can apply the same explanation for Level 2. Some students may

	not be able to ship 6 orders in 10 minutes but give those students the flexibility in terms of the goals given to the students in the time frame allotted.
Finish	*Time's up. Please close the game and give the iPod Touches back.*

Candy Factory Game Group Day-by-day Step-by-step Guide
5th day (03/23/2012) Friday – Fourth Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
Open the game and give the instruction for Level 1	*You are going to play the Level 1 for 10 minutes. But this time I want you to write down what fraction of order you are shipping before you ship each order. After you ship the order, compare the fraction that you wrote with the result using the symbols (<, >, =). Please also keep track of your orders and* ***try to ship 15 correct orders in 10 minutes in Level 1.***
	Right before students ship their bars, students need to write the fraction of the order that they are shipping. By this way, they will compare their fraction with the result in the last screen. You can help students if they have any questions or concerns related with the game. Some students can exceed the goal and some cannot. These goals are flexible. As a teacher, you can adjust the goals for individual students so that they can be successful.
Level 2	*Ok, now I want you to do the same thing in Level 2 for the rest of the 10 minutes and write down what fraction of order you are shipping before you ship each order. After you ship the order, compare the fraction that you wrote with the result using the symbols (<, >, =). Please also keep track of your orders and* ***try to ship 7 correct orders in 10 minutes in Level 2.***
	You can apply the same explanation for Level 2.
Finish	*Time's up. Please close the game and give the iPod Touches back.*

Candy Factory Game Group Day-by-day Step-by-step Guide
6th day (03/26/2012) Monday – Fifth Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
Open the game and give the instruction for Level 1	*You are going to play the Level 1 for 5 minutes. Again I want you to write down what fraction of order you are shipping before you ship each order. After you ship the order, compare the fraction that you wrote with the result using the symbols (<, >, =). Please also keep track of your orders and* ***try to ship 8 correct orders in 5 minutes in Level 1.***
Level 2	*Ok, now I want you to do the same thing in Level 2 for 10 minutes and write down what fraction of order you are shipping before you ship each order. After you ship the order, compare the fraction that you*

	wrote with the result using the symbols (<, >, =). Please also keep track of your orders and ***try to ship 8 correct orders in 10 minutes in Level 2.***
Level 3	*Ok, now I want you to play Level 3 for the rest of the 5 minutes and I only want you to count how many correct orders you ship in Level 2.* ***Try to ship 2 correct orders in 5 minutes in Level 3.***
	Level 3: Teaches improper fractions, as well as proper fractions as whole concept. A continuous candy bar is displayed with a fraction larger than a whole (e.g., 7/3).
Finish	*Time's up. Please close the game and give the iPod Touches back.*

Candy Factory Game Group Day-by-day Step-by-step Guide
7th day (03/27/2012) Tuesday – Sixth Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
Open the game and give the instruction for Level 1	*You are going to play the Level 1 for 5 minutes. This time I want you to write down a guess for the fraction of the order before choosing a number of partitions. You need to ship your guess and after you ship the order, compare the fraction that you wrote at the beginning with the result using the symbols (<, >, =). Please also keep track of your orders and* ***try to ship 10 correct orders in 5 minutes in Level 1.***
	Basically, students need to tap "order" and "get a candy bar" from the list, then they need to write down their guess for what fraction the customer order is of the whole. Then they need to ship their guess and compare them using the symbols. Again the goal is flexible for individual students for teacher's discretion.
Level 2	*Ok, now I want you to do the same thing in Level 2 for 10 minutes and write down a guess for the fraction of the order before choosing a number of partitions. You need to ship your guess and after you ship the order, compare the fraction that you wrote at the beginning with the result using the symbols (<, >, =). Please also keep track of your orders and* ***try to ship 10 correct orders in 10 minutes in Level 2.***
	Same explanation applies for Level 2. You can help students if they have any questions or concerns related with the game. Some students can exceed the goal and some cannot. These goals are flexible. As a teacher, you can adjust the goals for individual students so that they can be successful.
Level 3	*Ok, now I want you to play Level 3 for the rest of the 5 minutes and I want you to write down what fraction of order you are shipping before you ship each order. After you ship the order, compare the fraction that you wrote with the result using the symbols (<, >, =). Please also keep track of your orders and.* ***Try to ship 2 correct orders in 5 minutes in Level 3.***
	You only want them to write the fraction before they ship it and compare it with the result using the symbols, just like you did for Level

	1 and 2 yesterday.
Finish	*Time's up. Please close the game and give the iPod Touches back.*

Candy Factory Game Group Day-by-day Step-by-step Guide
8th day (03/28/2012) Wednesday – Seventh Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
Open the game and give the instruction for Level 1	*You are going to play the Level 1 for 5 minutes. This time I want you to write down a guess for the fraction of the order before choosing a number of partitions. You need to ship your guess and after you ship the order, compare the fraction that you wrote at the beginning with the result using the symbols (<, >, =). Please also keep track of your orders and* ***try to ship 12 correct orders in 5 minutes in Level 1.***
	Basically, students need to tap "order" and "get a candy bar" from the list, then they need to write down their guess for what fraction the customer order is of the whole. Then they need to ship their guess and compare them using the symbols. Again the goal is flexible for individual students for teacher's discretion.
Level 2	*Ok, now I want you to do the same thing in Level 2 for 5 minutes and write down a guess for the fraction of the order before choosing a number of partitions. You need to ship your guess and after you ship the order, compare the fraction that you wrote at the beginning with the result using the symbols (<, >, =). Please also keep track of your orders and* ***try to ship 6 correct orders in 5 minutes in Level 2.***
	Same explanation applies for Level 2.
Level 3	*Ok, now I want you to play Level 3 for the rest of the 10 minutes and I want you to do the same thing for Level 3. Please write down a guess for the fraction of the order before choosing a number of partitions. You need to ship your guess and after you ship the order, compare the fraction that you wrote at the beginning with the result using the symbols (<, >, =). Please also keep track of your orders and* ***try to ship 6 correct orders in 10 minutes in Level 3.***
	Same explanation applies for Level 3.
Finish	*Time's up. Please close the game and give the iPod Touches back.*

Candy Factory Game Group Day-by-day Step-by-step Guide
9th day (03/29/2012) Thursday – Eighth Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
Open the game and give the instruction for Level 1	*You are going to play the Level 1 for 5 minutes. This time I want you to write down a guess for the fraction of the order before choosing a number of partitions. You need to ship your guess and after you ship the order, compare the fraction that you wrote at the beginning with the result using the symbols (<, >, =). Please also keep track of your*

	*orders and **try to ship 14 correct orders in 5 minutes in Level 1.***
	Basically, students need to tap "order" and "get a candy bar" from the list, then they need to write down their guess for what fraction the customer order is of the whole. Then they need to ship their guess and compare them using the symbols. Again the goal is flexible for individual students for teacher's discretion.
Level 2	*Ok, now I want you to do the same thing in Level 2 for 5 minutes and write down a guess for the fraction of the order before choosing a number of partitions. You need to ship your guess and after you ship the order, compare the fraction that you wrote at the beginning with the result using the symbols (<, >, =). Please also keep track of your orders and **try to ship 7 correct orders in 5 minutes in Level 2.***
	Same explanation applies for Level 2.
Level 3	*Ok, now I want you to play Level 3 for the rest of the 10 minutes and I want you to do the same thing for Level 3. Please write down a guess for the fraction of the order before choosing a number of partitions. You need to ship your guess and after you ship the order, compare the fraction that you wrote at the beginning with the result using the symbols (<, >, =). Please also keep track of your orders and **try to ship 7 correct orders in 10 minutes in Level 3.***
	Same explanation applies for Level 3.
Finish	*Time's up. Please close the game and give the iPod Touches back.*

Candy Factory Game Group Day-by-day Step-by-step Guide
10th day (03/30/2012) Friday – Post-test data collection

Things To-Do	***Script* (in italics) and Related Explanation**
Thank students	*Two weeks has almost ended! You helped a lot to the professors and graduate students from Virginia Tech for this project. Your contribution is invaluable to them. Now again you will be asked to fill the surveys and solve some fraction problems for today. For two weeks, you have done some activities with Candy Factory game on iPod Touches every day for about 20 minutes. We would like to thank all of you for your efforts and contribution in this study.*
Remind each student their **IDENTIFIER**	An ID was given to each student according to their teacher's order list at the beginning of the project. Make sure that you have that IDENTIFIER paper with you to remind students their ID. The students need to fill the "Study ID" with the ID that was given before. Each student needs to write same ID in each test/survey.
Give students the **learner characteristics and math engagement post-test (10**	*Please answer each question carefully and be honest with your answers. Please also try to fill all of the survey items without leaving blank answers. Your answers are truly important for researchers. If you do not understand a word, phrase, or sentence, please let me know so that I can help you with that.*
	While collecting the surveys, please make sure everybody filled the

min) and tell students	surveys without leaving any blank answers or multiple answers in one item.
Give students the **Game Engagement and Game Features survey (10 min)** and tell students	*Please fill these two surveys carefully. These two surveys are intended to find your engagement with the game and the game features. Please try to fill the surveys as accurate as possible.*
	While collecting the surveys, please make sure everybody filled the surveys without leaving any blank answers or multiple answers in one item.
Give students the **Fractions 2 test (20 min)** and tell students	*You have 20 minutes to solve this multiple choice test. Please try to answer each question carefully. If you have any questions, please let me know. You are NOT allowed to use a rule during the test. You can use any space on the paper; you can use any type of pen/pencil as long as the right answer is visible. Do not forget that you are not going to be graded for this test.*
	After 20 minutes, please collect the tests, while collecting please take a look if there is any problems in the test (ex. multiple answer in one question, not clear which answer…etc.)

Candy Factory Game Day-by-day Guide

1st day (40 min) (03/19/2012) Monday	**Pre-test data collection** 1. Describe the project 2. Give Informed Assent from Student Form 3. Give IDENTIFIER 4. Give learner characteristics and math engagement pre-test (10min) 5. Give Fractions 1 test (20min)		
	Level 1	Level 2	Level 3
2nd day (20 min) **(03/20/2012) Tuesday**	5 min video 15 min free game play	-	-
3rd day (20min) **(03/21/2012) Wednesday**	Ship at least 10 correct orders in 15 min	Ship at least 3 correct orders in 5 min	-
4th day (20min) **(03/22/2012) Thursday**	Ship at least 13 correct orders in 10 min	Ship at least 6 correct orders in 10 min	-
5th day (20 min) **(03/23/2012) Friday**	Before you ship an order, write down what fraction you are shipping. After you ship, compare your fraction with the result using the symbols (<, >, =). Ship at least 15	Before you ship an order, write down what fraction you are shipping. After you ship, compare your fraction with the result using the symbols (<, >, =). Ship at least 7 correct orders in 10	-

	correct orders in 10 min	min	
6th day (20min) **(03/26/2012) Monday**	Before you ship an order, write down what fraction you are shipping. After you ship, compare your fraction with the result using the symbols (<, >, =). Ship at least 8 correct orders in 5 min	Before you ship an order, write down what fraction you are shipping. After you ship, compare your fraction with the result using the symbols (<, >, =). Ship at least 8 correct orders in 10 min	Ship 2 correct orders in 5 min
7th day (20 min) **(03/27/2012) Tuesday**	For each order, before choosing a number of partitions, write down a guess for what fraction the customer order is of the whole. After you ship (you do necessarily have to ship your guess), compare your first guess with the correct order, using the symbols (<, >, =). Ship at least 10 correct orders in 5 min	For each order, before choosing a number of partitions, write down a guess for what fraction the customer order is of the whole. After you ship (you do necessarily have to ship your guess), compare your first guess with the correct order, using the symbols (<, >, =). Ship at least 10 correct orders in 10 min	Before you ship an order, write down what fraction you are shipping. After you ship, compare your fraction with the result using the symbols (<, >, =). Ship at least 2 correct orders in 5 min
8th day (20 min) **(03/28/2012) Wednesday**	For each order, before choosing a number of partitions, write down a guess for what fraction the customer order is of the whole. After you ship (you do necessarily have to ship your guess), compare your first guess with the correct order, using the symbols (<, >, =). Ship at least 12 correct orders in 5 min	For each order, before choosing a number of partitions, write down a guess for what fraction the customer order is of the whole. After you ship (you do necessarily have to ship your guess), compare your first guess with the correct order, using the symbols (<, >, =). Ship at least 6 correct orders in 5 min	For each order, before choosing a number of partitions, write down a guess for what fraction the customer order is of the whole. After you ship (you do necessarily have to ship your guess), compare your first guess with the correct order, using the symbols (<, >, =). Ship at least 6 correct orders in 10 min
9th day (20 min)	For each order, before choosing a number of	For each order, before choosing a number of	For each order, before choosing a

(03/29/2012) Thursday	partitions, write down a guess for what fraction the customer order is of the whole. After you ship (you do necessarily have to ship your guess), compare your first guess with the correct order, using the symbols (<, >, =). Ship at least 14 correct orders in 5 min	partitions, write down a guess for what fraction the customer order is of the whole. After you ship (you do necessarily have to ship your guess), compare your first guess with the correct order, using the symbols (<, >, =). Ship at least 7 correct orders in 5 min	number of partitions, write down a guess for what fraction the customer order is of the whole. After you ship (you do necessarily have to ship your guess), compare your first guess with the correct order, using the symbols (<, >, =). Ship at least 7 correct orders in 10 min
10^{th} day (40 min) **(03/30/2012) Friday**	**Post-test data collection** 1. Thank students 2. Remind their IDENTIFIER 4. Give learner characteristics and math engagement post-test (10min) 5. Game engagement and game features survey 6. Give Fractions 2 test (20min)		

Appendix P

Walkthrough of the Candy Factory Game

Walkthrough of Candy Factory Game

The Candy Factory game (CFG) is an educational game that can be played in iOS platforms such as iTouch, iPad, and iPhone. The game addresses a specific topic in mathematics, fractions. Fractions, as an important topic especially in late elementary and early middle school grades, are needed to be addressed well enough to create a basis understanding for students' learning. The Candy Factory game is intended to help students gain a deep understanding of fraction concepts that are critical as they begin to learn algebra. Especially letting students comprehend and understand the features of denominator and numerator is the main focus of the game. The CFG will be different from its competitors in the sense of not providing instruction to the players but letting them to understand the new conception of fractions and splitting.

Instructional Objectives

The educational goal of the game is not to teach fractions as a topic but to support students' development of two important constructs: splitting and a new conception of fractions. Splitting is a mental action that composes existing mental actions of partitioning and iterating. Partitioning is breaking a continuous whole into n equal parts. For example, given a line segment, students can project five equal parts into it. Iterating is making connected copies of a given part. For example, given a 1/5 part, students can imagine what 3/5 would look like by making two more connected copies of the given part. Splitting composes partitioning and iterating as inverse operations; iterating and partitioning undo each other. For example, students who can split understand how they can move back and forth between 1/5 and 3/5 by iterating and partitioning; the two mental actions are coordinated.

The new conception of fractions is based on sizes relative to a given whole. Whereas most students understand a fraction like 3/5 as three parts out of five equal parts, we also want students to understand 3/5 as three iterations of 1/5, where 1/5 has a 1-to-5 size relation with the whole. Students should begin to conceive of 3/5 as a length that is a little bigger than 1/2. The game will allow students to connect and transfer the content emphasized in the game related with curriculum on fractions.

Scope

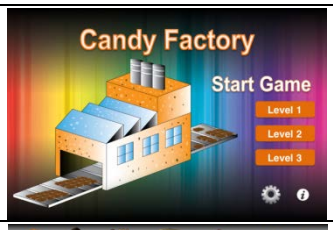
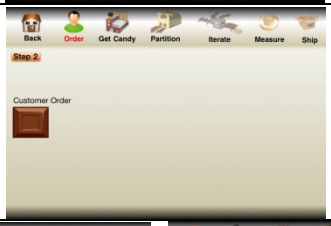
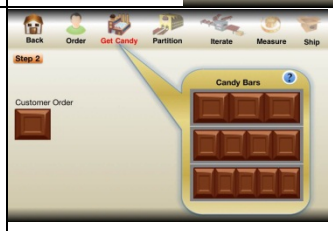
The Candy Factory game aims to answer the following question, "How can Candy Factory, an educational digital game, designed for networked mobile platforms produce lasting changes in student learning by enhancing engagement and interest in mathematics, specifically in fractions?" The Candy Factory game is designed to be used as a supplemental activity to the regular instruction of the following standards. It supports students' development of two important constructs: splitting and a new conception of

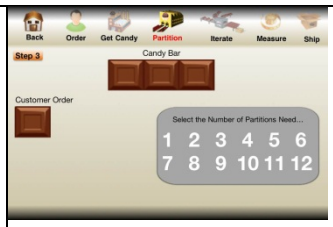
fractions. The CFG does not include adding, subtracting, multiplying and/or dividing the fractions because rather than practicing those skills, CFG helps, for example, students to understand 3/5 as three iterations of 1/5, where 1/5 has a 1-to-5 size relation with the whole. Besides, CFG helps students begin to have an understanding of 3/5 as a length that is a little bigger than 1/2. The CFG is expected to take no more than one hour to finish the game, so a typical player can finish the whole game with 5 levels in about 30-40 minutes.

Game Play

The Candy Factory game has three levels, starting from the easy tasks and continuing with hard tasks. Basically, the players receive a customer order as if they were the owner of the candy factory in specific chocolate bar(s) and they try to produce the exact size of the customer order by partitioning (slicing and separating) and iterating (copying) the chocolate bar(s). When they think that they have the same amount of chocolate bar, they measure the bar and ship it for the customer. If they are successful or unsuccessful in partitioning and iterating the chocolate bar, they get feedback at the end of the game by explaining the proper fractions.

Step-by-step walkthrough of the game is given below, but if you want to see the video please go to this address http://www.youtube.com/watch?v=W-fdHqUYU6A

1. Start the game from the applications screen	
2. Choose Level	
3. Step 1, tap “Order”	
4. Step 2, tap “Get Candy” and choose the suitable size of candy bar from the warehouse list (scrollable) appeared on screen	 

5. Step 3, tap “Partition” and select the number of partitions needed and when you tap, the chocolate will be broken into pieces (in the right screen, 3 is chosen and it breaks into 3 pieces)	 
6. Step 4, tap “Iterate” and select the number of iterations needed, when you tap, the partitioned chocolate will be iterated for how many times you want to iterate (in the right screen, 1 is chosen and it iterates one piece of chocolate)	 
7. Step 5, tap “Measure” and drag to see if your chocolate bar is same size with the customer order, if it is, drag&drop it over the “Ship” box to see if it is correct. If you think it is not true, you can always go back and change your decisions.	 
8. The feedback screen will show you the fractions and you can tap “New Game” to play a new game.	

Appendix Q

Pearl Diver Game Group Step-by-step Guide and Script

Pearl Diver Game Group Day-by-day Step-by-step Guide
1st day (03/19/2012) Monday – Pre-test data collection

Things To-Do	***Script* (in italics) and Related Explanation**
Explain the project	*This is a two week project that professors and graduate students from Virginia Tech are doing. In this project, you will be asked to fill the surveys and solve some fraction problems for today. Until next Friday, you will be playing an iPod Touch game called Pearl Diver every day for about 20 minutes. The Pearl Diver game has nine levels and it is about numbers, fractions, and decimals. During the gameplay you are expected to collect as many pearls as you can in a limited time. On Friday next week, you will be asked to fill out some surveys and solve fractions problems again. Participation will not affect your grade in this course in any manner. If you do not want to participate, that's fine, just please let us know. But we would like to have you in our study. If you would like to participate, would you please read and sign the Student Assent Form and give it back.*
Give students the "**Informed Assent from Student Form**"	*Please read the form and if you agree, write your name, date and sign it. Then, please give it back to me.*
	Please and let them read, write their name, date, and sign the student assent form. And then, please fill the Witness name as your name and sign it. Please collect all of the Student Assent forms
Give each student an **IDENTIFIER**	An ID is given to each student according to their teacher's order list to keep their information confidential. This key is needed to make sure that we will link the questionnaire responses on the first day and the last day from the same student. For example, the first student in the top of the teacher's list might get "1" as an identifier for that student. The students need to fill the "Study ID" with the ID that is given. Each student needs to write same ID in each test/survey.
Give students the **learner characteristics and math engagement pre-test (10 min)** and tell students	*Please answer each question carefully and be honest with your answers. Please also try to fill all of the survey items without leaving blank answers. Your answers are truly important for researchers. If you do not understand a word, phrase, or sentence, please let me know so that I can help you with that.*
	*The term "digital games" in the learner characteristics survey refers to any kind of game that can be played with computerized devices such as computer games, video games (PS3, Xbox, PS, Wii, Nintendo…etc.), iPhone, iPad, iTouch games, and online games. *How do they answer survey questions? For example, in Learner Characteristics survey question #1, if students think that they learn math digital games fast, they should choose "I strongly agree", if they think that they do not learn math digital games fast, they should choose

	"I strongly disagree". If they are not sure what they want to say, they can choose "I am not sure".
Give students the **Fractions 1 test (20 min)** and tell students	*You have 20 minutes to solve this multiple choice test. Please try to answer each question carefully. If you have any questions, please let me know. You are NOT allowed to use a rule during the test. You can use any space on the paper, you can use any type of pen/pencil as long as the right answer is visible. Do not forget that you are not going to be graded for this test.*
	After 20 minutes, please collect the tests, while collecting please take a look if there is any problems in the test (ex. multiple answer in one question, not clear which answer…etc.)

Pearl Diver Game Group Day-by-day Step-by-step Guide
2nd day (03/20/2012) Tuesday – First Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
Installation @Researcher & @Tech person	Before the second day of treatment, please make sure that all of the iPod Touches have the Pearl Diver game installed, if not please install the game from AppStore to the uninstalled iPod Touches.
Bring the iPod Touch to the classroom, hand-out @Teacher	Please take the iPod Touches and hand one to each of your students. This is going to be 20 minute session for students. It is up to teacher when they want to let students play the game. It can be at the beginning or in the middle of the course.
Open the game and give instruction	*Please now open the Pearl Diver game among the applications. If you want to change your settings, you can tap on the sound icon at the upper right corner of the screen to turn sound on/off.*
	Let students play the game. As this is going to be the first day of treatment, it would be better for the students to read the instructions on how to play the game carefully. Students can read the instructions at the beginning of the game.
Game play	If any question comes from the students about the game play, below some information is given:
	They need to have the diver dive into the correct place by dragging. They also need to be caution about the electric eel because when they touch it, one of their three lives is gone. They have 50 seconds to collect the minimum number of pearls in each level.
Tell the objective	*For today, I want you to **finish Level 3 in 20 min at least for 4 times**. You should count how many levels you have passed while playing the game. You can go higher levels and continue to play the game as long as you complete the objective for today.*
	They should count how many levels they have finished for how many times while they are playing. If students can finish the goal of today, it means that they completed their mission in this game for today. If they finish it earlier than 20 minutes, they can continue to play the game for

	collecting more points. You can help students if they have any questions or concerns related with the game. Some students can exceed the goal and some cannot. These goals are flexible. As a teacher, you can adjust the goals for individual students so that they can be successful. For example, it might be better for X student to pass only the first level once.
Finish	*Time's up. Please close the game and give the iPod Touches back.*

Pearl Diver Game Group Day-by-day Step-by-step Guide
3rd day (03/21/2012) Wednesday – Second Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
Open the game and tell the objective for today	*For today, I want you to **finish Level 4 in 20 min at least for 4 times**. You should count how many levels you have passed while playing the game. You can go higher levels and continue to play the game as long as you complete the objective for today.*
	They should count how many levels they have finished for how many times while they are playing. If students can finish the goal of today, it means that they completed their mission in this game for today. If they finish it earlier than 20 minutes, they can continue to play the game for collecting more points. You can help students if they have any questions or concerns related with the game. Some students can exceed the goal and some cannot. These goals are flexible. As a teacher, you can adjust the goals for individual students so that they can be successful. For example, it might be better for X student to pass only the first level once.
Finish	*Time's up. Please close the game and give the iPod Touches back.*

Pearl Diver Game Group Day-by-day Step-by-step Guide
4th day (03/22/2012) Thursday – Third Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
Open the game and tell the objective for today	*For today, I want you to **finish Level 5 in 20 min at least for 4 times**. You should count how many levels you have passed while playing the game. You can go higher levels and continue to play the game as long as you complete the objective for today.*
	They should count how many levels they have finished for how many times while they are playing. If students can finish the goal of today, it means that they completed their mission in this game for today. If they finish it earlier than 20 minutes, they can continue to play the game for collecting more points. You can help students if they have any questions or concerns related with the game. Some students can exceed the goal and some cannot. These goals are flexible. As a teacher, you can adjust the goals for individual students so that they can be

	successful.
Finish	*Time's up. Please close the game and give the iPod Touches back.*

Pearl Diver Game Group Day-by-day Step-by-step Guide
5th day (03/23/2012) Friday – Fourth Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
Open the game and tell the objective for today	*For today, I want you to **finish Level 6 in 20 min at least for 3 times**. You should count how many levels you have passed while playing the game. You can go higher levels and continue to play the game as long as you complete the objective for today.*
	They should count how many levels they have finished for how many times while they are playing. If students can finish the goal of today, it means that they completed their mission in this game for today. If they finish it earlier than 20 minutes, they can continue to play the game for collecting more points. You can help students if they have any questions or concerns related with the game. Some students can exceed the goal and some cannot. These goals are flexible. As a teacher, you can adjust the goals for individual students so that they can be successful.
Finish	*Time's up. Please close the game and give the iPod Touches back.*

Pearl Diver Game Group Day-by-day Step-by-step Guide
6th day (03/26/2012) Monday – Fifth Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
Open the game and tell the objective for today	*For today, I want you to **finish Level 6 twice and finish Level 7 once in 20 min**. You should count how many levels you have passed while playing the game. You can go higher levels and continue to play the game as long as you complete the objective for today.*
	They should count how many levels they have finished for how many times while they are playing. If students can finish the goal of today, it means that they completed their mission in this game for today. If they finish it earlier than 20 minutes, they can continue to play the game for collecting more points. You can help students if they have any questions or concerns related with the game. Some students can exceed the goal and some cannot. These goals are flexible. As a teacher, you can adjust the goals for individual students so that they can be successful.
Finish	*Time's up. Please close the game and give the iPod Touches back.*

Pearl Diver Game Group Day-by-day Step-by-step Guide
7th day (03/27/2012) Tuesday – Sixth Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
Open the game and tell the objective for today	*For today, I want you to **finish Level 7 in 20 min twice**. You should count how many levels you have passed while playing the game. You can go higher levels and continue to play the game as long as you complete the objective for today.*
	They should count how many levels they have finished for how many times while they are playing. If students can finish the goal of today, it means that they completed their mission in this game for today. If they finish it earlier than 20 minutes, they can continue to play the game for collecting more points. You can help students if they have any questions or concerns related with the game. Some students can exceed the goal and some cannot. These goals are flexible. As a teacher, you can adjust the goals for individual students so that they can be successful.
Finish	*Time's up. Please close the game and give the iPod Touches back.*

Pearl Diver Game Group Day-by-day Step-by-step Guide
8th day (03/28/2012) Wednesday – Seventh Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
Open the game and tell the objective for today	*For today, I want you to **finish Level 8 in 20 min twice**. You should count how many levels you have passed while playing the game. You can go higher levels and continue to play the game as long as you complete the objective for today.*
	They should count how many levels they have finished for how many times while they are playing. If students can finish the goal of today, it means that they completed their mission in this game for today. If they finish it earlier than 20 minutes, they can continue to play the game for collecting more points. You can help students if they have any questions or concerns related with the game. Some students can exceed the goal and some cannot. These goals are flexible. As a teacher, you can adjust the goals for individual students so that they can be successful.
Finish	*Time's up. Please close the game and give the iPod Touches back.*

Pearl Diver Game Group Day-by-day Step-by-step Guide
9th day (03/29/2012) Thursday – Eighth Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
Open the game and tell the objective for today	*For today, I want you to **finish the whole game in 20 min twice**. You should count how many levels you have passed while playing the game. You can go higher levels and continue to play the game as long as you complete the objective for today.*
	They should count how many levels they have finished for how many times while they are playing. If students can finish the goal of today, it means that they completed their mission in this game for today. If they finish it earlier than 20 minutes, they can continue to play the game for collecting more points. You can help students if they have any questions or concerns related with the game. Some students can exceed the goal and some cannot. As a teacher, you can adjust the goals for individual students so that they can be successful.
Finish	*Time's up. Please close the game and give the iPod Touches back.*

Pearl Diver Game Group Day-by-day Step-by-step Guide
10th day (03/30/2012) Friday – Post-test data collection

Things To-Do	***Script* (in italics) and Related Explanation**
Thank students	*Two weeks has almost ended! You helped a lot to the professors and graduate students from Virginia Tech for this project. Your contribution is invaluable to them. Now again you will be asked to fill the surveys and solve some fraction problems for today. For two weeks, you have done some activities with Pearl Diver game on iPod Touches every day for about 20 minutes. We would like to thank all of you for your efforts and contribution in this study.*
Remind each student their **IDENTIFIER**	An ID was given to each student according to their teacher's order list at the beginning of the project. Make sure that you have that IDENTIFIER paper with you to remind students their ID. The students need to fill the "Study ID" with the ID that was given before. Each student needs to write same ID in each test/survey.
Give students the **learner characteristics and math engagement pre-test (10 min)** and tell students	*Please answer each question carefully and be honest with your answers. Please also try to fill all of the survey items without leaving blank answers. Your answers are truly important for researchers. If you do not understand a word, phrase, or sentence, please let me know so that I can help you with that.*
	While collecting the surveys, please make sure everybody filled the surveys without leaving any blank answers or multiple answers in one item.
Give students the **Fractions 1 test (20 min)**	*You have 20 minutes to solve this multiple choice test. Please try to answer each question carefully. If you have any questions, please let me know. You are NOT allowed to use a rule during the test. You can*

and tell students	*use any space on the paper; you can use any type of pen/pencil as long as the right answer is visible. Do not forget that you are not going to be graded for this test.*
	After 20 minutes, please collect the tests, while collecting please take a look if there is any problems in the test (ex. multiple answer in one question, not clear which answer…etc.)

Pearl Diver Game Day-by-day Guide

1st day (40 min) **(03/19/2012) Monday**	**Pre-test data collection** 1. Describe the project 2. Give Informed Assent from Student Form 3. Give IDENTIFIER 4. Give learner characteristics and math engagement pre-test (10min) 5. Give Fractions 1 test (20min)
2nd day (20 min) **(03/20/2012) Tuesday**	Finish Level 3 in 20 min at least for 4 times
3rd day (20min) **(03/21/2012) Wednesday**	Finish Level 4 in 20 min at least for 4 times
4th day (20min) **(03/22/2012) Thursday**	Finish Level 5 in 20 min at least for 4 times
5th day (20 min) **(03/23/2012) Friday**	Finish Level 6 in 20 min at least for 3 times
6th day (20min) **(03/26/2012) Monday**	Finish Level 6 twice and finish Level 7 once in 20 min
7th day (20 min) **(03/27/2012) Tuesday**	Finish Level 7 in 20 min twice
8th day (20 min) **(03/28/2012) Wednesday**	Finish Level 8 in 20 min twice
9th day (20 min) **(03/29/2012) Thursday**	Finish the whole game in 20 min twice
10th day (40 min) **(03/30/2012) Friday**	**Post-test data collection** 1. Thank students 2. Remind their IDENTIFIER 4. Give learner characteristics and math engagement post-test (10min) 5. Give Fractions 2 test (20min)

Appendix R

Walkthrough of the Pearl Diver Game

Walkthrough of Pearl Diver Game

Pearl Diver: A number line math game that can be played in iOS platforms such as iTouch, iPad, and iPhone. The game addresses a specific topic in mathematics, fractions. Fractions, as an important topic especially in late elementary and early middle school grades, are needed to be addressed well enough to create a basis understanding for students' learning. Students learn the number line while diving for pearls amidst shipwrecks and sunken ruins. The game is perfect for grades 3-8 and other fun-loving seafarers. The game is intended to help students gain a deep understanding of number line, fractions as part of unit wholes and locations that are critical as they begin to learn algebra.

Instructional Objectives

Pearl Diver addresses number and operations standards - such as number line sense, whole numbers, decimals, mixed numbers and fractions - as established by the National Council of Teachers of Mathematics (NCTM), including:

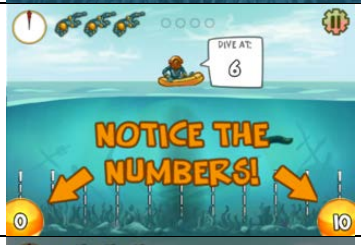
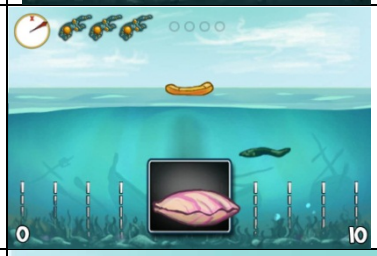
- Understanding numbers, ways of representing numbers, and number systems.
- Understanding and representing commonly used fractions.
- Understanding fractions as part of unit wholes and as locations on number lines.
- Comparing and ordering fractions, and finding their approximate locations on the number line.

Game Play

Although it is not clearly specified, the Pearl Diver game has nine levels, starting from the easy tasks and continuing with hard tasks. Basically, the players try to collect at least four pearls in each level by diving into the water, but the main point is that they need to dive into the given spot in order to collect pearls otherwise they waste their time. Besides, the challenge is that there is an electric eel that they need to watch closely, if they touch it while diving in or out, they lose one of their three lives. At the end of 50 seconds given for each level, they should be collected four pearls and if they collect more, they can earn more bonus points.

Step-by-step walkthrough of the game is given below. If you want to play it on your computer, you can go to this link http://mathsnacks.com/pearlDiver.php

1. Start the game from the applications screen	

2. Tap, “Play the Game”	
3. Read the instructions carefully. Notice the numbers on the bottom left and right of the screen,	
4. You can drag the diver to move left and right to dive in. You need to tap to the spot that you want the diver to dive in.	
5. When you dive in, the shell appears and in order to open the shell to take the pearl and get out, you need to tap on the shell 4 times.	
6. There are at least four pearls that you need to collect in each level and you have 50 seconds to collect four pearls. But you need to watch the electric eel if you do not want to lose one of your three lives.	
7. At the end of each level, the feedback screen is shown and it tells you how many pearls have been harvested, lives left, bonuses, and your score. You need to tap screen to continue to the next level	
8. The game continues until you finish all 9 levels, but it ends if you lose your three lives, if you cannot collect 4 pearls in 50 seconds.	

9. There are also “Sushi Round” games in between levels where you cut the eel into halves, thirds, fifths…etc. If you correctly cut the eel, it gives you extra bonus points. All you need to do is to take the knife and leave it where you think is appropriate.	

Appendix S

Virtual Manipulatives Group Step-by-step Guide and Script

Virtual Manipulatives Group Day-by-day Step-by-step Guide
1st day (03/19/2012) Monday – Pre-test data collection

Things To-Do	***Script* (in italics) and Related Explanation**
Explain the project	*This is a two week project that professors and graduate students from Virginia Tech are doing. In this project, you will be asked to fill the surveys and solve some fraction problems for today. Until next Friday, you will be doing some activities with Virtual Manipulatives every day for about 20 minutes. Those activities are also going to be related with fractions and you will be studying with computers. On Friday next week, you will be asked to fill out some surveys and solve fractions problems again. Participation will not affect your grade in this course in any manner. If you do not want to participate, that's fine, just please let us know. But we would like to have you in our study. If you would like to participate, would you please read and sign the Student Assent Form and give it back.*
Give students the "**Informed Assent from Student Form**"	*Please read the form and if you agree, write your name, date and sign it. Then, please give it back to me.*
	Please and let them read, write their name, date, and sign the student assent form. And then, please fill the Witness name as your name and sign it. Please collect all of the Student Assent forms
Give each student an **IDENTIFIER**	An ID is given to each student according to their teacher's order list to keep their information confidential. This key is needed to make sure that we will link the questionnaire responses on the first day and the last day from the same student. For example, the first student in the top of the teacher's list might get "1" as an identifier for that student. The students need to fill the "Study ID" with the ID that is given. Each student needs to write same ID in each test/survey.
Give students the **learner characteristics and math engagement pre-test (10 min)** and tell students	*Please answer each question carefully and be honest with your answers. Please also try to fill all of the survey items without leaving blank answers. Your answers are truly important for researchers. If you do not understand a word, phrase, or sentence, please let me know so that I can help you with that.*
	*The term "digital games" in the learner characteristics survey refers to any kind of game that can be played with computerized devices such as computer games, video games (PS3, Xbox, PS, Wii, Nintendo…etc.), iPhone, iPad, iTouch games, and online games. *How do they answer survey questions? For example, in Learner Characteristics survey question #1, if students think that they learn math digital games fast, they should choose "I strongly agree", if they think that they do not learn math digital games fast, they should choose "I strongly disagree". If they are not sure what they want to say, they

	can choose "I am not sure".
Give students the **Fractions 1 test (20 min)** and tell students	*You have 20 minutes to solve this multiple choice test. Please try to answer each question carefully. If you have any questions, please let me know. You are NOT allowed to use a rule during the test. You can use any space on the paper, you can use any type of pen/pencil as long as the right answer is visible. Do not forget that you are not going to be graded for this test.*
	After 20 minutes, please collect the tests, while collecting please take a look if there is any problems in the test (ex. multiple answer in one question, not clear which answer…etc.)

Virtual Manipulatives Group Day-by-day Step-by-step Guide
2nd day (03/20/2012) Tuesday – First Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
Installation @Researcher & @Tech person	Before the second day of treatment, please make sure that all of the computers in the lab can work with Java, if not please install Java to the uninstalled computers so that each computer can work with NLVM.
Take students to the computer lab @Teacher	Please take all of your students in the computer lab. This is going to be 20 minute session for students. It is up to teacher when they want to take students to the computer lab. It can be at the beginning or in the middle of the course.
First objective of the day	*Now please turn on your computers, open a webpage, and enter this address to the address bar www.nlvm.usu.edu, after you enter this website, click on Number & Operations for Grades 3-5. When the new page is open, scroll down the list and choose "**Fractions naming**". Then name the fraction shown by the shape by writing its number of colored parts in the picture (numerator) and the total number of parts in the picture (denominator). You need to find out if your fraction name matches the picture by clicking check button. I want you to **write 20 fractions correctly in 10 minutes**. Please take note when you answer correctly.*
	As today is the first day, the first activity is easier than the others. You can always click on the "instructions" if students have any question regarding this activity. You can help students if they have any questions or concerns related with the virtual manipulatives. Some students can exceed the goal and some cannot. These goals are flexible. As a teacher, you can adjust the goals for individual students so that they can be successful. If students reach the goal earlier, they can continue to work on the fraction related activities.
Second objective of the day	*Please now close the window and choose "**Fraction adding**" from the list. You need to choose "**Easier**" next to the "Difficulty level" for today. So you need to rename the two fractions so that the denominators are the same, then check your answer and then add the*

	two fractions, write the total and check if it is correct. Then you need to click the "New Problem" button for another problem. I want you to ***answer 10 problems correctly in 10 minutes.*** *Please take note when you answer correctly.*
	Same explanations apply for the second objective.
Finish	*Time's up. Please close the window and turn off the computer.*

Virtual Manipulatives Group Day-by-day Step-by-step Guide
3rd day (03/21/2012) Wednesday – Second Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
First objective of the day	*Now please turn on your computers, open a webpage, and enter this address to the address bar www.nlvm.usu.edu, after you enter this website, click on Number & Operations for Grades 3-5. When the new page is open, scroll down the list and choose "**Fractions equivalent**". Then find a new name for the fraction shown in the screen by using the arrow buttons to set the number of pieces. Enter the new name and check your answer is right or wrong. You need to find out if your fraction is equivalent by clicking check button. When you do it right, it will ask you to find one more so each problem has two answers. I want you to **answer 30 new fractions correctly in 10 minutes**. Please take note when you answer correctly.*
	Same explanations apply for the first objective.
Second objective of the day	*Please now close the window and choose "**Fraction adding**" from the list. You need to choose "**Harder**" next to the "Difficulty level" for today. So you need to rename the two fractions so that the denominators are the same, then check your answer and then add the two fractions, write the total and check if it is correct. Then you need to click the "New Problem" button for another problem. I want you to **answer 10 problems correctly in 10 minutes.** Please take note when you answer correctly.*
	Same explanations apply for the second objective.
Finish	*Time's up. Please close the window and turn off the computer.*

Virtual Manipulatives Group Day-by-day Step-by-step Guide
4th day (03/22/2012) Thursday – Third Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
First objective of the day	*Now please turn on your computers, open a webpage, and enter this address to the address bar www.nlvm.usu.edu, after you enter this website, click on Number & Operations for Grades 3-5. When the new page is open, scroll down the list and choose "**Fractions visualizing**". You need to show the fraction on the shape by dividing it then selecting the correct number of divisions. Then check your answer. I want you to*

	***answer 25 new wholes correctly in 5 minutes**. Please take note when you answer correctly.*
	Same explanations apply for the first objective.
Second objective of the day	*Please now close the window and choose "**Fraction adding**" from the list. You need to choose "**Hardest**" next to the "Difficulty level" for today. So you need to rename the two fractions so that the denominators are the same, then check your answer and then add the two fractions, write the total and check if it is correct. Then you need to click the "New Problem" button for another problem. I want you to **answer 15 problems correctly in 15 minutes.** Please take note when you answer correctly.*
	Same explanations apply for the second objective.
Finish	*Time's up. Please close the window and turn off the computer.*

Virtual Manipulatives Group Day-by-day Step-by-step Guide
5th day (03/23/2012) Friday – Fourth Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
First objective of the day	*Now please turn on your computers, open a webpage, and enter this address to the address bar www.nlvm.usu.edu, after you enter this website, click on Number & Operations for Grades 3-5. When the new page is open, scroll down the list and choose "**Fractions visualizing**". You need to show the fraction on the shape by dividing it then selecting the correct number of divisions. Then check your answer. I want you to **answer 25 new wholes correctly in 5 minutes**. Please take note when you answer correctly.*
	Same explanations apply for the first objective.
Second objective of the day	*Please now close the window and choose "**Fractions comparing**" from the list. You need to find different names for the two fractions using the same number of division pieces (same denominator). Then click check button to see if they are right. Then click on the number line to show where the given two fractions are located. Then you need to change the number of the number line divisions to find the fraction between these two fractions. Then you need to click the "New Fractions" button for another problem. I want you to **answer 10 problems correctly in 15 minutes.** Please take note when you answer correctly.*
	Same explanations apply for the second objective.
Finish	*Time's up. Please close the window and turn off the computer.*

Virtual Manipulatives Group Day-by-day Step-by-step Guide
6th day (03/26/2012) Monday – Fifth Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
First objective of the day	*Now please turn on your computers, open a webpage, and enter this address to the address bar www.nlvm.usu.edu, after you enter this website, click on Number & Operations for Grades 3-5. When the new page is open, scroll down the list and choose "**Fractions equivalent**". Then find a new name for the fraction shown in the screen by using the arrow buttons to set the number of pieces. Enter the new name and check your answer is right or wrong. You need to find out if your fraction is equivalent by clicking check button. When you do it right, it will ask you to find one more so each problem has two answers. I want you to **answer 40 new fractions correctly in 10 minutes**. Please take note when you answer correctly.*
	Same explanations apply for the first objective.
Second objective of the day	*Please now close the window and choose "**Fractions visualizing**". You need to show the fraction on the shape by dividing it then selecting the correct number of divisions. Then check your answer. I want you to **answer 40 new wholes correctly in 10 minutes**. Please take note when you answer correctly.*
	Same explanations apply for the second objective.
Finish	*Time's up. Please close the window and turn off the computer.*

Virtual Manipulatives Group Day-by-day Step-by-step Guide
7th day (03/27/2012) Tuesday – Sixth Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
First objective of the day	*Now please turn on your computers, open a webpage, and enter this address to the address bar www.nlvm.usu.edu, after you enter this website, click on Number & Operations for Grades 3-5. When the new page is open, scroll down the list and choose "**Fractions comparing**" from the list. You need to find different names for the two fractions using the same number of division pieces (same denominator). Then click check button to see if they are right. Then click on the number line to show where the given two fractions are located. Then you need to change the number of the number line divisions to find the fraction between these two fractions. Then you need to click the "New Fractions" button for another problem. I want you to **answer 5 problems correctly in 10 minutes.** Please take note when you answer correctly.*
	Same explanations apply for the first objective.
Second objective of the day	*Please now close the window and choose "**Fractions naming**". Then name the fraction shown by the shape by writing its number of colored parts in the picture (numerator) and the total number of parts in the*

	*picture (denominator). You need to find out if your fraction name matches the picture by clicking check button. I want you to **write 30 fractions correctly in 10 minutes**. Please take note when you answer correctly.*
	Same explanations apply for the second objective.
Finish	*Time's up. Please close the window and turn off the computer.*

Virtual Manipulatives Group Day-by-day Step-by-step Guide
8th day (03/28/2012) Wednesday – Seventh Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
First objective of the day	*Now please turn on your computers, open a webpage, and enter this address to the address bar www.nlvm.usu.edu, after you enter this website, click on Number & Operations for Grades 3-5. When the new page is open, scroll down the list and choose "**Fractions comparing**" from the list. You need to find different names for the two fractions using the same number of division pieces (same denominator). Then click check button to see if they are right. Then click on the number line to show where the given two fractions are located. Then you need to change the number of the number line divisions to find the fraction between these two fractions. Then you need to click the "New Fractions" button for another problem. I want you to **answer 5 problems correctly in 10 minutes.** Please take note when you answer correctly.*
	Same explanations apply for the first objective.
Second objective of the day	*Please now close the window and choose "**Fraction adding**" from the list. You need to choose "**Hardest**" next to the "Difficulty level" for today. So you need to rename the two fractions so that the denominators are the same, then check your answer and then add the two fractions, write the total and check if it is correct. Then you need to click the "New Problem" button for another problem. I want you to **answer 15 problems correctly in 15 minutes.** Please take note when you answer correctly.*
	Same explanations apply for the second objective.
Finish	*Time's up. Please close the window and turn off the computer.*

Virtual Manipulatives Group Day-by-day Step-by-step Guide
9th day (03/29/2012) Thursday – Eighth Day of Treatment

Things To-Do	***Script* (in italics) and Related Explanation**
First objective of the day	*Now please turn on your computers, open a webpage, and enter this address to the address bar www.nlvm.usu.edu, after you enter this website, click on Number & Operations for Grades 3-5. When the new page is open, scroll down the list and choose "**Fractions naming**".*

	*Then name the fraction shown by the shape by writing its number of colored parts in the picture (numerator) and the total number of parts in the picture (denominator). You need to find out if your fraction name matches the picture by clicking check button. I want you to **write 40 fractions correctly in 10 minutes**. Please take note when you answer correctly.*
	Same explanations apply for the first objective.
Second objective of the day	*Please now close the window and choose "**Fractions equivalent**". Then find a new name for the fraction shown in the screen by using the arrow buttons to set the number of pieces. Enter the new name and check your answer is right or wrong. You need to find out if your fraction is equivalent by clicking check button. When you do it right, it will ask you to find one more so each problem has two answers. I want you to **answer 40 new fractions correctly in 10 minutes**. Please take note when you answer correctly.*
	Same explanations apply for the second objective.
Finish	*Time's up. Please close the window and turn off the computer.*

Virtual Manipulatives Group Day-by-day Step-by-step Guide
10th day (03/30/2012) Friday – Post-test data collection

Things To-Do	***Script* (in italics) and Related Explanation**
Thank students	*2 weeks has almost ended! You helped a lot to the professors and graduate students from Virginia Tech for this project. Your contribution is invaluable to them. Now again you will be asked to fill the surveys and solve some fraction problems for today. For 2 weeks, you have done some activities with Virtual Manipulatives every day for about 20 minutes. We would like to thank all of you for your efforts and contribution in this study.*
Remind each student their **IDENTIFIER**	An ID was given to each student according to their teacher's order list at the beginning of the project. Make sure that you have that IDENTIFIER paper with you to remind students their ID. The students need to fill the "Study ID" with the ID that was given before. Each student needs to write same ID in each test/survey.
Give students the **learner characteristics and math engagement pre-test (10 min)** and tell students	*Please answer each question carefully and be honest with your answers. Please also try to fill all of the survey items without leaving blank answers. Your answers are truly important for researchers. If you do not understand a word, phrase, or sentence, please let me know so that I can help you with that.*
	While collecting the surveys, please make sure everybody filled the surveys without leaving any blank answers or multiple answers in one item.
Give students the **Fractions 2 test (20 min)**	*You have 20 minutes to solve this multiple choice test. Please try to answer each question carefully. If you have any questions, please let me know. You are NOT allowed to use a rule during the test. You can*

and tell students	*use any space on the paper; you can use any type of pen/pencil as long as the right answer is visible. Do not forget that you are not going to be graded for this test.*
	After 20 minutes, please collect the tests, while collecting please take a look if there is any problems in the test (ex. multiple answer in one question, not clear which answer…etc.)

Virtual Manipulatives Day-by-day Guide

1st day (40 min) **(03/19/2012) Monday**	**Pre-test data collection** 1. Describe the project 2. Give Informed Assent from Student Form 3. Give IDENTIFIER 4. Give learner characteristics and math engagement pre-test (10min) 5. Give Fractions 1 test (20min)	
2nd day (20 min) **(03/20/2012) Tuesday**	Fractions naming 10 min 20 correct answer	Fractions adding – Easier 10 min 10 correct answer
3rd day (20min) **(03/21/2012) Wednesday**	Fractions Equivalent (4 in 1 min) 10 min 30 correct answer	Fractions adding – Harder 10 min 10 correct answer
4th day (20min) **(03/22/2012) Thursday**	Fractions Visualizing (8 in 1 min) 5 min 25 correct answer	Fractions adding – Hardest 15 min 15 correct answer
5th day (20 min) **(03/23/2012) Friday**	Fractions Visualizing (8 in 1 min) 5 min 25 correct answer	Fractions Comparing (each 2 min) 15 min 10 correct answer
6th day (20min) **(03/26/2012) Monday**	Fractions Equivalent (4 in 1 min) 10 min 40 correct answer	Fractions Visualizing (8 in 1 min) 10 min 40 correct answer
7th day (20 min) **(03/27/2012) Tuesday**	Fractions Comparing (each 2 min) 10 min 5 correct answer	Fractions naming 10 min 30 correct answer
8th day (20 min) **(03/28/2012) Wednesday**	Fractions Comparing (each 2 min) 10 min 5 correct answer	Fractions adding – Hardest 10 min 15 correct answer
9th day (20 min) **(03/29/2012) Thursday**	Fractions naming 10 min 40 correct answer	Fractions Equivalent (4 in 1 min) 10 min 40 correct answer
10th day (40 min) **(03/30/2012) Friday**	**Post-test data collection** 1. Thank students 2. Remind their IDENTIFIER 4. Give learner characteristics and math engagement post-test (10min) 5. Give Fractions 2 test (20min)	

Appendix T

Walkthrough of the Virtual Manipulatives

Walkthrough of Virtual Manipulatives

One main concern about young children using computers for learning is that computer environments are not concrete; "what is 'concrete' to a child may have more to do with what is meaningful and manipulable than with physical characteristics" (Steen, Brooks, & Lyon, 2006, p. 375). One of these environments is virtual manipulatives. The National Library of Virtual Manipulatives (NLVM) is an NSF supported project that began in 1999 to develop a library of uniquely interactive, web-based virtual manipulatives or concept tutorials, mostly in the form of Java applets, for mathematics instruction (K-12 emphasis). The project includes dissemination and extensive internal and external evaluation. Learning and understanding mathematics, at every level, requires student engagement. Mathematics is not, as has been said, a spectator sport. Too much of current instruction fails to actively involve students. One way to address the problem is through the use of manipulatives, physical objects that help students visualize relationships and applications. We can now use computers to create virtual learning environments to address the same goals.

Instructional Objectives

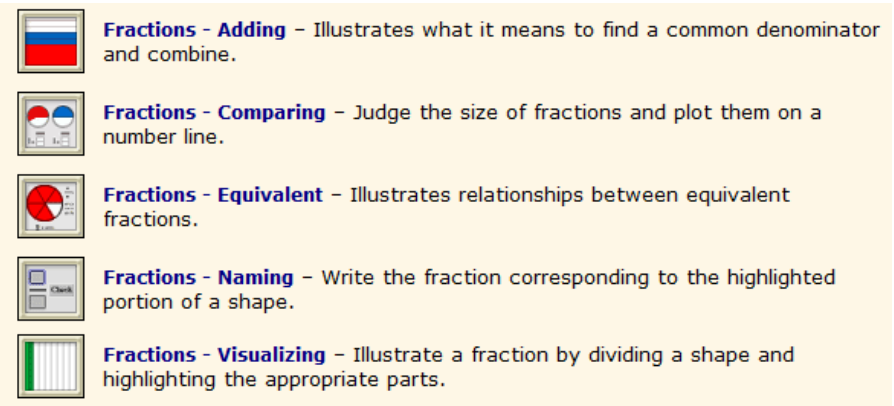
The NLVM is a resource from which teachers may freely draw to enrich their mathematics classrooms. The materials are also of importance for the mathematical training of both in-service and pre-service teachers. There are five different areas of mathematics in NLVM. Number & Operations, Algebra, Geometry, Measurement, Data Analysis & Probability are the categories for K-12 students. In each category, there are different types of activities that students can leverage. Virtual manipulatives allow students to connect their previous knowledge and experiences with abstract concepts of mathematics, especially with younger children (Suh, 2005). A virtual manipulative is described as "an interactive, web-based visual representations of a dynamic object that presents opportunities for constructing mathematical knowledge" (Moyer, Bolyard, & Spikell, 2002, p.372). Since early 90s, physical and virtual manipulatives have been used to help students reinforce mathematical knowledge on various topics. Specifically, National Library of Virtual Manipulatives has provided various types of activities and access to the students and teachers to leverage from this type of innovative technology tool at no cost.

Virtual Manipulatives (Number & Operations for Grades 3-5)

As this study specifically focuses on fractions as a topic, only the number and operations category for the grades 3-5 will be studied during the treatment. There are nine different sub-topics for fractions in NLVM. Therefore, each will be studied by the students. A detailed schedule of which sub-topics will be studied by the students are

given in a separate sheet. Nevertheless, a step-by-step walkthrough of the virtual manipulatives are given below.

Step-by-step walkthrough of virtual manipulatives:

<table>
<tr><td colspan="2">1. Open a webpage from your computer. Type www.nlvm.usu.edu in the address bar and press enter. You might need to install Java to the computer in order to be able to work with the Virtual Manipulatives.</td></tr>
<tr><td>2. Choose “Number and Operations” category for the “Grades 3-5” from the map.</td><td> 
</td></tr>
<tr><td>3. Scroll down the list of topics ordered by alphabet and see the fraction topics. Follow your script in terms of which topic you are supposed to do for that day. The script gives you a detailed information for each sub-topic.</td><td> 
</td></tr>
</table>

4. There is a “instructions ” section which gives a detailed information for each topic if students have any questions about what they are supposed to do in that activity.	

Appendix U

Paper-and-pencil Drills Group Step-by-step Guide and Script

Paper-and-pencil Group Day-by-day Step-by-step Guide

1st day (03/19/2012) Monday – Pre-test data collection

1. As this is the first day of treatment, please explain this project to the students. You can use this script given below to describe the project:
   This is a two week project that professors and graduate students from Virginia Tech are doing. In this project, you will be asked to fill the surveys and solve some fraction problems for today. Until next Friday, you will be doing some exercises on fractions every day for about 20 minutes. On Friday next week, you will be asked to fill out some surveys and solve fractions problems again. Participation will not affect your grade in this course in any manner. If you do not want to participate, that's fine, just please let us know. But we would like to have you in our study. If you would like to participate, would you please read and sign the Student Assent Form and give it back.
2. Please give students the "**Informed Assent from Student Form**" and let them read, write their name, date, and sign it. And then, please fill the Witness name as your name and sign it. Please collect all of the Student Assent forms.
3. Please give each student an **IDENTIFIER** so that their information is kept confidential. An ID is given to each student according to their teacher's order list. This key is needed to make sure that we will link the questionnaire responses on the first day and the last day from the same student. For example, the first student in the top of the teacher's list might get "1" as an identifier for that student. The students need to fill the "Study ID" with the ID that is given. Each student needs to write same ID in each test/survey.
4. Please give students the **learner characteristics and math engagement pre-test**. Let them fill these two surveys in 10 minutes.
   *The term "digital games" in the learner characteristics survey refers to any kind of game that can be played with computerized devices such as computer games, video games (PS3, Xbox, PS, Wii, Nintendo…etc.), iPhone, iPad, iTouch games, and online games.
   *How do they answer survey questions? For example, in Learner Characteristics survey question #1, if students think that they learn math digital games fast, they should choose "I strongly agree", if they think that they do not learn math digital games fast, they should choose "I strongly disagree". If they are not sure what they want to say, they can choose "I am not sure".
   *For question #13, if students think that they are playing digital games a lot, they should choose the option "Gamer", if they think they do not play digital games at all, they should circle "Non-gamer" option.
5. Please tell students to answer each question carefully. Tell them to be honest with their answers. Please also remind them to fill all of the survey items without leaving blank answers. Their answers are truly important for researchers to analyze for

current and future research studies. If they do not understand a word, phrase, or sentence; let them know that they can ask for any clarification.

6. Please give students the **Fractions 1** test. Let them solve the questions carefully and they have 20 minutes to solve this multiple choice test. If they have any questions, please try to help students. Students are NOT allowed to use a rule during the test. They can use any space on the paper, they can use any type of pen/pencil as long as the right answer is visible. Please remind them that they are not going to be graded for this test. After 20 minutes, please collect the tests, while collecting please take a look if there is any problems in the test (ex. multiple answer in one question, not clear which answer…etc.)

Paper-and-pencil Group Day-by-day Step-by-step Guide

2nd day (03/20/2012) Tuesday – 3rd day (03/21/2012) Wednesday – 4th day (03/22/2012) Thursday – 5th day (03/23/2012) Friday – 6th day (03/26/2012) Monday – 7th day (03/27/2012) Tuesday – 8th day (03/28/2012) Wednesday – 9th day (03/29/2012) Thursday – Control Group

4. Please hand out the paper-and-pencil drills to each of your students. This is going to be 20 minute session for students. It is up to teacher when they want to let students do the drills. It can be at the beginning or in the middle of the course.
5. Let students solve the questions for 20 minutes.
6. If there is any question from the students, please try to help them out with the problem.
7. At the end of 20 minutes, tell students to finish answering and collect the exercises sheets from students.

Paper-and-pencil Group Day-by-day Step-by-step Guide

10th day (03/30/2012) Friday – Post-test data collection

1. As this is the last day of treatment, please thank to the students. You can use this script given below to thank them:

   Two weeks has almost ended! You helped a lot to the professors and graduate students from Virginia Tech for this project. Your contribution is invaluable to them. Now again you will be asked to fill the surveys and solve some fraction problems for today. For two weeks, you have done some activities with paper-and-pencil drills every day for about 20 minutes. We would like to thank all of you for your efforts and contribution in this study.
2. Please remind each student their **IDENTIFIER** so that their information is kept confidential. An ID was given to each student according to their teacher's order list at the beginning of the project. The students need to fill the "Study ID" with the ID that was given before. Each student needs to write same ID in each test/survey.
3. Please give students the **learner characteristics and math engagement post-test**. Let them fill these two surveys in 10 minutes.

4. Please tell students to answer each question carefully. Tell them to be honest with their answers. Please also remind them to fill all of the survey items without leaving blank answers. Their answers are truly important for researchers to analyze for current and future research studies. If they do not understand a word, phrase, or sentence; let them know that they can ask for any clarification.
5. Please give students the **Fractions 2** test. Let them solve the questions carefully and they have 20 minutes to solve this multiple choice test. If they have any questions, please try to help students. Students are **NOT** allowed to use a rule during the test. They can use any space on the paper, they can use any type of pen/pencil as long as the right answer is visible. Please remind them that they are not going to be graded for this test. After 20 minutes, please collect the tests, while collecting please take a look if there is any problems in the test (ex. multiple answer in one question, not clear which answer…etc.)
6. Thank you!

Appendix V

Approval to use Pearl Diver Game

Yavuz SAMUR <yavuzsamur@gmail.com>

Pearl Diver Game & Research

4 messages

Yavuz Samur <yavuzsamur@gmail.com> Sun, Nov 27, 2011 at 10:56
To: kwiburg@nmsu.edu, bchamber@nmsu.edu

Dear Drs. Karin Wiburg and Barbara Chamberlin,

I am Yavuz Samur from Virginia Tech. I am a doctoral student in Instructional Design and Technology, Department of Learning Sciences and Technologies. Currently, I am in the proposal/prospectus stage for my dissertation and my prospective research includes your game "Pearl Diver" to be used in 5th grade classrooms and examine students' engagement. I am writing to you because I would like to ask if there is any reservations to my proposal, if not, could you share any reports or outcomes that you may want to share since it is also a part of an NSF-Funded project (Award#1118571).
Besides, I really would like to thank you for your efforts and contribution to our field. I think you are doing an amazing work with all of these games you provide. I hope we will keep in touch and share our experiences and outcomes with each other.

Best regards.

Yavuz Samur, M.Sc.
Instructional Design and Technology
Department of Learning Sciences and Technologies
School of Education
Virginia Tech

Barbara Chamberlin <bchamber@nmsu.edu> Mon, Nov 28, 2011 at 11:16
To: Yavuz Samur <yavuzsamur@gmail.com>
Cc: Karin Wiburg <kwiburg@nmsu.edu>

Hi Yavuz,

I think it's wonderful you are doing research on that. Have you seen our other math snacks at mathsnacks.com? The Number Rights animated movie complements Pearl Diver nicely. I'm also interested in which version of Pearl Diver you'll be using... web, iPhone/iPod Touch or iPad. Will you be comparing it to other games, or just measuring outcomes? How will you measure outcomes?

I fully support your research on this. Please let me know if we can help. We look forward to sharing your work... whatever your findings are.

Best to you,

Barbara

[Quoted text hidden]

Barbara Chamberlin, PhD

Associate Professor, Extension Instructional Design and Educational Media Specialist

aces.nmsu.edu/bchamberlin - learninggameslab.org - exergamesunlocked.org - mathsnacks.org

- sciencepirates.org

575/646-2848 (work), 575/640-7230 (mobile), 575/646-4275 (fax)

@bchamber (twitter), barbarachamberlin@mac.com (iChat or AIM), babschamberlin (Skype)

Mail: Media Productions, Box 30003, MSC 3AI, Las Cruces, NM 88003

Fed Ex/UPS: NMSU Media Productions, Gerald Thomas Hall, Rm. 286. 940 E. College Ave, Las Cruces, NM 88003

Karin Wiburg <kwiburg@ad.nmsu.edu> Mon, Nov 28, 2011 at 14:06
To: Barbara Chamberlin <bchamber@nmsu.edu>, Yavuz Samur <yavuzsamur@gmail.com>
Cc: Karin Wiburg <kwiburg@ad.nmsu.edu>

We are just beginning to gather data on outcomes in our pilot study this year. The first two years were spent in formative assessment and concentrated development of products and video support. I agree with Barb that you should also look at number rights and a video we will have available soon on Teaching about the Number Line. It would help your research. Thanks also for your kind words. Karin

Karin Wiburg, Associate Dean for Research

College of Education

New Mexico State University, MS-3R

575-646-2125 (office)

575-646-1407 (desk)

kwiburg@nmsu.edu

Appendix W

Permission to use National Library of Virtual Manipulatives

Virtual Manipulatives

Yavuz Samur
to cannon, bob, jim.dorward

Dear Drs. Cannon, Heal, and Dorward,

I am Yavuz Samur, a doctoral student in instructional design and technology at Virginia Tech. I am writing to you because I want to leverage from National Library of Virtual Manipulatives for my doctoral dissertation. Therefore, I wanted to kindly ask your permission to use NLVM in my research and put some images from NLVM site into my dissertation. I also would like to share my results with you if you are interested.

Thank you so much for providing students such a great service!

Best regards

Yavuz Samur, M.S.
Doctoral Candidate
Department of Learning Sciences and Technologies
Virginia Tech

James Dorward jim.dorward@usu.edu

to Lawrence, E, me

Hi Yavuz,

We often receive requests for permission to use screen shots in dissertations, and have always provided that permission.

You have our permission to reference and use screen shots from NLVM in your research. I would also be very interested in reading the results of your research.

If there is anything else, please do not hesitate to ask.

Jim

From: Yavuz Samur [yavuzsamur@gmail.com]
To: Lawrence Cannon; E Heal; James Dorward
Subject: Virtual Manipulatives