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Interactions Between Patterns of Gamer Behaviors and Time-on-Task for Mathematics Remediation in a Game-based HIVE

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Walden University
2015

Abstract

Interactions Between Patterns of Gamer Behaviors and Time-on-Task for Mathematics

Remediation in a Game-Based HIVE

by

Marvin Gene Fuller

MA, Adams State College, 2003

MA, Webster University, 1998

BS, Missouri University of Science and Technology, 1997

Dissertation Submitted in Partial Fulfillment

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Abstract

As the presence of digital game-based learning increases in United States classrooms, understanding their impact on achievement is critical. Digital games for learning offer many potential benefits, including reducing the number of students trapped in a remediation cycle, a contributor to college dropout. Despite the recognized potential of game-based learning, few researchers have explored the relationships between specific patterns of behaviors and types of digital game-based learning environments. The underlying theory for this study was patterns of gamer behaviors may predict in-game behaviors. Archival, third-party data regarding *The Lost Function - Episode 1: Sum of the Forgotten Minds* by Advanced Training & Learning Technology, LLC was used in this study. Using 4 case groups at the high school and college levels (n=114), self-reported levels of the 3 patterns of gamer behaviors, gender, and age-band were analyzed using multiple regression to determine relationships to time-on-task in a game-based highly interactive virtual environment, designed for mathematics remediation. While the results were inconclusive, this study supported the existing literature regarding gender differences and the lack of mutual exclusivity in behavior typing. Recommendations include additional research in how the statements used in the 3-factor model may be adjusted to allow for a broader population of game players. The social change implication is that further understanding of the relationship between learner traits and digital learning environment may assist educators that employ digital game-based learning a way to better align learners to the most appropriate digital learning environment, thereby increases their chances at success.

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Dedication

I dedicate this work to those who traveled this path with me. First, I would like to acknowledge my grandmother who did everything in her power to raise three daughters to be strong women and encouraged me to obtain a PhD. To my grandmother on my father's side, I would like to thank her for the continued prayers and spiritual encouragement. To my adopted grandfathers, who made everything possible for the women with whom they fell in love and their children. While some of my grandparents are not around to see the publication of this dissertation, they each believed in me.

To my mother, who provided moral support in many early more conversations, and, as an amazing woman, always encouraged me to give the world my best. You are my superhero. To my father, who allowed me to rant about scientific principles and methodologies. To my husband, who endured every moment of the doctoral process, put up with deadlines, and accepted weekends of writing. I love you. And to all of my friends and family who have graciously accepted that I chose to take some years to complete a PhD that resulted in reduced contact and quick phone calls instead of weekends and dinners.

Acknowledgements

I would like to thank my advisors, Dr. Dennis Beck and Dr. Rob Foshay with whom I may not have completed this journey. Their knowledge, combined with their encouragement and dedication to the field of teaching and learning are examples of staples to a peaceful, global society. Finally, I would like to thank the team at Advanced Training & Learning Technologies, LLC for providing the data used in this study as well as their support.

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Chapter 1: Introduction to the Study

Introduction

In May of 2014, the United States [US] Department of Education released the *Condition of Education 2014* report. The report noted that more than 3 million students graduated with a regular high school diploma in 2012, with over 2 million directly entering college the following fall semester. However, the recent National Assessment of Educational Progress (NAEP) report revealed that only 23% of US 12th grade students performed proficient or better in mathematics and predicted only 39% of 12th grade students were prepared for entry-level college mathematics (National Center for Educational Statistics, 2014).

While this situation appears daunting, there are instructional practices in place to bridge the gap between high school graduation and college preparedness. Traditional face-to-face courses, typically termed remedial or developmental, exist at the college level. However, these courses are noted to be ineffective, costly, delay graduation, and may contribute to dropout (Bailey, 2009; Bailey & Cho, 2010; Complete College America, 2012). While other options also exist, the inclusion of computer technologies represents one possible tool to reduce the burden of remediation on the student.

With computer technologies becoming increasingly commonplace as instructional tools (National Center for Educational Statistics, 2013), they represent an area for important research. Digital games are one form of computer-based instruction used in the US. Digital games have the potential to become a cost-saving alternative to address the remedial needs of students. Today, serious games, or games whose primary purpose is educational (Serious Games Association, 2013), represent a multibillion dollar industry in the US, with between $2 and $10 billion in revenues reported (Ambient Insight Research, 2013; Brown, 2013). While exact dollar amounts may not be readily available, the market for serious games has been identified as an area of growth, with a projected worldwide revenue of $51.5 billion within the next 4 years (Ambient Insight Research, 2013).

However, as with traditional classroom environments, the research is not conclusive as to what works best in the digital realm. Existing research regarding learning from nondigital environments may not consistently apply to digital environments. While researchers are unclear as to the specifics and causality, there is a general understanding that a relationship exists between the learning environment, the learner, and the content. The amount of research in each of these factors on learning demonstrates their significance to the behavioral science community.

Currently, a problem exists in the literature; minimal research exists into learning with regard to specific digital game-based learning environments available today. Specific to the realm of digital game-based learning, there is little research of the relationship between the learner and different game-based learning environments (Gee, 2011). While the problem is massive, I sought to explore one component of this picture, the relationship between patterns of gamer-behaviors and time-on-task when using a game-based highly interactive virtual environment (HIVE) designed for mathematics remediation used by students in the United States.

With the increased use of digital game-based learning products, understanding relevant traits of the learner that may correlate to factors that influence academic gains, such as time-on-task, within specific game-based digital learning environments is important. Understanding patterns of gamer behaviors may provide insight into the motivations to engage in specific behaviors in a particular gaming environment (Bartle, 1996; Bartle, 2004; International Hobo, Ltd, 2010; Yee, 2005; Yee, Ducheneaut, & Nelson, 2012). However, while theorists in this area have demonstrated relationships between self-reported patterns of gamer behaviors with in-game metrics (Yee et al., 2012) and suggested that these relationships may be important to education (Konert, Göbel, & Steinmetz, 2013), this understanding is not yet complete. It is critical to understand the degree to which patterns of gamer behaviors relate to factors influencing learning within digital game-based learning environments. Understanding this relationship may provide insight into how to develop or adopt game-based learning technologies to effectively meet the varied needs of learners.

To begin this investigation, the next sections of Chapter 1 introduce the research in this study. Chapter 1 will address the problem and purpose along with the research question and hypotheses. Next, I summarize the theoretical frameworks that provide the foundation of the study. Finally, I overview the research strategy including the nature of the study, definitions, assumptions, scope and delimitations, limitations, and the study's potential significance. Stepping backwards, this chapter begins with a summary of some of the literature explored in Chapter 2 as the background for this study.

Background

The background for this study has a social problem at its heart. In order to address the gap between high school graduation and college preparedness in mathematics, a myopic perspective of game-based learning was taken, holding as much constant in order to determine the degree to which the theory that certain patterns of gamer behaviors influence how a person engages with a game applies to serious games, and relates to something of educational value. Each of the following subsections is further explored in Chapter 2. To facilitate this conversation, the information presented regards the learning environment, the learner, and the content.

Learning Environment

To limit the learning context, this research concerns a specific game-based learning environment, the game-based HIVE. While digital game-based learning in HIVEs may inherit some of the influences on the learning experience from related areas such as play, game-based learning, and computer-based learning, research regarding traditional, face-to-face environments, may not transfer to the specific digital environment of HIVEs. Game-based HIVEs may provide social and collaborative experiences, free exploration of environments, and/or attainment of microachievements and rewards, all of which may not be available in traditional educational environments (Aldrich, 2009; Richter & Livingstone, 2011).

Despite the fact that digital game-based learning may be appropriate for some learners, the literature is clear that not every learner benefits equally from a given learning environment. Incongruence between the learner and the environment may cause the learner to disengage from the learning task (Karatas & Baki, 2013; Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2003). In order to isolate influences from patterns of gamer behaviors and understand their relationship and degree of applicability, a consistent environment was selected for this proposal, the game-based HIVE. Understanding the characteristics of this particular game-based learning environment and holding it constant throughout the study may allow for isolating the relationship between patterns of gamer-behaviors and time-on-task.

The Learner

Many factors of the learner that influence the learning experience are exposed in the literature, and some of the literature is contradictory or inconclusive. Focusing on facets relevant to digital game-based learning, two factors are important within the scope of this study because of their relevance to digital game-based learning.

First, the literature acknowledged relationships between patterns of gamer behaviors and how players engage in a game-based HIVE. Patterns of behavior may be lumped together to form archetypal systems, such as Bartle's four player types. Other researchers, such as Yee (2005), noted the limitations of strict categories and present a continuum approach to patterns of gamer behaviors. However, while researchers investigating patterns of gamer behaviors differ in opinion on which personality traits most significantly contribute to engagement, it is consistently noted that what defines “fun” and contributes to engagement is individual and is related to personality traits.

Subsequently, these patterns of behavior have demonstrated both positive and negative interactions with factors influencing learning, including motivation and engagement (Bartle, 2004; Park, Song, & Teng, 2011; Yee, 2005; Yee, Ducheneaut, & Nelson, 2012). Researchers noted the significance of exploring gamer-traits in relation to other areas where gaming is included (Bartle, 2004; International Hobo, Ltd, 2010; Park et al., 2011; Yee, 2005; Yee et al., 2012). However, the existing body of research lacks the connection to time-on-task and a focus on mathematics remediation. In the end, researchers into internal differences in learners supported the idea that learners may benefit differently from different digital learning environments.

Research into gender relationships demonstrated differences in learner needs when computer technologies are employed (Bonanno & Kommers, 2008; Chen, Chen, & Liu, 2010; Park et al., 2011). Gender differences demonstrated influences on learning; attending to these needs may increase access to content (Amory, 2010; Bonanno & Kommers, 2008; CAST, 2011; Charoenying, 2010; Chen et al., 2010; Rose & Strangman, 2007; Vogel et al., 2006). Chen et al. (2010) and Park et al. (2011) noted that gender also related to perception and attitudes towards digital gaming, factors influencing engagement in these environments.

Attitudes and perceptions also may impact academic performance because of their relationships to contextual engagement (Berk, 2010; Childress & Braswell, 2006), employment of metacognitive strategies (Kim, Park, & Baek, 2009), motivation (Pekrun, Goetz, Titz, & Perry, 2002), perceived effectiveness (Artino, 2008; Chen et al., 2010), and emotional states (Palloff & Pratt, 2007). For example, Artino (2008) noted that perception of task value was one of the most significant predictors of satisfaction, a factor influencing task engagement (Charoenying, 2010; Csikszentmihalyi, 2000).

Content

While the learning environment and traits of the learner may influence the learning experience, this study focused specifically on mathematics remediation; therefore, the significant factors influencing mathematics achievement were also important. Even though mathematics performance is a complex phenomenon influenced by factors such as gender (Louis & Mistele, 2012), reading ability (Larwin, 2010) and prior experiences in mathematics (Dupuis et al., 2012; Hemmings & Kay, 2010; Wamala, Maswere, & Mwanga, 2013), the learning environment also may influence academic achievement in mathematics (Hossain & Tarmizi; 2012; Jitendra et al., 2013; Karatas & Baki, 2013; Kosko & Miyazaki, 2012; Nunnery, Chappell, & Arnold, 2013).

Researchers exposed many other factors influencing mathematics achievement. Hattie (2009), noted the relative effect sizes of these factors. Some factors that affect mathematics achievement are too complex to measure, such as learners' prior experiences in mathematics. In contrast, measurable influences on achievement in mathematics from digital game-based learning and remediation include factors such as reading ability, perceptions regarding the content and quality of the content, attitudes towards gaming, gender, and time-on-task. With many factors demonstrating influence on learning and, more specifically, mathematics achievement, it is nearly impossible to attribute causality to any one factor, explained further in the section on limitations. The nature of investigating historical data may not lend itself to eliminating all moderator variables or accounting for all confounding variables. As any measurable effect on mathematics growth would be minimal compared to the myriad of other confounding factors, this study focused on a factor that demonstrated a positive relationship to achievement (Hattie, 2009; Karweit, 1982; Meyer, 2013), is relevant to mathematics achievement (Louw, Muller, & Tredoux, 2008), and is quantifiable: time-on-task.

The social problem of remediation in mathematics at the college level provides the foundation for this body of research. The numbers of students entering college requiring developmental courses in mathematics are staggering, with some post-secondary education institutions reporting up to 85% of entering students requiring remediation (Complete College America, 2012). The enrollment and graduation rates for these students is also appalling, with a reported 30% never enrolling and 40% of those enrolled in developmental courses dropping out. Furthering this issue is the content area of mathematics. Bailey (2009) reported that while 68% and 71% pass developmental writing and reading courses, only 30% pass developmental mathematics courses. Researchers exposed many factors that influence learning including factors related to the learning context, those internal to the learner, and factors that influence academic achievement in mathematics. However, understanding of the interaction between specific learner traits and specific components of digital game-based learning is limited.

Problem Statement

While the literature about some of the topics encasing the understanding of the interaction between learner traits and the learning experience was expansive, little research existed into relationships between specific patterns of behaviors and specific digital game-based learning environments. The research problem addressed in this study was the lack of research into the interaction between the patterns of gamer behaviors outlined by Yee et al. (2012) as social, immersion, and achievement motivations, to time-on-task in a game-based HIVE designed for mathematics remediation. Understanding how patterns of gamer behaviors outlined by Yee et al. interact with time-on-task within a game-based HIVE designed for mathematics remediation may add to the macro level understanding of the relationship between learner and digital learning experience, important to both educational decision makers and developers of digital learning content.

Purpose of the Study

The purpose of this quantitative study was to explore the relationships between the patterns of gamer-behaviors of social, immersion, and achievement motivations to time-on-task for students using a game-based HIVE for remediation in mathematics. The quantitative research design used in this study was correlational, using historical data from four case studies. All participants from each case group received mathematics remediation using the same game-based HIVE, *The Lost Function – Episode 1: Sum of the Forgotten Minds* by Advanced Training & Learning Technology, LLC (AT&LT). For the purposes of this paper, the game-based HIVE is referred to as *The Lost Function* for simplicity and clarity. The independent variables of this study were the three motivational patterns of gamer behaviors identified by Yee et al. (2012): social, immersion, and achievement motivations. As other researchers noted a relationship between age and gender to pattern of player behavior (Berk, 2010; Park & Teng, 2008; Yee, 2005; Yee et al., 2012), they were included as control variables. The dependent variable for this study was time-on-task while learning in a game-based HIVE. The model representing this study is provided in Figure 1.

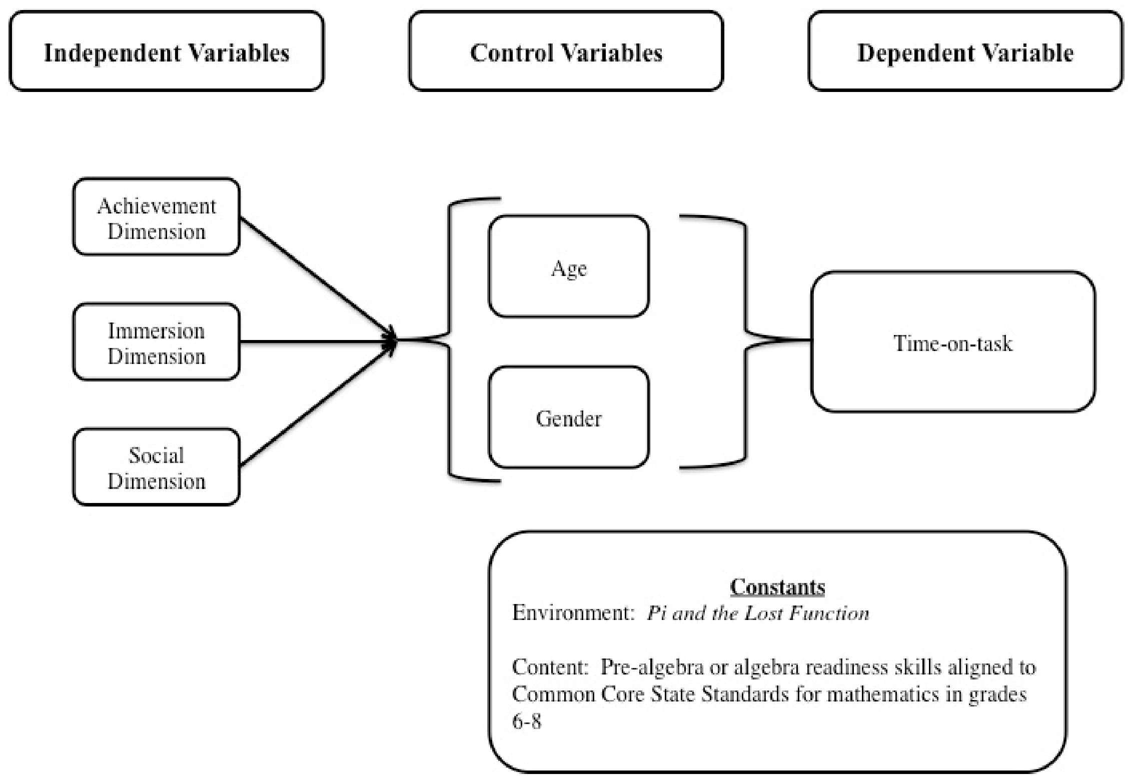

Figure 1. Study design.

Research Questions and Hypotheses

The research question of this study was

> Is there a significant relationship between patterns of gamer behaviors and time-on-task as a result of mathematics remediation in a game-based HIVE for US students when controlling for gender and age-band?

The following hypotheses were investigated in this study

$H_0$1: There is no relationship between patterns of gamer behaviors and time-on-task in students requiring remediation in mathematics when learning in game-based HIVEs when gender and age-band are considered control variables.

H_a1: There is a relationship between patterns of gamer behaviors and time-on-task in students requiring remediation in mathematics when learning in game-based HIVEs when gender and age-band are considered control variables.

Factors internal to the learner, the learning environment, and the context in which the learning tool was applied have demonstrated an influence on engagement, thus all may influence game-usage patterns. Holding the learning environment and the content constant for this study allowed for focus on the learner traits and their relationship to usage in a specific situation as shown in Figure 1. However, while usage may demonstrate engagement in the game-based HIVE, it may not be relevant to learning. For example, a learner may spend time exploring the world but not engaged in the mathematics remediation. On the other hand, time-on-task is internally measured by active time in problem solving and in remediation within the game environment. With the relevance of time-on-task to learning and transfer, investigating relationships between patterns of gamer-behaviors to time-on-task may uncover the relationships that foster positive learning experiences when employing game-based HIVES for mathematics remediation.

Conceptual and Theoretical Framework for the Study

Any discussion of teaching and learning should include the perspective of what defines good teaching and what defines learning. The conceptual lens through which this proposal was written is framed by the concept of play. Instruction and learning may take on the form of play, specifically when using game-based HIVEs as the learning environment (Aldrich, 2009; Richter & Livingstone, 2011). While research into causal relationships between play and learning is inconclusive, it is accepted to be significant and contributes to engagement (Csikszentmihalyi, 2000; Lillard et al., 2013; Vogel et al., 2006). Next, learning in a digital game-based environment occurs through engagement with the software. As engagement is a critical component of the learning experience, the idea of the flow-state was chosen to represent the ultimate level of engagement. Flow-states, according to Csikszentmihalyi (2000), are optimal states of engagement where one is engrossed in a task to the extent that one ignores extraneous stimuli. Both engagement and flow-states are difficult to measure beyond self-report questionnaires. Time-on-task, however, was used as a proxy measurement of engagement and was recorded by the software. Finally, the three pedagogical theories of differentiated instruction, universal design for learning, and accountable game design demonstrate the importance of meeting learner needs. While different, each of these current best practices highlights the necessity to support the needs of the learner in order to maximize access to the content (CAST, 2013; Charoenying, 2010; Rose & Strangman, 2007).

The theory that understanding patterns of gamer behaviors relates to in-game behaviors and motivations was the theory underlying this research. Evolving out of psychological fields of personality and motivation, Bartle (1996) initially proposed a player type system to explain why players engage in an early form of game-based HIVEs. Subsequently, the field of understanding patterns of gamer behaviors has included scales developed specifically for the purpose of looking at player motivations and the inclusion of common personality metrics to understand in-game behaviors. Player types theory and the subsequent evolutions may allow for better understanding of how players engage in serious games.

Figure 2 shows the following theories and their relationship to this research.

- Three pedagogical design theories of differentiated instruction, universal design for learning, and accountable game design, which highlight the importance to attending to learner needs as well as the role of the learning environment in the learning experience (CAST, 2011; Charoenying, 2010; Gregory & Chapman, 2007; Rose & Strangman, 2007);
- The ideas and theories of Csikszentmihalyi (2000) regarding the optimal state of experience, its relationship to engagement, as well as his statements regarding the significance of enjoyment to the learning

experience. As time-on-task may act as an indicator of engagement (O'Connor, 2013; Romero & Barberá, 2011; Schaaf, 2012) and has demonstrated relationships to course grade (Guillaume & Khachikian, 2011; Schaaf, 2012), the ideas of Csikszentmihalyi (2000) regarding engagement represents the foundation to investigating time-on-task; and

- Patterns of digital game playing behaviors can be categorized and used to provide insight into the player and their interaction with the digital game (Bartle, 1996; Bartle, 2004; International Hobo, Ltd, 2010; Yee, 2005; Yee et al., 2012).

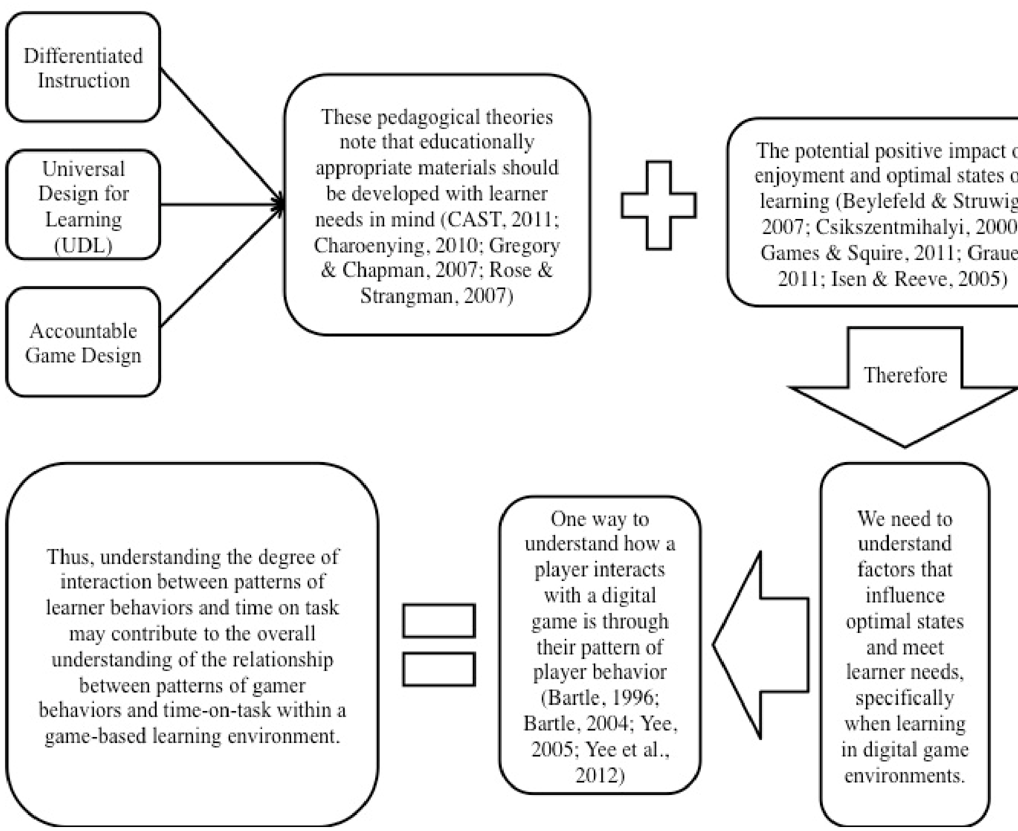

Figure 2. Included theories and their relationship to the rationale behind the study.

While each unique in its perspective on the learning experience, differentiated instruction, universal design for learning, and accountable game design provide a foundation of possible educational best practices. First, differentiated instruction highlights the significance of learner choice when it comes to content, product, and process in order to provide support for individual learning needs (Gregory & Chapman, 2007; Heacox, 2002). Universal design for learning (UDL), on the other hand, is about instructional design to meet the needs of all learners rather than providing for choice based on learning preferences. The principles of UDL advocate for maximizing access to learning through well designed lessons, which provide multiple means of representation, expression, and engagement (CAST, 2013). The third theory, accountable game design, provides design factors specific to game-based learning that must be attended to in order to maximize access.

While the three theories of pedagogical design are different in their details, each contains the underlying idea of addressing the needs of the learner noted in Figure 2. While impossible to measure all factors that may influence academic success, the literature demonstrates that attending to the cognitive, social, and emotional needs leads to the individual's perception of a positive learning environment which, in turn, contributes to a positive perception of the quality of the learning experience (Beylefeld & Struwig, 2007), deep engagement to the content (Csikszentmihalyi, 2000), increased intrinsic motivation (Isen & Reeve, 2005), and development of critical characteristics including self-regulation and metacognitive strategies (Kim et al., 2009). In order to understand factors that influence these positive perceptions and actualize any potential, specifically from game-based learning experiences, we must understand the interactions between the digital learning experience and the user. Yee et al. (2012) created a scale specific to digital game play in HIVEs to identify patterns of player behaviors. Conclusively, one place to begin this discussion is by investigating the interaction between patterns of gamer behaviors, relevant to learning in a game-based environment, and a specific digital environment. Further explanation and detail are provided in Chapter 2.

Nature of the Study

This study was both exploratory and quantitative in nature. The exploratory nature into learning in specific digital environments for remedial mathematics students meant this research began with the question of what interactions occur between the digital learning environment, learner behaviors and characteristics, and academic achievement. While the scope of this area of research is broad, a focus on one digital environment and a specific population provided a step towards understanding this relationship. The purpose was to test the extent of the interactions between the patterns of behaviors identified by the online gaming motivations scale by Yee et al. (2012) to time-on-task when mathematics remediation occurs within a game-based HIVE.

As a result of the numerical nature of the data collected and analyzed, as well as the intent to explore relationships, quantitative statistical measures were employed, discussed further in Chapter 3. Multiple regression was the main statistical measure employed to examine how the personality traits relate to time-on-task. Multiple regression was selected as it can accommodate multiple independent variables that influence one dependent variable. The data used in this study were historical, third party data provided by AT< therefore, there was no control over sampling strategy nor sample size. The data provided for each case group included gender, age group, and responses obtained during an initial introduction provided during pilot orientations, including the online gaming motivations scale by Yee et al. (2012), detailed in Chapter 3. While the game-based HIVE collects a substantial amount of in-game metrics, such as number of practice problems, total amount of time in the game, and types of remediation tools accessed, much of the data collected by the game itself was beyond the scope of this study. The data collected and analyzed in this study addressed the exploratory and quantitative nature of developing an understanding of the interaction between gamer behaviors and time-on-task in a specific digital learning environment.

The key variables of this study were the three patterns of gamer behaviors of social, immersion, and achievement, identified through the instrument by Yee et al. (2012), and time-on-task, as noted in Figure 1. For the purposes of this study, time-on-task was used as a quantifiable measure of engagement. While engagement is difficult to quantify and studies regarding time-on-task have been riddled with problems, such as what defines “off-task” behavior (Karweit, 1982), digital collection of this information as an in-game metric reduces some of the difficulties noted in the literature regarding time-on-task. Time-on-task may correlate with learners’ patterns of behavior based in the environment of a game-based HIVE used for mathematics remediation, therefore, may indicate engagement (O'Connor, 2013; Romero & Barberá, 2011; Schaaf, 2012). As engagement is a critical factor of the learning experience, attending to time-on-task is critical in the understanding of best fits between learner and learning environment. Chapter 2 provides further exploration of these concepts.

Setting and Sampling Strategy

The data used in this study were historical data provided by AT&LT regarding four case groups, details on each setting are provided in Chapter 3. Participants included in each sample were selected by convenience sampling, as they were members of a pre-existing group prior to beginning the use of *The Lost Function*, also detailed in Chapter 3. For example, one case group involved all students attending a private liberal arts university in the southeastern United States enrolled in two methods of teaching mathematics courses designed for pre-service teachers.

For multiple regression, it is suggested that the statistical power should be at least 0.80 (Soper, 2014; StatSoft, Inc., 2013; Trochim, 2006). This value was the standard comparison power yielding a recommended minimum sample size of 43 participants for a large effect and 91 participants for a medium effect (Soper, 2014). As each case group had a predetermined sample size, details are provided in Chapter 3 to note differences that may result from variations from the suggested minimums.

Definitions

I explored the interaction between patterns of gamer behaviors to time-on-task for students using the game-based HIVE, *The Lost Function*, for mathematics remediation. The following operational definitions were used in this study.

Age: Ages were categorically grouped into high school, and college levels. This was necessary as numerical age was not provided in the data by AT&LT.

Gender: Defined by the response provided by the student from the survey instrument, a component of the data provided by AT&LT, and was selected by each participant as either male or female.

Patterns of gamer behaviors: Categorized into three groups based on motivation according to Yee et al. (2012): achievement, social, and immersion factors. Being that these patterns of behaviors tend to exist across spans of time (Bartle, 1996; International Hobo, Ltd, 2010; Yee, 2005; Yee et al., 2012), they will be classified as a trait.

Time-on-task: This was measured by the sum of time spent completing problems on each concept as well as the time spent in the intervention tool. These two time measurements are in-game metrics representing the actual time spent in problem solving and within the tutorial system. This is an important distinction as the system also represents total time spent in the game. These values may differ significantly as players may have to travel from one quest to the next, may vary in the amount of time spent in dialogue with pedagogical agents or non-player characters, or choose to spend time engaged in the environment as opposed to the mathematics. Time-on-task measured in this way potentially provides a quantifiable measure of engagement with the mathematics.

Trait: Defined as any defining characteristic of an individual that is stable across time and situations (Diefendorff, 2007; Sonnentag & Sparr, 2007; Wallenstein, 2002). While this definition is broad, it provides a sense of potential for including biological, cognitive, social, and emotional differences that combine together to make each individual unique.

Assumptions

The following assumptions were made in this study:

- Participants required remedial education in mathematics. While all participants were determined to need remediation in mathematics, their level of required remediation may have varied. The determination of need or how the sample for each case group was selected will be further detailed in Chapter 3.
- Participants honestly rated their gamer preferences when completing the scale by Yee et al. (2012). While there is no way to account for this measure, it should still be noted as an assumption as it represents a threat to validity.
- Pilot program administrators honestly reported information to AT&LT. Like participant honesty, honesty must be assumed from program administrators as falsified data represents an external threat to validity.

While most data were captured within the game environment itself, honesty may still represent a potential threat to validity.

- All information provided by AT&LT is correct and accurate including statements made about the company and the case groups. This includes accurately coding and pairing participant data aligning in-game performance to individual participant survey data. While this may be considered an unmitigated assumption similar to participant and pilot program administrator honesty, it is necessary to note.
- Participants had the appropriate means to use the program including time and technology resources; therefore, appropriate amounts of time-on-task were available to be gathered. Details of implementation will be provided with each study overview in Chapter 3.
- No external policy or practice restricted the use of the program within the scope of each pilot study. While this information may not be explicitly available, all pilot studies required some form of permission at the site, noted in Chapter 3.
- I also assumed that all participants read at or above a 6th grade level. This assumption was important as the game-based HIVE used in this study provides problems within the quests in a text-only format, averaging at a 6th grade reading level. However, in-game remediation is available in both

audio and visual formats (D. B. Cavitt, personal communication, 17 October 2013).

Scope and Delimitations

While the Mega level understanding of the interaction between the learner and the learning environment is massive, this proposal narrowed the focus to the interaction between behaviors and engagement. Further narrowing meant I specifically investigated the relationship between patterns of gamer-behaviors, as defined by Yee et al. (2012), and time-on-task when remediation occurs in a game-based HIVE. Mathematics remediation, along with the curriculum of algebraic concepts required to enter a credit-bearing post-secondary mathematics course was selected as they represent areas of concern for colleges and universities (Bailey, 2009; Bailey & Cho, 2010; Complete College America, 2012; National Center for Educational Statistics, 2013; Sparks & Malkus, 2013; National Center for Educational Statistics, 2014). Time spent in solving mathematics problems and mathematics remediation within the game environment was the one in-game variable included, therefore no other classification of student, environmental context, or content area is addressed within the scope of this study.

The tool selected to investigate patterns of player behaviors contributed to both the scope and the boundaries of this study. The patterns of gamer-behaviors identified by Yee et al. (2012) were the focus behaviors for this study because of the nature of investigating learning and remediation in a game environment. The patterns identified by Yee et al. began from the early idea of gamer archetypes (Bartle, 1996) and were refined from subsequent studies by Bartle (2004) and Yee (2005). While many other scales exist to measure patterns of behavior, personality characteristics, and archetypes, the scale by Yee et al. is specific to gaming behaviors, thus may assist in our understanding of how learners behave and engage with game-based learning environments. While focus on one scale provides a lens to understanding relationships between learner and learning environment, this study did not include any other measure of personality or behavior. Therefore, results may not apply or relate to other forms of categorizing patterns of behavior.

Next, I focused on a single environment of digital games: HIVEs. While many environments of digital games exist, HIVEs represent the three-dimensional gaming environment with which many of today's traditional students are already familiar from digital game playing for entertainment purposes. The interactive environment of HIVEs has demonstrated greater learning gains over both the traditional classroom environment and other digital game-based learning environments (Vogel et al., 2006). HIVEs were selected as the environment over other game-based learning environments because of inherent features such as increased control and ability to explore, noted to contribute to engagement (Csikszentmihalyi, 2000). Finally, HIVEs may support game design to support all learners by attending to cognitive, social, and emotional needs (e.g. Cannon-Bowers, Bowers, & Procci, 2011; Chatham, 2011; Childress & Braswell, 2006; Richter & Livingstone, 2011; Ratwani, Orvis, & Knerr, 2010; R. Smith, 2010; Tüzün, Yılmaz-Soylu, Karakusß, Inal, & Kızılkaya, 2008; Vogel et al., 2006).

While other game environments may attend to some of these factors, game-based HIVEs may potentially provide support in all of these areas. As many other gaming environments exist, the results may not be generalizable to other game-based learning environments because of differences in learner control and levels of interactivity. I only investigated the interaction between player patterns of behavior to the environment of HIVEs and not other game-based learning environments, such as first-person shooter or platform type games. The environment was further limited as this study used data from four case groups from the game-based HIVE, *The Lost Function* by AT&LT. While this study may provide insight into learning in game-based HIVEs, the results represent relationships found in one specific game-based HIVE as other game-based HIVEs for mathematics remediation may yield different experiences.

Each case group was selected based on a need for remediation of math skills typically learned prior to entering high school. As this study was focused only on those requiring remediation in mathematics, the samples should not include those who have mastered all prealgebra concepts addressed within the game environment. Therefore, I did not look at how on-grade level or advanced students perform within the game. Additionally, college level participants may not have elected to not participate because of a disagreement with something in the end user license agreement (EULA), and the individual reasons to not participate were beyond the scope of this study. Furthermore, this study did not target students outside of the United States, though the pilot samples may include international students.

As the study design was correlational using historical data across separate pilot studies, generalizability may be limited. However, being that this study was exploratory in nature, it contributes to the conversation regarding the relationship between the learner and the learning environment as well as further explores learning in game-based HIVEs.

Limitations

Academic achievement is a complex phenomenon influenced by many factors. Accounting for all of the factors that may influence individual learning experiences would be difficult, if not impossible. The following limitations for this study are acknowledged:

- Participant responses may be skewed during the orientation, though measures were in place to ensure a consistent orientation process, detailed in Chapter 3. Skewed responses, specifically related to their responses to the scale by Yee et al. (2012) may misrepresent the player. Examples of this may include uncooperative participants or participants with fundamental negative value judgments of games.
- The scale by Yee et al. (2012) has seen limited application with regard to educational game-based learning. While Yee et al. provided the scale's validity and reliability, there is the potential that something in the case groups skewed the results in an unforeseen manner. As this study used historical data, this could not be accounted for in the study design.

- Though case groups were selected at each site, the students may not have been provided choice. Additionally, this forced choice may create a natural bias, and this study does not examine the participants' motivations to engage in the game-based HIVE. Thus, the forced nature of participating introduces another potential limitation as some participants may find the game-based HIVE unmatched to their individual learning preferences and needs, or may simply elect not to participate.
- Time-on-task collected by the game environment may accurately reflect usage as the measurement pauses if the user leaves the game window. However, it is impossible to know if a participant was in the middle of an assessment question or intervention and walked away from the computer or engaged in any other off task behavior during the problem solving and remediation processes.
- The a prioiri Sample Size Calculator by Soper (2014) required an estimated effect size. Soper (2014) suggested the used values meaning these values may be considered a limitation as these values are estimates.

Significance

A social problem is the backbone of this research; millions of students enter college each year and require remedial mathematics education (Bailey, 2009; Bailey & Cho, 2010; Complete College America, 2012; National Center for Educational Statistics, 2013). For instance, Complete College America (2012), a nonprofit whose goal is to increase the number of degree-earning Americans and close achievement gaps, reported over half of those entering 2-year colleges and almost one-fifth of those entering 4 year universities required remedial courses. Bailey (2009) found nearly 60% of the students in the National Education Longitudinal Study took at least one remedial course, and predicted many more students would be arriving with significant gaps in at least one core content area. Even though many students enter the college and university level underprepared in mathematics, remedial education at the post-secondary level is often ineffective and costly, leading to a delay in certificate or degree attainment, or dropout (Bailey, 2009; Bailey & Cho, 2010).

Remedial courses at the postsecondary level place students into a track from which many cannot escape. Often, students may not progress on to credit-bearing courses until the completion of remedial coursework (Bailey & Cho, 2010; Complete College America, 2012). For example, of those participating in the National Education Longitudinal Study, only 30% passed remedial mathematics courses (Bailey, 2009). Additionally, one-fifth of those placed into a remedial tract never enrolled and only a fourth of those placed into remedial courses completed a degree or certificate within 8 years while 40% of those not placed in remedial courses completed the same programs. Not only is there a significant impact to degree or certificate attainment, Bailey (2009) noted that remedial courses at the community college level cost $1.9 to $2.3 billion annually. Furthermore, Bailey and Cho (2010) found the cost of remedial courses to be a significant factor in why students never enroll.

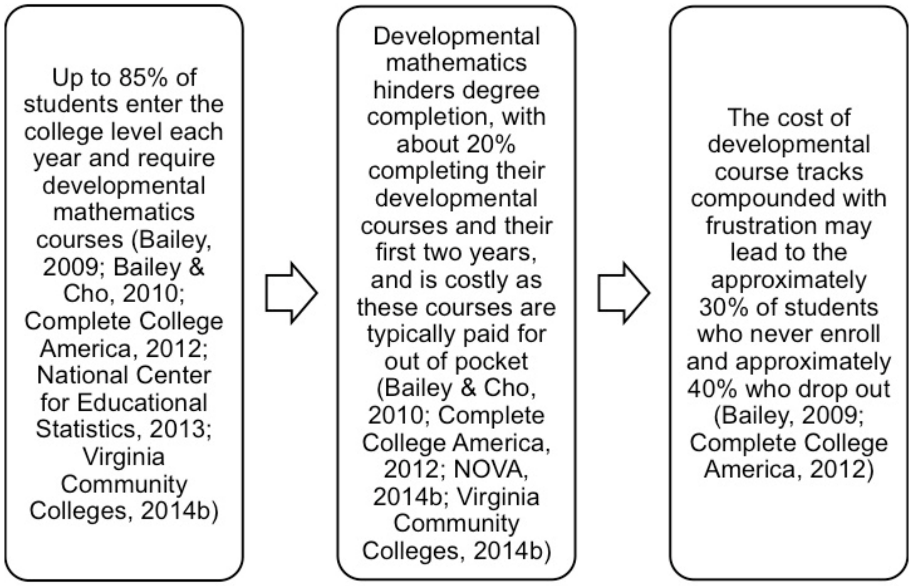

Figure 3. The problem with remedial mathematics at the college level.

The most obvious solution to students needing remediation at the college level is to ensure that students graduate from high school prepared for college (Bailey & Cho, 2010). Since at least the days of the Sputnik era, including the No Child Left Behind initiative by former U.S. President George W. Bush (2001), state and national measures have attempted to address the gaps between students graduating high school and being college ready (Editorial Projects in Education, 2012). Recently, the National Governors Association (2012) implemented the Common Core State Standards national initiative to help ensure that all US students experience a consistent core education and graduate ready for college and careers. While initiatives have been implemented in the US, recent results for the NAEP estimated only one-third of high school seniors were prepared for entry-level college mathematics (National Center for Educational Statistics, 2014).

However, despite the fact that appropriate reform in K-12 education may reduce the need for remedial education at the college and university levels, colleges will always deal with the remediation needs of students.

Students may require remediation for reasons outside of the control of K-12 education. For example, students may take developmental courses because they have forgotten mathematical concepts due to time or have language barriers impeding assessment performance (Bailey & Cho, 2010). While current college readiness assessments can identify those outside a range around a cut-score, these assessments do not indicate why students struggle. National and state K-12 initiatives, such as the Common Core State Standards, support a consistent curriculum and high school graduate preparedness for college. However, they do not address other factors such as language barriers or loss of understanding due to time.

Nevertheless, the mathematics problem goes beyond students underprepared for college level mathematics courses. Mathematics has a long-standing bad reputation and is generally perceived negatively. Its negative perception influences performance and conversely, performance influences perception (Bilican, Demirtasli, & Kilmen, 2011; Dogan, 2012; Guner, 2012; Opolot-Okurut, 2010). Additionally, high levels of frustration experienced by learners of mathematics may contribute to the negative perception of mathematics (Baker et al., 2008). The negative perception may promote gaming the system behavior, ways in which the student can cheat in a digital learning environment by exploiting in-game features such as automatic interventions. In particular, Baker et al.

(2008) indicated that some students engage in gaming the system behavior purely from a dislike of mathematics. Moreover, the potential negative behavior of gaming the system also highlights the importance of addressing emotional states when learning in digital environments. Specifically, high interest learning environments, such as game-based HIVEs, have the potential to change the perception through in-game learner support designed to reduce frustration.

The social significance of this study explored a possible remediation solution to the nationwide problem of students requiring noncredit bearing, developmental mathematics courses when entering higher education. In particular, digital game-based learning may provide a viable option to students trapped in an expensive cycle of remedial courses. On the other hand, the significance of this proposal reaches into many theoretical areas including Csikszentmihalyi’s (2000) significance of engagement to learning, CAST (2011) and Charoenying’s (2010) ideas of design to support all learners, and gamer-behavior theories proposed by Bartle (1996) and Yee (2005). As a result, understanding this relationship may lead to actualizing the potential of learners by furthering our understanding of matching the learner to the most appropriate digital learning environment.

Computer technology and gaming is pervasive in classrooms and households in the United States with more than 90% of classrooms having at least one computer with Internet connection and over 50% of households have at least two dedicated gaming devices (Anderson & Rainie, 2012; Entertainment Software Association, 2014; National

Center for Educational Statistics, 2013; Richards, Stebbins, & Moellering, 2013). Games and play have been noted throughout history as having educational benefits (Cohen, 2006; Games & Squire, 2011; P. Smith, 2010; R. Smith, 2010). Digital games have demonstrated relationships to factors influencing the learning experience (Beylefeld & Struwig, 2007; Brinthaupt & Shin, 2001; Csikszentmihalyi, 2000; Games & Squire, 2011; Ratwani et al., 2010; Richter & Livingstone, 2011; Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011; Vogel et al., 2006). Therefore, conclusive results support the idea that digital games may contribute to a positive learning experience.

One area of significance to the body of research is within the content area of mathematics. Even though mathematics performance is a complex phenomenon influenced by factors such as gender, reading ability and prior experiences in mathematics (Dupuis et al., 2012; Hemmings & Kay, 2010; Larwin, 2010; Wamala et al., 2013), the learning environment also may influence academic achievement in mathematics (Hossain & Tarmizi; 2012; Jitendra et al., 2013; Karatas & Baki, 2013; Kosko & Miyazaki, 2012; Nunnery et al., 2013). However, research regarding traditional, face-to-face environments, may not transfer to the specific digital environment of HIVEs as HIVEs allow for opportunities unavailable in traditional educational settings. However, incongruence between the learner and the environment may cause the learner to disengage from the learning task (Csikszentmihalyi, 2000; Karatas & Baki, 2013; Shernoff et al., 2003). On the other hand, appropriate matches may meet individual intrinsic motivations to play by fostering engagement, yielding increased time-on-task.

Similarly, gamer behaviors may enhance or undermine the learning experience (Artino, 2008; Childress & Braswell, 2006). While a lack of research regarding the relationship between gamer-behaviors and time-on-task when using game-based HIVEs for mathematics remediation exists, this study may reach beyond the scope of learners requiring remediation. Therefore, results concern all learners, instructors, and game developers because all students may be impacted by the selection of digital game-based environments. With many students entering college requiring remediation in mathematics (Bailey, 2009; Bailey & Cho, 2010; Handel & Williams, 2011; Sparks & Malkus, 2013) and an increase in the use of digital gaming environments for learning (Richards et al., 2013; Richter & Livingstone, 2011; Tobias, Fletcher, Dai, & Wind, 2011), we need to explore the relationship between learner behaviors in specific digital learning environments and time-on-task to explore options to address the remediation problem at the college level leading to the purpose of this proposed study.

This research furthers the understanding of the Mega level relationship between learner and learning environment. At the macro level, this study contributes to the understanding digital game-based learning and contributes to the understanding of patterns of gamer-behaviors. As an illustration, imagine an increase in the employment of digital learning to reduce the cost of remedial courses at the college level. As a cost savings, colleges and universities may elect to select only one digital tool for remediation. Patterns of gamer-behaviors may juxtapose with the gaming environment leading to a potential unfair advantage for some or extreme disadvantage to others. As a result, it is necessary to further understanding of the relationships between patterns of learner behaviors, engagement, and specific digital learning environments.

Also at the Mega level, conclusive results may provide support for a variety of theories in the importance of play in education, the significance or advantage of computer and game-based learning experiences, the significance of environment in learning, and the related research area of transforming noneducational MMORPGS, such as World of Warcraft, into games for learning. This research also furthers the understanding of applying principles of digital game design for all learners, including UDL and accountable game design. In the end, this research is the beginning of connecting the dots between patterns of gamer-behaviors and their potential influence on level of engagement, to academic growth from specific learning environments. As not all learners benefit equally from the same learning environment (CAST, 2011; Gregory & Chapman, 2007; Heacox, 2002; Rose & Strangman, 2007), further understanding may help maximize the learning experience through appropriate choices.

Revealing relationships between the learner and the environment may further our understanding of which may facilitate maximizing access to content and learning. This study may also provide insight into learning by students requiring remediation in mathematics, their academic achievement from learning in game-based HIVEs, and the role of gamer behaviors when learning in game-based environments. Games and Squire (2011) noted educators must attend to the potential of games for learning in order to make an impact on the future through the children of today. Finally, research into digital learning environments helps developers understand and incorporate best practices to develop games targeted to the appropriate audiences (Charoenying, 2010; Richter & Livingstone, 2011; Tobias et al., 2011). This research is significant because of its potential contributions to areas including learning mathematics, gaming in education, gamer-behaviors, learning environments, and design for all learners with an underlying epistemological idea of understanding knowledge, its sources, and its limitations.

Summary

Remediation at the college level is a poignant national problem. While remediation can be provided in many ways, digital game-based remediation is one alternative. Though literature exists surrounding many areas of this topic, little research exists into mathematics remediation using game-based HIVEs. This study was designed to explore relationships between gamer-behaviors and time-on-task to help educators and developers maximize access, a principle of UDL. In addition, principles of differentiated instruction, UDL, and accountable game design theories demonstrate the importance of attending to learner needs. In particular, a deeper understanding of the traits and behaviors of the learner in specific learning environments can further our understanding of their interactions within specific digital learning environments. These understandings may lead to maximizing the learner's academic potential. I explored the ideas of engagement, design to support all learners, the significance of play, HIVEs, learner traits, and patterns of behaviors in Chapter 2.

Chapter 2: Literature Review

Introduction

The goal of this literature review was to provide a synthesis and evaluation of recent scholarly writings into mathematics remediation using game-based HIVEs. However, minimal literature was available regarding the proposed topic. Therefore, three areas of focus were included representing elements of the environment, learner, and content relevant to the proposed study. Chapter 2 beings with a section on literature search strategies. Then, I provide the overarching conceptual ideas for this research: play is an inherent component of game-based learning, engagement with the content is important to learning, and meeting learner needs may increase access to content. Next, I provide the theoretical framework that patterns of gamer behaviors can predict in-game motivations. Then, a summary of the literature overviews the variables of the learner, the learning environment, and the learning content related to this study. Finally, the conclusion provides a brief summary of the themes of the literature review as well as highlights the need for this and future studies.

Literature Search Strategies

For this literature review, I accessed the following databases: Academic Search Complete, ACM Digital Library, Business Source Complete, Computers & Applied Sciences Complete, EBSCOhost, Education Research Complete, ERIC, ProQuest Central, PsycARTICLES, PsycBOOKS, SAGE, ScienceDirect, and SocINDEX. I also used Google Scholar when necessary to expand the search beyond the Walden Library.

My searches included the following search terms individually and in combinations: *archetype*, *academic*, *achievement*, *achievement gap*, *attitude*, *Bartle*, *characteristic*, *college readiness*, *computer-based*, *computer game, Csikszentmihalyi*, *cultural differences*, *development*, *developmental*, *differentiated instruction*, *digital gaming*, *education*, *emotion*, *engagement*, *enjoyment, environment, factor*, *flow*, *flow state*, *flow theory*, *game*, *game-based*, *gaming*, *gaming the system*, *gender*, *generalize*, *history*, *HIVE*, *impact*, *influence*, *interactive environment*, *learn*, *learner profile*, *learning*, *learning environment, mathematics*, *mathematics problem*, *massively multiplayer*, *meta-analysis*, *measurement, metacognitive strategy*, *MMORPG*, *online*, *motivation*, *perception*, *personality, personality type*, *play*, *remedial*, *remediation, scale, support for all learners*, *technology enhanced*, *time-on-task, traits*, *UDL*, *universal design for learning*, *virtual*, and *virtual environment.* All database searches included the "full text" and "peer reviewed" criteria. I initially restricted searches from 2009 to 2014 yielding over 500,000 results. To narrow the results, I included combinations of search terms as well as quantifiers such as *relationship between.* I accessed 512 relevant articles from the noted databases and Google Scholar and included 211. Finally, I accessed definitions of play from online dictionaries Merriam-Webster, Dictionary.com, and Google's "define" feature. In order to frame the problem, this literature review begins with the conceptual foundation of this research.

Conceptual Framework

Three general concepts provided the foundational perspectives as well as the context for the study. First, because of its inherent nature to game playing and game-based learning, is that play is important. Next is that engagement with the content is important for learning. Finally, in order to maximize access to the learning content, learner needs must be considered. The key ideas of the underlying perspective are provided in a visual summary in Figure 4.

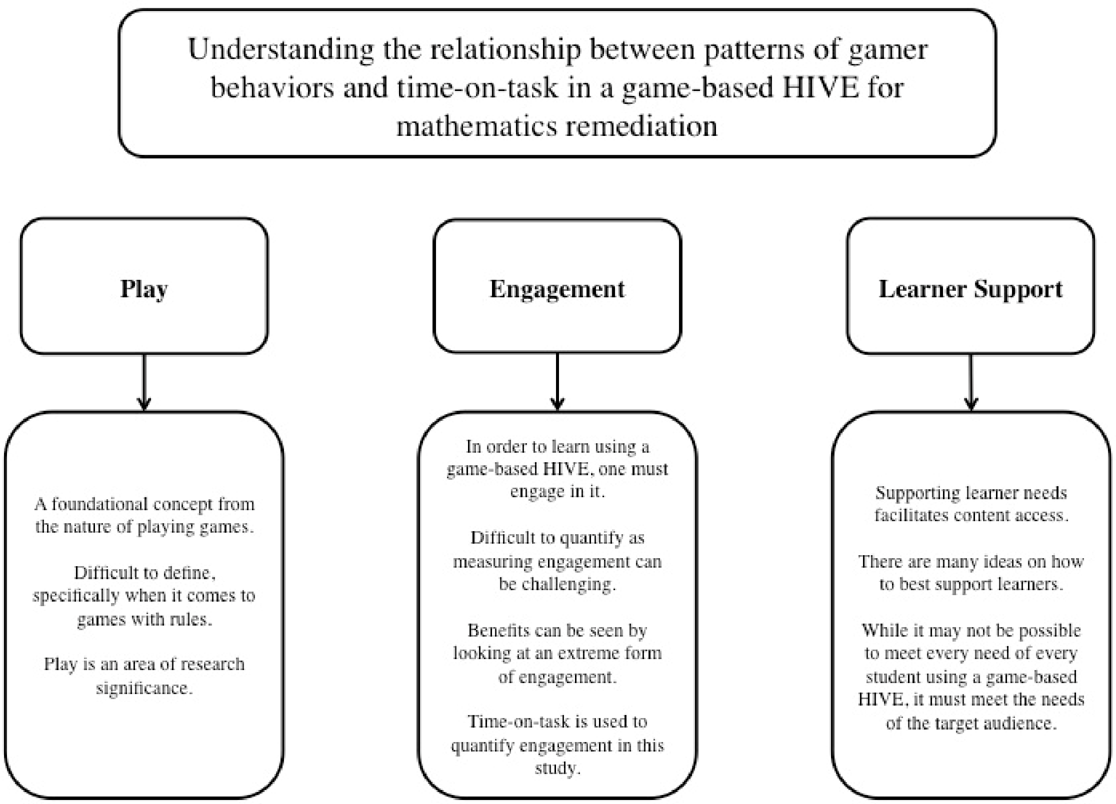

Figure 4. Overview of the conceptual framework.

Play

Play is a term with many definitions, making the concept potentially difficult to understand. Online dictionaries Merriam-Webster (n.d.) included 12 distinct categories of definitions of play and Dictionary.com (n.d.) included 49 different meanings. Similarly, equally lengthy lists were available through hyperlinks, though the "define" feature of Google (n.d.) provided the simplest definitions of play applicable to this research: an "activity engaged in for enjoyment and recreation" (n.d.) as well as engaging in such activities. Illustrating the difficulty in defining play, P. Smith (2010) provided vignettes where play behavior was both obvious and questionable, and Myers (2010) likened defining play to accepting a self-referencing paradox. Play is also often culturally defined, resisting a uniform definition.

One discrepancy in defining play is the area of games. While P. Smith (2010) did not include games with rules, such as soccer, in the definition of play, Myers (2010) suggested that playing games inherently falls under the category of play because of the self-referential definition of play. Meanwhile, Google's (n.d.) definition fits between P. Smith (2010) and Myers (2010) as it implied that both recreation and enjoyment are components of defining play-behavior, yet did not explicitly eliminate games with rules.

Similar to games with rules, most definitions imply the exclusion of work-like behaviors; but, these behaviors and activities may be incorporated into learning through play (P. Smith, 2010). While learning may be seen as work, work can take the form of play activities, such as caring for a pretend infant, household chores such as cleaning, and chasing pretend predators. Like work, games with rules also incorporate play-behavior (Myers, 2010; P. Smith, 2010). In particular, P. Smith (2010) noted that rules do not necessarily define a behavior as non-play. As an illustration, games such as football can be seen as play to a younger age group or work to an older age group. Subsequently, rules may define a structure, but, in younger children, are more flexible, blurring the lines between a game and play. In particular, P. Smith highlighted Piaget's study of boys playing marbles as a demonstration of the unclear boundary between games and play. Therefore, age, ability, and stability of rules contribute to the discrepancies in defining play. In addition, Myers (2010) suggested that humans engage in play behavior when we play games regardless of the presence or lack of other characteristics, "all games - all play - are, after all, virtual. And in our current age of the virtual, games and play occupy central positions" (p. 8). Furthermore, Google's (n.d.) definition supported the blurred boundary between games and play because it did not sweepingly eliminate games with rules.

In an attempt to clarify the definition of play, P. Smith (2010) had adults rate videoed behavior of nursery-school children as playful or non-playful behavior using five criteria: flexibility, positive affect, nonliterality, intrinsic motivation, and means/ends. While P. Smith found some combinations of present criteria were always noted as playful behavior and the more criteria present, the more clearly defined playful behavior was to the participants, some criteria, such as intrinsic motivation, were not necessarily predictive. Despite being more encompassing of games, Google's (n.d.) definition implied a more simplified qualification: if the activity is for recreation and engaged in for the purposes of pleasure, it is play, else it is not. P. Smith noted that thinking of behaviors falling onto a continuum between play and non-play may accommodate the discrepancies in what defines play. This continuum allows for Myers' (2010) idea that game playing is a form of play. Although play may not be easy to define, it is an expansive area of research because of the amount of time devoted to it in children, the variety of types of play, and the development that arises out of play behavior (P. Smith, 2010).

Importance of play. Historically, the significance of play has been written about since the days of Plato (Games & Squire, 2011; P. Smith, 2010). While these early writings focused on the value of play to survival, domestic, and trade skill acquisition, writings from the Middle Ages shifted the focus of play to moral development; the 20th century brought about a more serious focus on play with regards to child development and learning (Cohen, 2006; P. Smith, 2010). This transformation began in the 18th century with contributions from Pestalozzi, Froebel, Darwin, Montessori, Spencer, Freud, Erikson, Piaget, Locke, and Groos, among many others (Cohen, 2006; P. Smith 2010). Many of these early theorists noted the significance of play to child development leading to what P. Smith (2010) referred to as the "play ethos" (p. 28). In particular, this mindset created "a strong and unqualified assertion of the functional importance of play, namely that it is essential to adequate human development" (P. Smith, 2010, p. 28).

A renewed attention to the study of play occurred in the 1970s and 1980s. P. Smith (2010) noted that this stemmed from two factors: a change in perspective in psychology to incorporate cultural factors as opposed to only looking at biological influences, and acceptance of natural observation as a viable research methodology in social sciences. P. Smith indicated that this form of research methodology has only been accepted in social science research since the 1970s. However, as a research method, naturalistic observation may limit transferability and generalizability (Dawidowicz, 2010). Nevertheless, while limited quantitative evidence of the effectiveness of play in the classroom setting exists, evidence still highlights the importance of play (Games & Squire, 2011; Lillard et al., 2013; Weisberg & Hirsh-Pasek, 2013).

The relationship of play to learning. Although difficult to define and limited quantitative studies into the effectiveness of play in the classroom exists, a substantial body of research surrounds play behavior and learning. Recent research into play in learning contexts has demonstrated a broad spectrum of relationships as well as contradictory results. Examples of these areas include language development, emotional development and coping skills, and early mathematics development.

Ludén and Silvén (2011) demonstrated observed play in parent-child interactions with 7-month old children positively correlated with language development at 14 months old. While Ludén and Silvén investigated Finnish and Finnish-Russian mother-child and father-child dyads (n=96) and was undertaken to determine if a significant relationship to language acquisition existed between monocultural and bicultural families, their research was inconclusive in this area. However, one significant finding was the amount and type of play at 7 months old correlated to language development at 14 months old ($p<0.05$).

Like other studies in the area of play, the study by Ludén and Silvén suffers from methodological limitations including the use of qualitative measures including observations of initial parent-child interactions at 7 months and parent-reported understanding of vocabulary at 14 months. Cultural differences may exist as the sample only included families where both parents were Finnish or families with a Russian mother and Finnish father.

Also in an attempt to understand the relationship between play and language development, Smith and Jones (2011) investigated the relationship between object substitutions during play and language learning. They found in 18 to 30-month old children (*n*=63) visual object recognition was more predictive of play substitutions than language development. While earlier research in this area is noted to have demonstrated a strong relationship between object substitution and language development, once factors such as age and average number of nouns recognized were accounted for, their regression analysis indicated the only significant predictor was sparse object recognition, the ability to recognize a generic three-dimensional shape. Smith and Jones noted that it is not until the child recognizes three-dimensional objects that object substitutions in play occur, and visual recognition may be a component of the gap between language development and object substitution in play.

Similarly, Fiorelli and Russ (2012) argued that pretend play influences both cognitive and affective development, which may relate to object substitution through use of coping strategies. In their study of 1st to 5th grade girls (*n*=30), they found a positive relationship between emotional themes in play and overall affect, and a positive relationship between imagination and coping strategies. The researchers noted a positive relationship between organization and imagination scores to coping ability ($p<0.05$); however, opposite of their hypothesis, children who were observed to express less emotion during play reported a greater overall satisfaction in life.

Furthermore, a longitudinal component of their study revisited the girls after 18 months. Participants who initially demonstrated greater levels of imaginative play demonstrated greater coping skills after 18 months (Fiorelli & Russ, 2012). While the researchers noted the predictability of imaginative play and later coping skills, they provided little insight into the relationship. However, it was suggested that greater coping skills may allow for increased flexibility in object use, similar to the research into object substitutions by Smith and Jones (2011), and that play may provide an opportunity for practice of emotional and cognitive responses (Fiorelli & Russ, 2012). This study also includes a methodological limitation: all participants came from a single, all girls private school. This sample may include unmitigated influences from home and school that may influence the development of coping skills, imagination, and affect. Studies such as those by Smith and Jones and Fiorelli and Russ highlight discrepancies in research findings and in what we believe to be causality. However, a difference in findings or in perception is by no means reason to discount the importance of play.

The National Association for the Education of Young Children (NAEYC; 2013) noted the importance of play to the early development of mathematical thinking and abilities in their joint position paper with the National Council of Teachers of Mathematics. Within their recommendations for educators, nine of the 10 suggested incorporating mathematical reasoning into natural play behaviors of children. One recommendation specifically encourages professionals to allow young learners to engage in play behavior and capitalize on play to foster a sense of discovery and exploration of mathematical concepts. Examples provided include sorting and classifying, comparing amounts, making connections between quantities and numbers, and problem solving skills. Play not only provided opportunities for exploration of mathematical concepts, such as symmetry, but also allowed for mathematical thinking through symbolic representation and pattern recognition. The NAEYC noted “mathematics is too important to be left to chance, and yet it must also be connected to children’s lives” (p. 9), supported by the ideas of many, including Graue (2011) and Miller and Almon (2009), where play is the natural way children learn.

Others, such as Lillard et al. (2013), noted that many problems exist within the current body of research regarding play including methodological issues leading to false attribution of causality, unmitigated confounding variables, and small sample sizes resulting from qualitative inquiry. Although their analysis of approximately 40 years of research into the field of pretend play and its influence on developmental factors resulted in no strong evidence demonstrating any causal relationship between play and development, they noted the room for growth in the understanding of the impact of play on development and the school environment. However, Lillard et al. indicated that while existing literature is insufficient to attribute causality, the significance of play may be thought of in other ways. They suggested that play may either be one of many routes to factors of development or that play may coexist with factors of development yet not have a causal relationship. Their meta-analysis was limited to the area of pretend play, and their findings may not extrapolate to other forms of play, such as purposeful play engaged in for learning.

It appears that even with inconclusive evidence regarding causality, there is still importance in understanding play, and modern researchers encourage schools to embrace play as a venue for teaching and learning (Games & Squire, 2011; P. Smith, 2010; Weisberg & Hirsh-Pasek, 2013). Play, as a research area is fuzzy, yet continues to be investigated. Furthermore, agencies exist that advocate for play as a component of schools, such as the Alliance for Childhood (Miller & Almon, 2009) and the NAEYC (2013). While causal attributions may not exist, play is an important component to childhood; therefore, understanding play is equally important. Although Lillard et al. (2013) provided much explanation as to issues within the literature regarding play and development, they also noted that research exists supporting play in educational settings for other, nondevelopmental reasons, and that more research needs to be conducted.

Though causality may not be attributable, play may serve as a motivator with regard to learning. Isen and Reeve (2006) found that opportunities for play in the classroom acted as extrinsic motivators and fostered positive mood. In their study, college students (n=60) were first primed to one of two affects, positive and neutral. Then participants were oriented to an inherently interesting and an uninteresting task, and were provided time to complete any task, including an off-task behavior. Play, used as a motivator, enhanced positive affect and increased motivation to participate in work. Furthermore, Isen and Reeve found that when given the choice, participants would engage in both work and play, and the inclusion of play did not impact the quality of work negatively. Similar to the analysis provided by Lillard et al. (2013), the research by Isen and Reeve also suffers from some of the fallbacks of previous literature for attribution of causality. Although Isen and Reeve demonstrated results using quantitative measures, they ignored interaction effects. The conditions of their study also make it difficult to extrapolate their controlled situation to another environment. However, this does not discount the idea that play may still act as a motivator whether intrinsic or extrinsic.

Though the body of literature regarding play may include discrepancies regarding causality, the motivating factors of play and the positive relationship to mood may contribute to deeper engagement with the content and learning. While research into play demonstrates a variety of perspectives and problematic methodology, play and its impact needs to be looked at as the sum of its parts (Weisberg & Hirsh-Pasek, 2013). Accepting the definition of play as falling on a continuum (P. Smith, 2010), then, as noted in Figure 4, for the purposes of this study, play is significant, but we do not yet understand exactly how or why.

Engagement

According to Wang, Lin, Yu, Wu, and Gung (2013), the concept of academic engagement has held a fairly consistent definition from 1984 to 2009, reflecting the time and energy placed into an academic activity. However, the concept of engagement, while relevant in today's educational discussions, is difficult to understand because it is difficult to quantify (Fredricks et al., 2011). According to the US Department of Education report regarding scales related to engagement, at least 21 instruments exist to measure academic engagement from upper elementary to high school; however, of those included in the report, 14 are self-report style questionnaires, and 7 are based on teacher observations (Fredricks et al., 2011). While 20 of the 21 instruments included in the report were noted to have high reliability and validity, each measured different combinations of social, affective, cognitive, and behavioral dimensions. These differences highlight the subjective nature of measuring engagement.

Furthermore, accurately measuring engagement beyond self-report style inventories requires the use of specialized hardware. In the field of human-computer interactions, measurements traditionally involve pressure plates in the floor or chair, accelerometers, magnetic field sensors, or multiple cameras to capture micromotions (Witchel, Westling, Healy, Chockalingam, & Needham, 2012). Additionally, Witchel et al. (2012) noted that many previous studies lacked a comparison between different methods of measurement, therefore, limited comparative validity. Witchel et al. compared pairs of measurements from an 8-camera motion sensing device, an accelerometer mounted on the participants head, high-speed video capture, and pressure plates in the floor. They found poor correlations between the results from each tool and noted that each of these technological methods of measuring engagement had faults. For example, breathing created noise in the pressure plate data, and accelerometer measurements failed to detect certain motions due to interference from other head movements. Subtle movements were noted to be difficult to detect using any one of these technologies, highlighting additional challenges in measuring engagement. While difficult to operationalize, its importance to learning is still valid; in order to learn, one must engage in the material (Hattie, 2009).

Examining the extreme end of the engagement spectrum also illuminates its importance. A concept that evolved out of the field of positive psychology, flow theory, is defined flow as the "state of optimal experience that people report when they are intensely involved in doing something that is fun to do" (Csikszentmihalyi, 2000, p. 381). Beylefeld and Struwig (2007) added to this definition to include situations where enjoyment stimulates learning. In particular, Csikszentmihalyi (2000) identified eight common factors of flow experiences including increased concentration, the ignoring of irrelevant stimuli, and a resulting feeling of reward. As this state of intense engagement occurs across activities as well as cultures (Csikszentmihalyi, 2000), flow-states may provide significant benefits to education. As an extreme representation, flow theory contributes to the perspective behind the rationale that engagement is critical to the learning experience.

The literature demonstrates beneficial relationships between educational factors and flow states. For example, an appropriate balance of challenge and skill supported flow-states (Inal & Cagiltay, 2007; Moneta & Csikszentmihalyi, 1996; Shin, 2006) as did the individual perception of control within the learning environment (Shernoff et al., 2003). Additionally, work fostered flow-states more often than leisure and increased overall levels of happiness and satisfaction (Csikszentmihalyi & Hunter, 2003; Csikszentmihalyi & LeFevre, 1989). Furthermore, intense focused study lead to flow-states (Brinthaupt, & Shin, 2001), but preconceived attitudes towards learning did not impact flow-states (Winberg & Hedman, 2008). While flow-states present potential benefits to education, learners require the appropriate environment and learning activity to engage in states of flow.

Flow-states, similar to play, require a balanced approach to maximize attainment of learning goals (Moneta & Csikszentmihalyi, 1996; Pui-Wah, 2010). As an illustration, Montessori schools, which typically incorporate purposeful play into the learning experience, spur greater flow experiences in students than traditional schools (Rathunde & Csikszentmihalyi, 2005). Similarly, the idea of play in education supports Csikszentmihalyi's (2000) claim "if children do not enjoy learning, they will not get much from schools and will seek out opportunities for enjoyment that often impair their future development" (p. 381).

There is an issue with the current state of research regarding flow-theory. Although the body of literature defines the concept, little research operationalizes the flow-state beyond the use of self-reporting measures that mimic the characteristics of experiencing a flow-state. For example, the Flow State Scale by Jackson and Marsh (1996), along with its second iteration, has been used in many studies involving measuring flow states. However, the initial scale was designed to target high-performing athletes (1996) and may not apply in other areas (Carter, 2013). Carter (2013) noted that Jackson's shorter revised version of the scale has users simply self-report the nine characteristics of flow-states identified by Csikszentmihalyi on a Likert-type scale of 1 to 5. Furthermore, without going into biological measures, such as done in studies by Nacke and Lindly (2009), and Mauri, Cipresso, Balgera, Villamira, and Riva (2011), it may not be possible to accurately measure flow-state without simple self-reporting.

While it is not the intent of this section of this literature review to delve deeply into flow theory, the theory provides a lens for understanding mathematics remediation using digital game-based learning from an engagement perspective. However, it is important to distinguish the flow-state from engagement and on-task behaviors. While the idea of the flow-state is often seen as a heightened sense of engagement from it's characteristics (Csikszentmihalyi, 2000), it includes specifics that are beyond that of what might be considered engagement. Academic engagement is a more nebulous continuum of the individual's value of education and participation in academia (Gresalfi & Barab, 2011; Huy, 2014). It is important to note that one can be on-task, yet not engaged, as well as one can be engaged but not in a flow-state. However, since many theories exist underlying being on task and being engaged, such as motivation, flow theory was selected to represent the optimal state. Furthermore, the research into flow-theory complements learning in game-based HIVEs through the benefits of increased focus and attention, yet it also illuminates the necessity of attending to learner engagement needs. While flow theory is not measured within the scope of this proposed study, it provides support for the foundational argument that engagement is significant to the learning experience.

On the other hand, time-on-task is easier to quantify than flow-states, specifically in digital environments. Digital environments can measure the amount of time a student is within the program though this too has potential measurement issues. Without self-reported, observational, or motion tracking technology data, it would be impossible to know if a user walked away from the computer or engaged in another task. Another issue exists with time-on-task; it has been noted that while many factors have considerably greater influence on academic achievement, time-on-task plays a relatively small role (Hattie, 2009). However, time-on-task is noted to be "very significant in a practical way because time is a resource that educators can control" (Karweit, 1982, 1). Though time-on-task, taken independent of other factors, has a relatively small effect size according to Hattie (2009), it serves as a measure of engagement for the purposes of this study as noted in Figure 4.

Design to Support All Learners

Attending to learner needs by putting measures in place to make the content accessible to everyone provides the support necessary for all learners. Nevertheless, many ideas exist regarding ways to maximize access to content, and the idea of tailored instruction is by no means a new concept. Examples of some of these theories to reach a broad spectrum of learners include the zone of proximal development (Vygotsky, 2004); the social aspect of learning (Bandura, 1977); addressing self-efficacy needs (Zimmerman, 2000); and changing the assessment paradigm (Popham, 2008). While these and many other specific pedagogical concepts may support the learning needs of students, no one method can accommodate the needs of every learner all of the time. Therefore, three underlying theories bring together many best practices framing this research into addressing the mathematics problem using learning in game-based HIVEs: differentiated instruction, universal design for learning, and accountable game design.

Differentiated instruction. This is the idea that instruction should meet learners' needs with appropriate challenge and choices (Gregory & Chapman, 2007) and comes in the form of content, product, and/or process (Heacox, 2002). Additionally, in differentiated instruction, the structure of the learning task should accommodate a variety of learning modalities (Gregory & Chapman, 2007; Heacox, 2002). Differentiated instruction notes the importance of attending to the needs of the learner to maximize the depth of learning (Gregory & Chapman, 2007; Heacox, 2002). Even though Berk (2010) noted that the youth of today have a preference for visual learning, differentiated instruction notes that all learning preferences should be considered, and learner choice is critical to the learning experience (Gregory & Chapman, 2007; Heacox, 2002).

Universal design for learning. Similar in idea to differentiated instruction, UDL principles not only to support varied learning preferences but also varied abilities and disabilities through intentional design (Rose & Strangman, 2007). Based on the architectural approach of making spaces available to the widest range of users, the same holds true with regard to learning tasks (CAST, 2011; Rose & Strangman, 2007). Accordingly, successful learning requires interaction with the environment to engage in pattern recognition behavior, development of strategies, and reflection according to the premises of UDL (CAST, 2011; Rose & Strangman, 2007). Additionally, UDL seeks to reduce the negative influence of deficiencies in these three areas to support learning for all students (CAST, 2011; Rose & Strangman, 2007). Similar to differentiated instruction, UDL seeks to increase access to content by attending to learner needs. In contrast, UDL builds on the differentiated instruction foundation by incorporating learner accommodations through the intentional design of learning tasks and curricula (Rose & Strangman, 2007, p. 385).

While social science research grounds the ideas behind differentiated instruction (Gregory & Chapman, 2007), cognitive neuroscience research, the complexity of understanding cognition, and the factors influencing it form the basis for UDL (CAST, 2011; Rose & Strangman, 2007). Thus, UDL extends the premise of differentiated instruction to address cognitive needs. Furthermore, Rose and Strangman (2007) overview the research underpinning UDL noting three main biological and cognitive functions that affect memory, language, speech, problem solving, and thinking: pattern recognition networks, strategic networks, and affective networks.

First, pattern recognition networks help us understand the world, filtering sensory information. Pattern recognition and pattern generation manage our interaction with the environment (Rose & Strangman, 2007). Supporting the importance of pattern recognition networks to learning, Rose and Strangman (2007) noted that these networks "are essential to many higher cognitive tasks, and pattern recognition pervades all academic content areas" (p. 382). Therefore, learner differences in pattern recognition influence how learning tasks are approached and managed, and must be accounted for in the design of the learning activity.

Next, strategic networks allow us to construct meaning, make plans, and make hypotheses regarding patterns once we take in information from recognition networks (Rose & Strangman, 2007). For example, in the mathematics classroom, strategic networks impact goal identification, recognition of pertinent information, and strategy selection, related to the best practices identified in the National Governors Association's (2012) Common Core Standards for Mathematical Practice. Consequently, differences in strategic networks influence a range from dyslexia to gifted mental manipulation of figures (Rose & Strangman, 2007). Attending to strategic networks means lesson design allows learners a variety of methods to make their own meaning and hypotheses.

Finally, affective networks influence motivation, our ability to empathize with others, engage emotionally in the environment, respond to emotional stimuli, make decisions, and persevere in tasks (Rose & Strangman, 2007). The affective system also determines how we perceive and react to our environment. Accordingly, differences in the functioning of this system lead to perceptions of learning and the learning environment, as well as the emotional response to these perceptions. UDL's inclusion of design attending to affective networks demonstrates the significance of emotion to the learning experience. In summary, Rose and Strangman noted the three networks played a significant role in learning because they influenced engagement and motivation, and that technology may open access to learning by incorporating the principles of UDL.

Accountable game design. Extending the ideas of differentiated instruction, UDL, and instructional game theory, accountable game design applies the premise of maximizing access through intentional choices made in the design of game-based learning activities (Charoenying, 2010). Charoenying provided seven principles for accountable game design: intended audience, learning goals, group dynamics, complexity of rules, criteria for success, protocol for interaction, and choice of media. Admitting that it is impossible for one game to account for all possible educational needs of the learner, Charoenying suggested that educational game design must include an intentional choice for each principle in order to maximize access for the target audience.

First, game-based learning experiences should reflect the intended audience (Charoenying, 2010). While many games do not target all audiences, accounting for access needs of diverse learners helps maximize the intended audience. Because of its significance, the intended audience influences how the other six principles of accountable game design should appear, beginning with the learning goals. Learning goals include the intended outcomes from the game-based learning experience. In particular, the manner in which learning goals are presented is important as it defines perception of game factors. Consequently, games may be perceived where learning the content is primary or where the content is merely a means to further game play (Charoenying, 2010; Chatham, 2011). Furthermore, Charoenying (2010) noted that learning goals must be obvious to the learner. Therefore, if the learning goal is not explicit, this gap must be bridged to redirect learners to the learning goals. As an illustration of the importance of learning goals, Tüzün et al., (2008) found that the intent of the game can be lost, and the focus can shift from the learning goals to the game itself. As a result, a focus shift to game performance over learning may lead to negative behaviors such as cheating (Baker et al., 2008). Identically, Chatham (2011) and Amory (2010) highlight the importance of learning goals, noting that underlying ideology must be taken into account in game design to ensure the focus is on the intended learning goals.

Group dynamics strongly influences attainment of learning goals and supports the social needs of the learner. Group dynamics focuses on the in-game interactions whether competitive, cooperative, or collaborative (Charoenying, 2010). Similarly, Tüzün et al. (2008) support the critical nature of social needs addressed by the idea of group dynamics by suggesting voice-over-Internet protocol (VoIP) to support player collaboration in games without built-in communication systems. Nonetheless, communication does not require other players; pedagogical agents, or non-player characters (NPCs), may be useful in digital learning environments, supporting learners' social needs (Amory, 2010; Schroeder & Adesope, 2014). While the meta-analysis performed by Schroeder and Adesope (2014) identified human-to-human interactions as preferable, systems employing pedagogical agents were perceived more effective and more satisfying than systems that did not contain these types of NPCs. Furthermore, pedagogical agents contributed to increased motivation, increased perceived improvement in performance, and increased engagement. Accordingly, group dynamics directly impacts motivation and engagement with learning goals (Charoenying, 2010) reinforcing the value of the inclusion of learner interaction, whether through NPCs, with the classroom teacher, or with peers.

Complexity of rules impacts motivation and engagement: highly complex games limit access, but attend to the needs of skilled learners; simpler games increase access, yet stimulate boredom in skilled players (Charoenying, 2010). As a result, complex rules or behaviors make for a steeper learning curve of the game mechanics, potentially inhibiting transfer and increasing anxiety. Not to mention, as a component of complexity, games based entirely on skill cause those with lower skill levels to retreat and creates anxiety. Subsequently, Charoenying noted chance and surprises enhance motivation and engagement for those with lower skill abilities but must be used in moderation for skilled players. As a result, games may address the complexity of rules by increasing the level of complexity progressively, adjusting automatically to match player skill level, or by limiting game design to a specific audience (Charoenying, 2010; Whitton, 2012).

Coupled with the other factors of accountable game design, learners must know what success looks like, how to attain it, and how they will know when it has been achieved. Thus, the criteria for success appropriate to the target audience make the learning goals attainable (Charoenying, 2010). Similar to learning goals, the criteria for success should meet learners' needs and should be explicit (CAST, 2011; Charoenying, 2010; Rose & Strangman, 2007). In essence, all factors of accountable game design influence or are influenced by the criteria for success (Charoenying, 2010).

Protocol for interaction refers to real-time versus turn-based games (Charoenying, 2010). Similar to group dynamics and complexity of rules, it directly impacts a student's ability to meet the criteria for success. Like criteria for success and complexity of rules, game speed influences engagement and motivation differently for those of low and high skill levels. Consequently, choice of real-time versus turn-based may limit the target audience through levels of experience and skill.

Choice of media applies to all forms of games, not only digital ones. In addition, Charoenying (2010) supplied several reasons supporting Internet-based games, such as socialization opportunities, but also included disadvantages such as Internet access and speed. Therefore, the selected media should meet the students' learning needs and allow for broad access (CAST, 2011; Charoenying, 2010; Gregory & Chapman, 2007; Rose & Strangman, 2007). As a result, the characteristics of the intended audience should influence the selection of appropriate media choices.

Accountable game design highlights the overarching significance in the selection of the intended audience and its relationship to the other six factors identified by Charoenying (2010). Although games can be designed to attend to most audiences through adaptive technologies, it is difficult to attend to all factors adequately. However, using principles of UDL, designers can maximize the intended audience (CAST, 2011; Charoenying, 2010). At the same time, a broad spectrum intended audience must include those who function in the middle and the higher end. While a focus on a specific intended audience limits the potential pool of users, it allows designers to provide adequately for a target audience's needs through careful selection of the other six principles.

In addition to the seven principles presented in Charoenying's accountable game design, Amory (2010) suggested five additional factors that must be in place in order to support success

- the ideological positions of designers are important to understand the learning environment;
- in-game contradictions must be avoided, which may have a negative impact on learning opportunities;
- items with which the player can interact must be clearly understood as an object or a tool;
- NPCs should support complex problem solving or facilitate in-game progression; and

- opportunities must be provided where learners must work collaboratively to accomplish goals.

In the same way, Chen et al. (2010) and Cannon-Bowers et al. (2011) support these premises highlighting the importance of ensuring the quality of the game, including in-game assistance for both content and information about the game. Subsequently, the twelve factors presented by Charoenying (2010) and Amory (2010) support the principles of UDL by addressing learner needs. Hence, as shown in Figure 5, meeting the needs of learners may influence engagement (Beylefeld & Struwig, 2007; Brinthaupt, & Shin, 2001; Charoenying, 2010; Csikszentmihalyi, 2000).

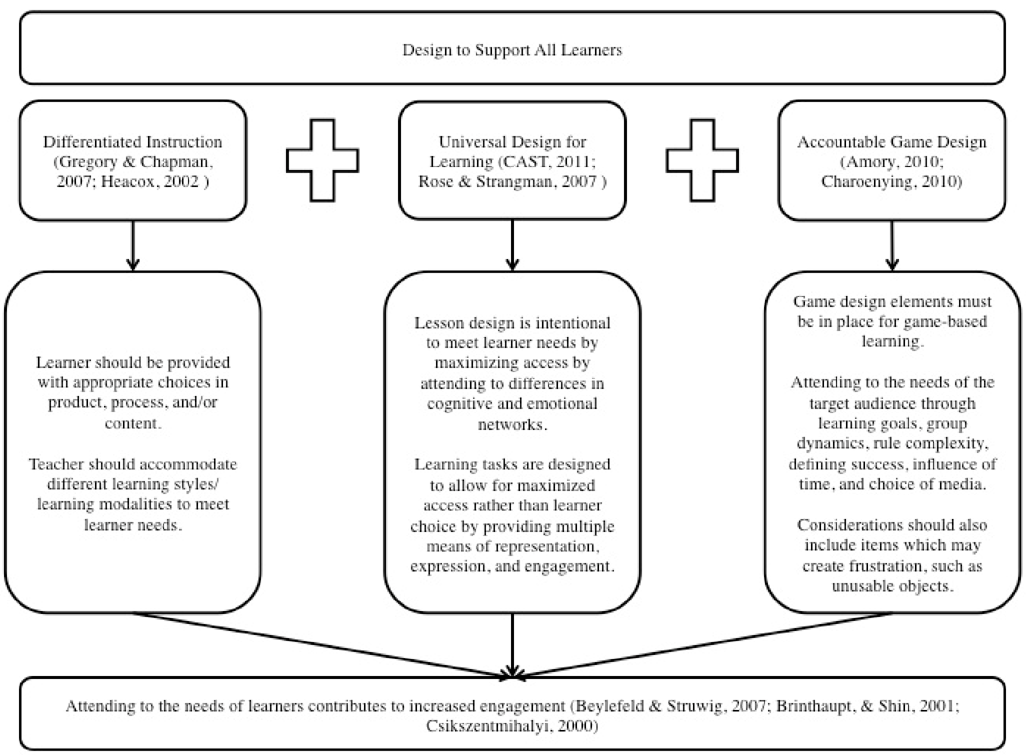

Figure 5. Pedagogical theories representing best practices targeting the significance of engagement.

Understanding the overarching concepts of play, engagement, and design to support all learners provided the conceptual framework for this research, as shown in Figure 4. Play is an underlying idea in game-based learning; therefore, accepting its importance is critical to the nature of this study. Engagement with the material is also critical to learning; however, time-on-task represents a proxy measurement because of the complexities in measuring engagement. Finally, design for all learners demonstrates the importance of attending to the needs of learners, but also highlight the significance of engagement to the learning experience.

Theoretical Foundation

The theoretical base allows for three important functions: facilitation of communication using agreed-upon concepts; development towards a shared perspective; and a foundation from which to provide shared experiences (Frankfort-Nachmias & Nachmias, 2008). As a result, this section will attempt to synthesize research to demonstrate the theoretical framework underlying this proposal: self-reported patterns of gamer-behaviors may be classified and may predict in-game preferences and behaviors.

While theories exist to classify individuals by traits and behaviors, research into applying similar concepts to digital game environments became illuminated with the four player archetypes proposed by Bartle. Bartle (2004) noted that rules imbedded in the code influence game balance, adjustments to the smallest factors can create in-game changes with repercussions such as tipping the economic balance or alienating certain player types. Consequently, Bartle (2004) proposed any change in the digital game environment benefited some players and created disadvantages for others. The premise was that with balance came maximum engagement from all player types. In order to understand factors that balance populations in multiuser dungeons (MUDs), Bartle (1996) developed four player types to describe players. Through informal qualitative analysis of discussions by high-level players on online forums, Bartle (1996) noted that players of MUDs fell into one of four archetypes:

- Achievers seek to act on the world.
- Explorers seek to interact with the world.
- Socializers seek to interact with other players.
- Killers seek to act upon other players (1996).

Each archetype is based on two dichotomies, player versus world and acting versus interacting. Therefore, a socializer interacts with other players while an achiever interacts with the world. Likewise, an explorer acts on the world while a killer acts on other players. Although Bartle (1996) noted that players have one predominant type, he also acknowledged that players may shift between the four classifications to further their needs within their predominant archetype. Bartle noted the significance of accommodating all four player types. For example, to encourage participation and interaction, a balance must exist between a player focused and world focused environment. Furthermore, to minimize the feelings of paralysis and limit repetition, the environment must be balanced between acting and interacting, important for attending to learner needs and stimulating engagement. While Bartle's archetypes are not grounded in scientific theory and the information provided concerned player interactions and game balance, his work provided the initial step to understand patterns of gamer behaviors and their relationship to in-game behaviors.

Yee (2005) noted that Bartle's pigeon-holing of players into one archetype limited understanding of player motivations. Yee also noted that Bartle's research did not allow for overlapping of different patterns of behavior, and no form of assessment or identification was provided. Subsequently, Yee used a factor analysis approach to cluster 39 statements from a large sample of *World of Warcraft* players (n=3,200) reducing the statements to 10 clusters: advancement, mechanics, competition, socializing, relationship, teamwork, discovery, role-playing, customization, and escapism. While the ten clusters represented 60% of the variance, Yee performed another reduction arriving at three principle domains representing 54% of the variance: achievement, social, and immersion. While Yee noted that players demonstrated differing levels within the domains, they are not independent of one another and players may be high or low in each of the domains. Like Bartle, Yee provided how players scoring high in each of the clusters act within the game world.

However, Yee (2005) noted theoretical issues with Bartle's proposal. First, people do not fall into neat boxes using an either-or typing system, but should be rated on each domain or component. Next, Bartle (1996) noted that one motivation tended to suppress the others, thus the either-or dichotomies make sense. However, Yee (2005) noted that the r-values between the domains were approximately 0.10 and demonstrated the lack of relationship between the three domains through scatterplots. Finally, Yee noted that scoring low within a domain was just as informative as scoring high. Yee provided the example of those who score low in socialization; these players tend to not like games where the social component is forced upon them. On the other hand, Bartle et al. (2009) noted a significant difference between the initial dichotomous scale and Yee's work. Bartle's player types explain why people play, while Yee's scale is about what players do (Bartle et al., 2009, p. 132). While Bartle provides "player types", Yee identifies continuums for player motivations (Yee, 2005).

Building upon Yee's work, Yee, Ducheneaut, and Nelson (2012) continued refinement of Yee's (2005) three domains with the intent of reducing the scale to consist of fewer questions, explore cross-cultural relationships to determine if the domains cross the east-west divide, and provide predictive validity through comparison of self-reported values to in-game metrics. Preliminary studies were conducted (each with $n>300$) to determine the 12 statements in the revised scale (Yee et al., 2012). Then, the revised scale was administered to a large group of *World of Warcraft* players ($n=2017$). Exploratory factor analysis resulted in the same three domains from Yee's initial study, with each having a high internal reliability ($\alpha>0.70$) and eigenvalues greater than 1 (Yee et al., 2012). The second part of their study included participants from Hong Kong and Taiwan ($n = 645$) and used confirmatory factor analysis. Their findings demonstrated consistency with the US data, and may indicate that the three proposed domains persist across cultures. Finally, comparisons were made between the self-reported scale to in-game metrics from a sample of *World of Warcraft* players from the US (n=500), Hong Kong, and Taiwan (n=500) to determine predictive validity. A significant relationship was found between self-reported data and in-game metrics (at minimum $p<0.01$).

While Yee (2005) and Yee et al. (2012) explored the creation of a scale specific to relating personality traits to motivations to play online games, other researchers have attempted to apply pre-existing scales to understand player motivations and related in-game behaviors. Park et al. (2011) noted that many personality factors may relate to game playing behaviors beyond those proposed by Bartle and Yee, and factors may be culturally related. As personality is considered stable, elements of games that provide satisfaction of individual needs may provide insight into the relationship between personality and motivation to play games (Park et al., 2011). They proposed that elements of gaming foster intrinsic motivation to play based on the individual's needs.

Jeng and Teng (2008), Park et al., (2011), Graham and Gosling (2013), and Konert et al. (2013) each used the Big Five personality dimensions within their studies on motivations to play games. The Big Five personality dimensions are extraversion, agreeableness, conscientiousness, emotional stability (neuroticism), and openness to experience. Jeng and Teng (2008) compared the Big Five personality factors to five of Yee's initial ten characteristics from Taiwanese students with online game experience (n=92). Using multiple regression they found significant relationships (all $p\leq0.06$) between extraversion and teamwork; agreeableness and achievement; conscientiousness and escapism; neuroticism and teamwork; and openness and discovery.

Park et al. (2011), on the other hand, used a broader range of 34 statements from previous research and interviews with current online game players. Using factor analysis, Park et al. found five clusters in the 34 statements: relationship, adventure, escapism, relaxation, and achievement. Comparing the five clusters to the Big Five personality dimensions along with gender and age, they found no relationship between personality traits and number of years playing or preferred genres in their participants (n=524). However, a strong relationship was found between agreeableness and extraversion to playing online games. Consistent with other studies, Park et al. noted many relationships between each of the five personality factors and their five clusters of motivations to play. Park et al. also noted that their five motivation factors may relate to Yee's proposed three factors, though noted that escapism and relaxation were separated in their study yet combined in Yee's.

Graham and Gosling (2013) modified Yee's initial scale and included two additional dimensions: leadership and independence. Comparing data from the modified version of Yee's Motivations to Play Online Games to the Big Five personality data for a large sample of *World of Warcraft* players (n=1,413) demonstrated results similar to Jeng and Teng (2008) and Park et al. (2011). Participants high in Yee's social domain scored higher in extroversion and agreeableness; participants high in achievement scored higher in extroversion, but a significant negative relationship was found to agreeableness; and participants high in immersion scored higher in neuroticism and openness (Graham & Gosling, 2013). In the additional two domains included by Graham and Gosling, leadership positively correlated with extroversion but negatively correlated with agreeableness; independence was positively correlated with openness (all at $p \leq 0.01$). However, Graham and Gosling noted that their findings were not similar to previous research into generalized motivations and that continued research should be conducted investigating specific traits in specific environments.

Konert et al. (2013) added an extra dimension to the comparison between the Big Five personality dimension and game player motivations through the inclusion of Kolb's Learning Style Inventory. They hypothesized that by knowing the personality traits using the Big Five, predictions could be made about their player type, using Bartle's theory, and learning style. Using 9th-grade students from Germany (n=72), Konert et al. found relationships between the Big Five domains and player motivations, similar to other studies. However, no relationship was found with Kolb's Learning Style Inventory, and predictability was inconclusive from the Big Five personality dimensions.

While the theory that personality traits may predict online gaming motivations and, therefore, in-game behaviors, is acknowledged in the literature, differences in opinion on which personality factors to measure and how to measure them exist. Similar to research in related areas, there are pervasive methodological limitations. In the initial study by Bartle (1996), no data analysis was performed, and the information provided was based on informal observation. The studies by Yee (2005), Yee et al. (2012), and Graham and Gosling (2013) used players of one online game, *World of Warcraft*, while Jeng and Teng (2008) and Park et al. (2011) included players with experience in any online game within their studies. While Park et al. (2011) noted that cultural factors may influence game playing behaviors specifically in Eastern cultures, Yee et al. (2012) found, in the east-west comparison component of their study, no significant difference in motivations and no significant differences when comparing motivations to in-game metrics. Table 1 summarizes the measured dimensions and relevant findings from these studies. However, though each of these studies demonstrates relationships between traits and in-game motivations, little literature exists extrapolating the idea that traits may be used to understand in-game motivations and behaviors to educational or serious games.

Table 1

Studies Investigating Patterns of Gamer Behaviors

Researcher(s)	Trait Measurement	Findings
Bartle (1996)	No metric - Dichotomies: acting versus interacting and world versus players. Labeled as player types: achievers, explorers, killers, and socializers	Predominant pattern of gamer behavior can be determined. This pattern indicates why players engage. In-game elements support or detract from the gaming experience, encouraging some players and alienating others.
Yee (2005)	10 initial components: advancement, mechanics, competition, socializing, relationship, teamwork, discovery, role-playing, customization, and escapism Reduced to 3 principle components: achievement, immersion, and social	Each factor and component represents a continuum from low to high. Though Yee identifies each component as how players “derive satisfaction” from the game environment, related behaviors are also provided.
Jeng & Teng (2008)	Big Five personality dimensions (extraversion, agreeableness, conscientiousness, emotional stability, and openness to experience) compared to Yee’s advancement, discovery, escapism, role-playing, and teamwork.	Personality traits may predict gamer motivations. Extraversion correlated to teamwork. Agreeableness correlated to advancement. Conscientiousness correlated to escapism. Emotional stability correlated to teamwork. Openness correlated to discovery and role-playing.

Table 1: Continued

Researcher(s)	Traits	Findings
Park, Song, & Teng (2011)	Big Five personality dimensions compared to five factors determined from preliminary components of their study: achievement, adventure, escapism, relationships, and relaxation.	Extraversion and agreeableness correlated to game playing, however personality traits did not correlate with amount of game playing or genre of preferred game. Extraversion correlated to achievement, adventure, escapism, and relaxation. Agreeableness correlated to achievement, adventure, escapism, and relationships. Conscientiousness, emotional stability, and openness to experience were not found to have a significant relationship to any of the 5 motivation components. Gender correlated to relationships, with female participants valuing relationships more than males. Age correlated with escapism.
Yee, Ducheneaut, & Nelson (2012)	Yee's 3 principle components	Revision of initial scale to a shortened form. Made East-West comparisons, finding data from Hong Kong and Taiwan consistent with data from the US. Self-reported data correlated to in-game behaviors providing predictive validity.

Table 1: Continued

Researcher(s)	Traits	Findings
Graham & Gosling (2013)	Big Five personality dimensions compared to a modified version of Yee's initial principle components with the addition of leadership and independence motivations.	Extraversion correlated to achievement, social, and leadership. Agreeableness correlated to achievement, social, and leadership. Conscientiousness correlated to achievement, immersion, and leadership. Emotional stability correlated to achievement, immersion, and social. Openness correlated to achievement, immersion, social, leadership, and independence.
Konert, Göbel, & Steinmetz (2013)	Big Five personality dimensions compared to Bartle's 4 player types and Kolb's Learning Style Inventory (doing, experiencing, reflecting, and thinking).	Negative correlations existed between each of Bartle's 4 player types. Between the three measures: Bartle's achievers correlated to Kolb's thinking. Bartle's socializers correlated to Big Five conscientiousness. Kolb's experiencing correlated to Big Five openness. Big Five may not be useful to predict in-game behaviors, except for socialization. Big Five was not useful for predicting learning style.

The three concepts of the potential of play in learning, the importance of engagement, and the critical nature of attending to the needs of learners provided the overarching perspective of this research as noted in Figure 4. Furthermore, the theory that player traits can be measured and reflect in-game motivations supplied the foundation for this research into understanding the relationship between traits and time-on-task when using a game-based HIVE for mathematics remediation. Studies relevant to the underlying theory are summarized in Table 1. Figure 6 illustrates the overarching ideas within the conceptual and theoretical framework and provides the connection.

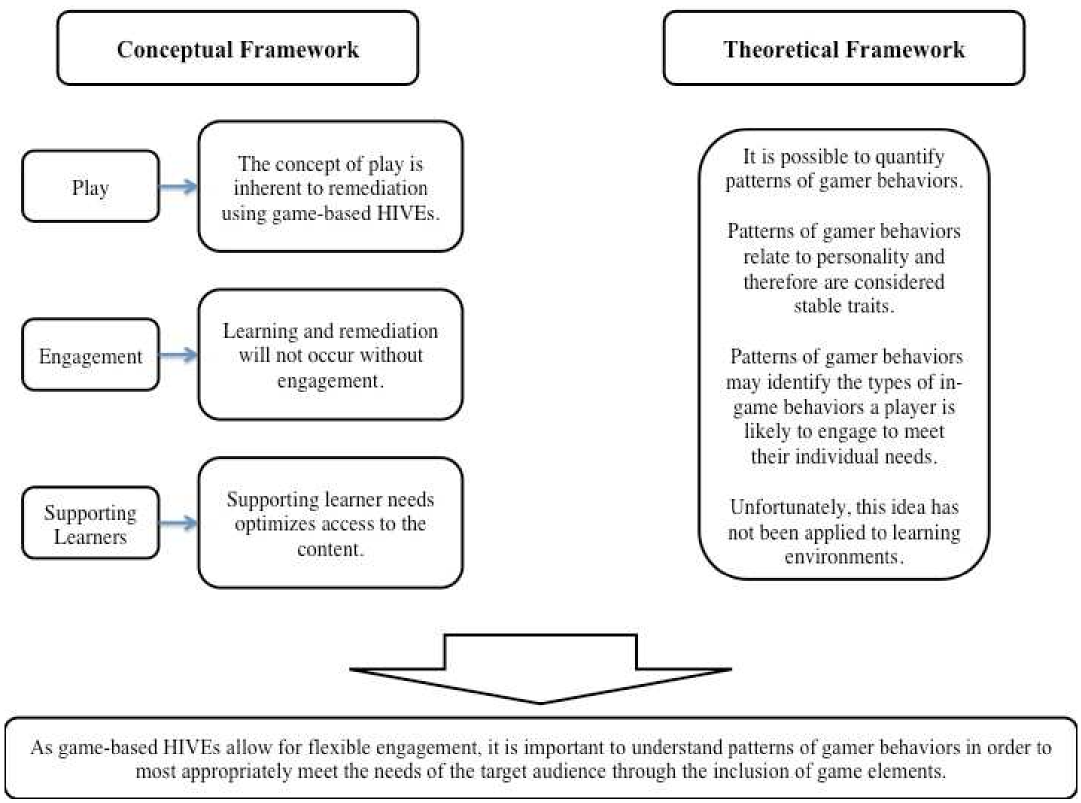

Figure 6. Connection between the conceptual and theoretical frameworks.

In a game-based HIVE it is important to understand factors that relate to how individuals engage in the environment in order to maximize access for the target audience. While these concepts and theories provide the lens through which this research was approached, characteristics of the environment, the learner, and the content represent the overarching key concepts to understanding gamer behaviors when mathematics remediation occurs in a game-based HIVE. Next, I provide a review and synthesis of relevant literature regarding these three areas. Each subsection following includes an overview of the topic as well as the significance to this research into digital game-based learning.

Learning Environment

In 2009 Clark and Ernst reported that 65% of American households had people who played computer games, with 94% of those being under the age of 18. This is also an area of growth (Anderson & Rainie, 2012; Richards et al., 2013). For example, the Entertainment Software Association (2014) reported that over half of U.S. households had an average of two dedicated gaming consoles and spent over $20 billion on digital gaming in 2013. As a result, the pervasiveness of both experience of the K-12+ learner (Anderson & Rainie, 2012; Clark & Ernst, 2009; Entertainment Software Association, 2014) and access in the American classroom (Bilican et al., 2011; National Center for Educational Statistics, 2013) demonstrate one reason learning in digital game-based environments is an area requiring additional research to actualize the full potential of these environments. Particularly, the demonstrated benefits of digital game-based learning included stimulating engagement (Games & Squire, 2011; Richter & Livingstone, 2011), improved academic achievement over traditional settings (Ratwani et al., 2010; Tamim et al., 2011; Vogel et al., 2006), and attendance to principles supporting individual learner needs (Charoenying, 2010; Pekrun et al., 2002) highlight additional potential of digital game-based learning to address an educational problem. Finally, the attention through websites dedicated to educators using games as well as journals specializing in research into digital game-based learning, illustrates the need to explore the potential of these environments further (Games & Squire, 2011; Richter & Livingstone, 2011). Naturally, understanding learning in game-based HIVEs must begin with the broader topics of game-based learning, computer-based learning, and the environments of digital games.

Game-Based Learning

Game playing behavior has been around since written record exists (Cohen, 2006; Games & Squire, 2011; P. Smith, 2010; Tobias et al, 2011). Throughout history, games teach basic skills and culturally dependent concepts (Cohen, 2006; Knijnik, 2012; Myers, 2010; P. Smith, 2010) and may represent the natural way children learn (Graue, 2011). Additionally, while not necessarily for the purpose of learning, some researchers suggested all people play games (Berne, 2009; Brinkerhoff, 1993). For instance, some games, such as tic-tac-toe and rock-paper-scissors, show up in diverse cultures around the world, while others, such as Go, are culturally dependent (Anderson & Rainie, 2012, Knijnik, 2012). Some games, such the Brazilian language games used to develop peasant mathematics, have a specific educational intent (Knijnik, 2012; P. Smith, 2010), while others, such as many modern video games, have an entertainment purpose (Anderson & Rainie, 2012). As a result, the pervasiveness of games and game playing behavior has made the scope of research into educational gaming both deep and broad (Tobias et al., 2011). While the following is not a comprehensive overview of the field of research into game-based learning, research studies have demonstrated benefits to educational game playing.

First, skill acquisition and transfer of knowledge have been investigated with regard to game-based learning, and is the area with largest body of literature. Chee and Tan (2012), for example, compared two groups of high achieving middle grades students in two chemistry classes. The control group (n=38) received traditional, lecture style information regarding chemistry while the intervention group (n=39) learned the same topics through the use of a game, *Legends of Alkhimia*. Students in the intervention group were able to transfer knowledge from learning experience to assessment better than those in the control group, in both separation of solutions and a general understanding of chemistry, the two assessed areas (p=0.026 and p=0.002 respectively) on a written post assessment (2012). Similarly, Chen, Lin, Looi, Shao, & Chan (2012) found in their sample of 4^{th} grade students (n=83), those in the treatment groups playing a cross-number puzzle game performed significantly better at the arithmetic learned than those in a traditional setting (p=0.002 and p=0.008) with an average increase in scores of 13 points in the treatment groups versus a 0.01 average increase in the control group from their two-tailed t-test analysis.

With regard to language learning, Griva & Semoglou, (2012) found 2nd grade students in Greece learning English as a foreign language performed better when learning in a game environment than those in a traditional setting. With pre-test scores in 4 domains (word production, understanding simple events, producing a word in context, and understanding the function of language) both control and treatment groups' means were within 0.5 points. On the post-assessment, the mean scores of students in the treatment group were 2.09, 0.78, 0.05, and 1.45 points higher in each of the domains.

Finally, with regard to learning and transfer, Wang, Hu, and Xi (2011) investigated third year medical undergraduates (n=214). The students in the treatment group (n=107) played a guessing game where one person was given a medical term and 10 seconds to describe or explain it, while the others had 5 seconds to provide a correct answer. Participants in the treatment group outperformed those in the control group (p=0.024) with the majority (76.5%) reporting the guessing game was more enjoyable than traditional lecture. The fun factor may be related to increased motivation and engagement.

Studies have been conducted to demonstrate that games have a positive relationship to increased motivation and engagement. Tüzün et al., (2008) investigated intrinsic and extrinsic motivation in 4th and 5th grade students in Turkey (n=17) before and after game playing for learning geography. Using separate scales to measure intrinsic and extrinsic motivation, Tüzün et al. found participants' mean intrinsic motivation scores increased after playing the game (27.6 to 31.4; $p<0.05$) and mean extrinsic motivation scores decreased (31.7 to 27.8; $p<0.01$). Dickey (2011) found, in a qualitative study of undergraduate students ($n=20$), game playing increased intrinsic motivation to investigate and write persuasively. Using *Murder on Grimm Isle*, a game designed to facilitate persuasive writing, Dickey found that 90% of the participants willingly engaged in the persuasive writing activity though most participants identified that they did not like to write. Similarly, Hui-Chuan and Chen (2012) found that low motivated college students enrolled in English as a foreign language courses displayed significant gains when learning in a game environment. Entering Taiwanese freshmen ($n=79$) demonstrated significantly increased scores ($p<0.001$ on all comparisons) after playing adapted versions of poker, chess, and gobang that required players to create compound nouns in English.

Additionally, in the mixed methods study by Matas & Natolo (2010) of college level advanced Spanish learners ($n=14$), students created games to help with learning grammar in Spanish. While the students reported a traditional textbook style learning of Spanish grammar in the past, 12 of the 14 noted an increased enthusiasm for learning grammar and that the time spent creating and playing the games was valuable. Rowe, Shores, Mott, and Lester (2011) used *Crystal Island* with middle grades students in North Carolina ($n=137$) addressing the game's microbiology content. They found participants post-assessment scores improved significantly ($p<0.001$) and a strong relationship existed

($p<0.01$) between post-assessment score and situational interest. The authors noted that when prior knowledge was accounted for, engagement and situational interest may be predictors of post-assessment performance ($p<0.01$) because of the engaging environment and narrative of *Crystal Island*.

Games have also demonstrated success in enhancing perception and self-awareness. Lichtenwalter and Baker (2010) modified *Jenga* to teach structural oppression by adding rules such as the use of only one hand, a time limit, or limiting the players by their attire. Additionally, frustration was increased for certain groups by allowing student "judges" to make unfair and biased rulings. Students were not only able to understand their own frustrations, but were also able to apply the same ideas to structural and institutional oppression, noting the challenges that must be overcome by some but not by others. However, no long term change was provided. Yang, Chien, and Liu (2012) used a mixed methods approach to teach energy conservation to graduate students in Taiwan ($n=23$). Using *ECOPET*, students had to balance maintaining the happiness of their pet while adjusting electronic devices to minimize energy consumption. Participants demonstrated a significant increase in self-awareness with regard to energy consumption ($p=0.013$). Further investigation into the participants' self-awareness revealed 100% of the participants reported an increased willingness to conserve energy, 90% reported increased knowledge of energy consumption, and 95% reported that the game influenced the way they use energy.

While games have demonstrated a variety of positive influences on learning, games also may support engagement as well as accommodate a variety of learner needs. Lin et al. (2013) conducted an experiment using a modified version of *Monopoly* to help with remediation in mathematics. Sixth grade students (n=62) learning mathematics regarding circles were divided into a control group, which answered questions on a computer and received remediation through videos, while the treatment group played the game that included similar questions with remediation through the same videos. While both groups in the experiment by Lin et al. demonstrated significant gains in the post-assessment (p<0.001), the treatment group revealed a greater gain on the post-assessment (mean increase of 3.6 versus 13.56; p<0.05).

Marino et al. (2014) used a longitudinal mixed-methods approach to collect data from 341 students in 5th and 7th grades in the United States, with 57 identified as having a learning disability. However, they found no significant difference in post-assessment scores (p=0.70) between students with and without learning disabilities when games were used in instruction. Additionally, Marino et al. noted their quantitative data did not reveal significant differences in groups receiving game-based instruction aligned to the principles of UDL, though students self-reported an increased understanding of the content. However, the authors note that this discrepancy may be due to only allotting one class period per topic for game playing.

Ke and Abras (2013) used three games in their case study, *Lure of the Labyrinth, Ker-Splash,* and *Lemonade Stand*, with a group of students considered academically disadvantaged (*n*=9), including students with learning disabilities, physical disabilities, and language barriers. They identified game elements that supported student learning and engagement during the 3-week, 15 hour study including rich narratives, engaging environments, immediate feedback, humor, and reward systems. On the other hand, some game elements were noted as distracting including too many visual elements, limited intuitiveness in the game design, lengthy directions or directions not written at an appropriate level for understanding, and perceived levels of unfairness. Furthermore, the researchers noted that two of the games allowed students to disengage from the mathematics by allowing for guessing and trial and error approaches. While games may improve academic performance, they may also provide support for all students if appropriate types and amounts of scaffolding are included.

While factors such as attention to learner emotional needs should be considered to meet the principles of UDL and accountable game design, even games not designed for learning may result in learning gains if appropriate metacognitive strategies are employed by the learner (Kim et al., 2009). For example, in their study, Kim et al. investigated three metacognitive strategies and their relationship to achievement and problem solving ability (*n*=132): self-recording involves the learner writing plans and processes their own actions with the intent to improve, modeling involves learners watching others and developing their own strategies, and thinking aloud involves the teacher modeling the thinking process in problem solving out loud. As a result, the strategies of thinking aloud ($p<0.001$) correlated to social problem solving ability. Additionally, self-recording and modeling related to in-game achievement and learning, while thinking aloud and social problem solving (each at $p<0.001$) demonstrated an impact on academic achievement. Likewise, employment of a variety of learning strategies supports a variety of learner needs (CAST, 2011; Charoenying, 2010; Rose & Strangman, 2007) thus may reduce learning barriers. Correspondingly, Kim et al. (2009) noted

> learning strategies and gaming strategies adopted to implement problem solving strategies in game-based learning may be the primary factor behind the high achievements in both learning and gaming. This implies that higher scores in learning and gaming require better problem solving abilities, which require, in turn, well-chosen strategies for both learning and gaming. (p. 801)

Thus, including metacognitive strategies with game-based learning may support learner needs even when the game environment does not include adequate learner support; therefore, all games have potential benefit to learning.

Given that game-based learning offers many educational benefits, the concept of game-based learning is not the only component to learning in game-based HIVEs. For example, game-based HIVEs are computer-based, meaning understanding digital game-based environments includes the overarching idea of computer-based learning. Support for learner needs, as well as advantages of game-based learning, demonstrate the importance of computer technologies to education. What is more, the prevalence of computer and Internet technology in US classrooms (National Center for Educational Statistics, 2013) allows for easy access to digital games making them both important and accessible to the 21st Century US classroom. As a consequence of being a subset of game-based learning, digital game-based learning inherits some of the advantages of game-based learning while focuses the learning environment to the digital realm.

Computer-Based Learning

The broad field of computer based learning has the potential to change the classroom culture (Cannon-Bowers et al., 2011; Chatham, 2011; Clark & Ernst, 2009; Games & Squire, 2011) demonstrating an increase in learner motivation, attention to task, learning, and employment of cognitive strategies. While digital technologies can provide opportunities by reducing barriers, such as physical issues and learning disabilities, Rose and Strangman (2007) and the CAST (2013) noted three critical features to help maximize access: flexible representation, flexible strategic support, and flexible means of engagement.

First, flexible representation implies movement beyond one form of display. Examples supporting flexible representation include multimedia elements; customizable adjustment to font size, resolution, support, and visual layout; multiple representations of concepts; and embedded support such as hyperlinked items. What is more, multiple representations may increase access and may allow the learner to create connections between ideas (Rose & Strangman, 2007). For instance, in remediation settings, alternative methods of presentation offer more opportunities for content access and engagement. Next, flexible strategic support can be supported by technology through choices to access to external information via hyperlinks and the ability to represent knowledge in a variety of formats. Additionally, in-game help and immediate feedback support this model. Finally, flexible means of engagement allow all students to receive challenging work that is not frustrating (Rose & Strangman, 2007; Vygotsky, 2004). In conclusion, Rose and Strangman (2007) noted that technology can add factors including “choice in appearance, level of support, type of support, method of response, content, speed, and distractors” (p. 388), influencing the learner's emotional connection to the digital environment.

Though not always a component of computer-based learning, the prevalence of Internet access in US classrooms (National Center for Educational Statistics, 2013) adds the potential access to the advantages of online learning to computer-based learning. In addition to the benefits of computer based learning, online learning has several additional advantages over traditional face-to-face learning environments, one of the most important being increased opportunities and access to learning (Berk, 2010; Buckenmeyer, 2010; Cannon-Bowers et al., 2011; Ke & Abras, 2013). Moreover, Anderson's (2008) idea of the "semantic web", online applications that search, aggregate, and create meaning of vast amounts of information, is an additional advantage. Furthermore, Ally (2008) also discussed the idea of learning objects: reusable digital activities or assignments designed to teach a concept. Subsequently, Ally (2008) and Anderson (2008) both indicated the importance of highlighting additional strengths of online education, such as the ease of updating digital content, instead of merely providing equity. Therefore, by making effective use of the benefits of online education, including taking advantage of global diversity, communication, and collaborative interaction (Siemens, 2007), educators may provide opportunities for deepened engagement and flow experiences (Smyslova & Voiskounsky, 2009). Potentially, computer-based learning may further the fundamental goal of meeting the needs of the learner. Learning can be achieved in the method best for each student (Ally, 2008) in an environment most applicable to the activity (Anderson, 2008). A final narrowing of game-based learning combines the premises and advantages of game-based learning and computer-based learning into digital game-based learning.

Digital Game-Based Learning

A new category of educational gaming entered with the age of the computer. Digital game-based learning incorporates the benefits of game-based learning and computer-based learning (Games & Squire, 2011; Kim et al., 2009; R. Smith, 2010). Equally important, digital games vary from simple text-based games with limited interaction to highly complex, persistent virtual worlds. Therefore, digital games may be categorized by environment, method of interaction, number of players, player visual perspective, genre, goals type, or platform (Games & Squire, 2011; Richter & Livingstone, 2011; Rutter & Boyce, 2006).

In 2006, Rutter and Boyce noted the lack of research into digital game-based learning; since then, the field of research has expanded greatly (Games & Squire, 2011; Richards et al., 2013; Tobias et al., 2011). One reason supporting this expansion is that digital games, simulations, and HIVE's have expanded the teaching and learning capabilities of traditional games to include complex situations that could not be replicated in a traditional classroom (Barnett & Archambault, 2010; Chatham, 2011; Ratwani, et al., 2010; Richter & Livingstone, 2011). Moreover, digital games are often learned through feedback, trial and error, and goal seeking behavior allowing the user to persist longer than in a traditional environment (Barnett & Archambault, 2010; Richter & Livingstone, 2011). As a result, the reduced cost of risk taking behavior, and allowing for experimentation and hypothesis testing encourages learner persistence (Barnett & Archambault, 2010; Ratwani et al., 2010). Therefore, employment of these strategies reduces inhibition and supports learning student-centered investigations.

Unfortunately, it is often too costly to create new educational games (Bateman & Nacke, 2010; Chatham, 2011), and games made specifically for educational purposes struggle to compete with commercially produced games in terms of engagement (Kim et al., 2009). Subsequently, this limits the educational use of digital gaming to pre-existing games repurposed to have an educational slant or the few quality games built with an educational purpose (Cannon-Bowers et al., 2011). In order to use commercial or off-the-shelf games, teachers must employ specific learning strategies to turn the game into one with instructional value (Kim et al., 2009). While games designed with an entertainment focus may appeal to learners, these types of games are challenging for teachers to employ for instructional use (2009). Though digital game-based learning can provide effective learning experiences, the environments of these games can vary greatly, impacting learning.

Environments of Digital Games

Many categories of digital games exist, stemming from differing environments. While the game environment can vary dramatically, including differences in visual perspective, complexity of player controls, player interface, levels of interaction with the environment, and interaction with other player and non-player characters, the environment is critical because it can influence learning. Barnett and Archambault (2010) noted an important difference inherent to the environment: learning with technology requires external intervention or interaction, while learning in technology requires the environment to be integral to the learning objectives. Moreover, environmental differences in digital games can impact engagement (Charoenying, 2010; Marino et al., 2014).

In particular, environmental design characteristics contribute to the overall experience. For example, Tüzün et al. (2008) found participants in their study “were disappointed after discovering that many of the virtual places and objects were not functional...Similarly, they criticized the game for offering vehicles that were not able to move” (p. 7). Therefore, elements that incorrectly convey significance remove the learner from the learning experience as they spend time exploring unimportant objects or zones, suggesting that in-game elements must serve a purpose. Likewise, Ke and Abras (2013) noted students in their study became distracted by food elements within the game environment, turning their attention towards lunch. In-game elements that relate to real-world events may also distract the learner from the learning experience, though Ke and Abras noted that these elements also foster immersion.

Highly interactive virtual environments. Aligned with the need for focus when discussing learning in digital environments, HIVEs further narrow the focus of digital games by environment. HIVEs allow players to interact with their environment and other characters (Aldrich, 2009). Furthermore, interaction with the virtual world fosters engagement in the environment. Specifically, in HIVEs, users may move freely in a three-dimensional open-world environment and interact with a variety of in-game elements (Aldrich, 2009; Richter & Livingstone, 2011). Additionally, game-based HIVEs have demonstrated success in military training, resulting in increases in task performance and unit cohesion (Ratwani et al., 2010; R. Smith, 2010). Equally important, HIVEs have demonstrated greater academic gains than traditional learning environments (Chatham, 2011; Richter & Livingstone, 2011; Vogel et al., 2006), with the two of the most researched areas of massively multiplayer online role-playing games (MMORPGs), such as *World of Warcraft*, and open world virtual environments, such as *SecondLife*.

For example, in their meta-analysis of 32 studies looking at cognitive gains from a variety of digital game-based learning research, Vogel et al. (2006) found the virtual world environment of HIVEs demonstrated significant cognitive gains over traditional learning environments and noted that other environments of digital games may produce less significant results. Moreover, the significant gains produced by increasing learner control in the game environment forms the basis of their argument, though not supported conclusively by their data. Although the sample of research studies used in their meta-analysis did not include a large enough pool of research comparing academic gains in HIVEs versus other digital game environments, they found that digital games with reduced learner control through automatic or no navigation may be less effective than traditional classroom teaching methods. While the study by Vogel et al. did not definitively place HIVEs ahead of other game environments, their conclusion of the importance of learner control reflects the conceptual premises of design for all learners. Without reservation, Csikszentmihalyi (2000) noted that learner control facilitates engagement. Therefore, HIVEs are an important focus because of the environment, relationships, autonomy, and choice, all significant to task engagement.

In addition, HIVEs may solve an issue noted by Childress and Braswell (2006) regarding online education: the difficulty in building a sense of community to foster authentic discussions. Whereas online education typically includes substantial amounts of asynchronous communication potentially limiting discussion, virtual environments may support an increased sense of community and "provide an additional level of personality that is missing from the typical chatroom environment" (2006, p. 188). Furthermore, HIVEs provide important opportunities to education, including travel to places not accessible to students in the physical world. Additionally, the game environment has shown a relationship to gaming the system behavior (Baker et al., 2008). HIVEs can provide an engaging environment, perhaps reducing the desire to engage in negative behaviors. As a result of their potential, MMORPGs and simulations are the focus of much of the literature on game-based HIVEs.

Massively multiplayer online role-playing games. MMORPGs evolved out of a form of text-based role-playing games called a MUD, or a multi-user dungeon, where players engaged in interactive virtual realities by typing text commands (Childress & Braswell, 2006). MUDs first appeared in the 1970's and are considered the first digital, collaborative gaming activities where participants work together to complete in-game tasks. Incidentally, early MMORPGs, such as Ultima Online and Everquest, included characteristics of early text-based games. Surprisingly, according to Curry (2010) almost 30 million players worldwide spent, on average, 22 hours a week playing MMORPGs in 2006. Correspondingly, researchers suggest the steady increase in participation comes from game factors such as immersion, socialization, and positive feelings gained from achievements (Dauriat et al., 2011; Konert et al., 2013; Richter & Livingstone, 2011; Yee, 2005). With this in mind, these online environments immerse the player in a pervasive world.

MMORPGs involve roleplaying, real time communication, interaction with non-player characters, game progression by the completion of tasks, the potential for voice communication, and 3-D customizable graphical avatars that facilitate social interaction. In addition, proponents note that MMORPGs employ a model of experiential learning in an online environment and often involve complex situations requiring collaboration to complete assigned tasks (Barnett & Archambault, 2010; Childress & Braswell, 2006;

Curry, 2010; Kim et al., 2009; Suh, Kim, & Kim, 2010; Zhong, 2011). In general, MMORPGs allow for an increased sense of community over text-based environments (Childress & Braswell, 2006) stemming from engagement factors of MMORPGs including 3-D virtual worlds, personalizable avatars, and interaction with the environment and other players (Barnett & Archambault, 2010; Childress & Braswell, 2006; Curry, 2010; Richter & Livingstone, 2011).

A major component of MMORPGs is the interaction between players, which takes place in the form of language (Suh et al., 2010). In fact, Suh et al. (2010) proposed that the number of players interacting online at any given time may be the most significant quality of MMORPGs, which promotes experiential learning. Similarly, Curry (2010), Kim et al., (2009), and Richter and Livingstone (2011) touted the benefits inherent to the environment MMORPGs as they are persistent worlds where participants must interact and collaborate engaging in higher levels of cognition. To emphasize this benefit, the study by Suh et al. (2010) demonstrated an improvement in learning English when learning was experienced in the MMORPG environment. In their study of 4th and 5th grade students in South Korea (n=302), the treatment group, which learned and practiced English within the MMORPG environment of *Nori School* twice a week for two months, significantly outperformed the control group (p<0.01) in areas of listening, reading, and writing. Suh et al. noted factors such as prior knowledge and motivation demonstrated a significant influence on learning (p<0.01), though these are factors that may be beyond the control of the educator. However, Suh et al. noted that technology issues, including network speed, influenced performance ($p<0.01$), though other technology factors, including computer skill ($p=0.67$), game skill ($p=0.63$), computer capacity ($p=0.46$), and computer accessibility ($p=0.46$) were not significant.

Another illustration is the meta-analysis by Peterson (2010) that also supported the use of MMORPGs in English language learning. Peterson argued that language learning in the MMORPG environment immerses the learner in the environment, provides contextual challenge, and requires complex cognitive skills. Peterson's analysis of studies using MMORPGs as a method of computer assisted language learning identified an increase in socialization because of inherent development of interpersonal relationships within the game environment as well as the limited amounts of research in this area. Furthermore, Zhong (2011) defended this by noting the inherent social factor involved in MMORPGs as "collective MMORPG play involves collaborating with each other to fulfill joint tasks, giving a hand to other players when they are in need of help, joining virtual communities to accomplish collective goals, etc." (p. 2352). Zhong investigated the relationship between online collective play and offline social capital for Chinese players of MMORPGs ($n=232$), though did not find a significant causal relationship between the two. However, Zhong found a significant positive relationship ($p<0.01$) between online collective play and offline civic engagement. Zhong attributed this to social collaboration and the sense of group membership and community within the game.

Educational game-based HIVES, such as America's Army, DARWARS Ambush!, Full Spectrum Warrior, Madison 2200, Quest Atlantis, Littoral Combat Ship Readiness Control Officer, Re-Mission, River City, Tactical Iraqi, The Radix Endeavor, and Virtual Battle Space 2 capitalize on the immersion and collaboration benefits of MMORPGs (Alion Science and Technology Corporation, 2013; Barnett & Archambault, 2010; Chatham, 2011; Games & Squire, 2011; Navy Air Warfare Center, 2013; Ratwani et al., 2010; Richter & Livingstone, 2011; Scheller Teacher Education Program, 2014; Shilling, Zyda, & Wardynski, 2002; Tate, Haritatos, & Cole, 2009). For instance, the U.S. Navy uses Littoral Combat Ship Readiness Control Officer, a game-based HIVE, to orient Naval trainees to shipboard controls, maintenance procedures, and ship spaces (Navy Air Warfare Center, 2013). In addition, the Navy's Damage Control Trainer, another game-based HIVE, demonstrated a 50 to 80 percent reduction in errors during real-life exercises (Alion Science and Technology Corporation, 2013). Moreover, factors influencing immersion within a game-based HIVE demonstrate relationships to memory and retention while highlighting the importance of the environment engaging emotions (Shilling et al., 2002), a characteristic of the environment of quality game-based HIVEs.

Aside from environmental factors, Curry (2010) concluded that MMORPG environments have low barriers to participation; allow for increased communication; facilitate the creation of informal mentorships and bonding formed by semi-permanent in-game groups; provide opportunities for collaborative problem solving; produce an exceptional level of engagement; and support the importance of participatory cultures in learning experiences. Accordingly, Richter and Livingstone (2011) supported Curry's argument by noting characteristics of virtual worlds including high level of interaction, contextualization through visualization, promotion of exploratory play, and fostering a sense of community.

Notably, these factors are so critical to learning that Curry (2010) even suggested incorporating characteristics of the MMORPG environments in traditional face-to-face classrooms. First, Curry noted a "guild" idea can impart a collaborative experience that creates a sense of social obligation. Second, achievements and accomplishments drive players forward. In particular, systems of achievement such as badges can be replicated to encourage recognition of group effort and success in the classroom (2010). Finally, active classroom environments involving challenging learning replicates the high cognitive engagement required of MMORPGs. Important to realize, the social experiences within MMORPGs help students develop collaboration and pro-social skills both in and out of the classroom. However, it is important to note that Curry's research is based on theory regarding participatory cultures and does not include support from independent research.

While the significance of real-world problems and social interaction are beneficial features of MMORPGs, Barnett and Archambault (2010) remind us of one potential pitfall. Namely, effective play in MMORPGs often comes from game knowledge, a significant contributor to success. In other words, MMORPGs often require customization and optimization due to specialization; thus, game knowledge can be a barrier, as messing up resource allocation can make the game unplayable, resulting in wasted time with regard to instruction.

Trust is a significant factor that causes breakdowns, especially in collaborative environments. Trust, as noted by Hurst and Thomas (2008), comes in multiple levels, including contract, commitment, and character while facilitating community building. Indeed, as social beings, we need a sense of community in order to facilitate collaborative interactions (Anderson, 2008; Hurst & Thomas, 2008; Palloff & Pratt, 2007). Furthermore, Palloff and Pratt stated "online communities are essentially human communities" (2007, Chapter 3, Section 9, para. 2). Therefore, trust fosters the sense of community, and the sense of community contributes to trust at the same time (Hurst & Thomas, 2008; Palloff & Pratt, 2007). While gained efficiency may transfer to real-world applications such as savings and task completion through the relationship to application of in-game concepts to real-world situations, MMORPGs can present an inherent barrier where learners must be provided the appropriate support (Richter & Livingstone, 2011; Tobias et al., 2011). As a result, trust is critical to supporting the sense of community, collaboration, and self-efficacy.

Although the multiplayer aspect may or may not be relevant, players demonstrate significant preference for learning in virtual environments and digital games (Vogel et al., 2006). Additionally, HIVEs can create the same stimulus response similar to a real-world environment (Barnett & Archambault, 2010; Ratwani et al., 2010; Richter & Livingstone, 2011). Furthermore, exposure to ideas within gaming environments may influence external behavior and collaborative engagement in real-world situations may impact student learning (Aldrich, 2009; Barnett & Archambault, 2010; Ratwani et al., 2010; Richter & Livingstone, 2011; R. Smith, 2010; Vogel et al., 2006). Though an area of emerging research, Tobias et al. (2011) noted limitations to generalizability in the literature, including methodological problems such as small sample sizes and inattention to confounding factors supporting the need for continued research into game-based learning. As demonstrated, game-based HIVEs may support learning needs, emotional states, motivation, and perception, which contribute to engagement and promotion of flow-states, yet learner traits and behaviors also influence individual performance.

Traits of the Learner

Indeed, using game-based learning has demonstrated positive influences on learning as well as increased engagement potentially stimulating flow-states in the learner. For example, Chiang, Lin, Cheng, and Liu (2011) noted game features that support flow-states include "rich and immediate feedback to player actions, enjoyment, playfulness, and the ability to induce high levels of player concentration" (p. 107). In addition, perceived challenge and skill influenced flow-states (Inal & Cagiltay, 2007; Moneta & Csikszentmihalyi, 1996; Shin, 2006) with players of non-violent games reporting stronger flow experiences than players of violent games (Chiang et al. 2011). Because of these relationships to flow-states, educational games must be balanced to achieve desired engagement. In other words, games that are too easy over stimulate relaxation and cause boredom; games that are too challenging spur negative emotional states causing the user to revert to rigid strategies and rely less on metacognition (Artino, 2008; Kayaoğlu, 2013). Similar to the Goldilocks Principle from many hard sciences, the appropriateness of the challenge must be "just right" to foster engagement and encourage the state of flow. However, it is not easy to identify this balance in education as this range is dependent on the learner. Several learner traits are noteworthy including general traits of the generation, gender differences, attitudes and beliefs, emotional state, and personality.

The Net Generation

Notably, today's traditional learner differs from that of 30 years ago, though there is conflict in defining the population. Berk (2010), who compiled data from 10 large-scale studies providing useful general characteristics of this population, determined approximately 90 million learners

> carry an arsenal of electronic devices with them. Those are key ingredients in their world. Their use of the technology focuses on social networking, music, videos, TV programs, and games. They live in a world of media overstimulation and absolutely love it. (p. 3)

Accordingly, a majority of today's learners own a computer and/or a cell phone, use the Internet for research, and begin searching for anything with a search engine such as Google (Berk, 2010). Significantly, more than half of this group also used instant messaging and chat boards, read news online, created online media, used social networking sites such as Facebook, and possessed an MP3 player. Therefore, the ubiquitous nature of technology in the lives of these learners highlights the need for teachers to attend to the needs of this cultural group.

While individual needs are important to consider, general characteristics of learners are worth attention to maximize access to the content. To clarify, Berk noted ten common characteristics of those born in since 1982 that indicate that technology, computer-based learning, and game-based learning can support both group and individual learner needs. For instance, reliance on search engines provides immediate access to information, allowing for information on demand. In general, interactive multimedia and tools designed for content creation supported varied preferred styles of learning and presentation. As a result, engagement and active learning were critical to these learners (2010), however was not limited to this generation. Often, computer based learning involves engaging in multiple tasks at the same time, such as reading, watching a video, taking notes, and/or writing a paper. Consequently, the current state of technology allows learners to maximize this experience by providing opportunities to juggle multiple tasks.

By and large, computer-based learning supports preferences for visual and auditory as opposed to text only learning. In fact, digital environments that include rich graphics, icons, and photographs grab the attention of these users allowing learners to make the information meaningful in the context of their lives (Berk, 2010). Furthermore, emotional openness, stemming from experiences with social networking, means these students prefer to work collaboratively and appreciate the variety of input provided by peers. Finally, learners gain comfort and support from the vast array of editing tools in word processors allowing them to express themselves while lowering barriers such as spelling and mechanics.

What is more, Berk (2010) noted that combined with an affinity for typing over writing for notes, papers, and homework, those born after 1982 not only have preferences for components of computer-based learning but also are supported by tools for expression. Subsequently, America's youth and young adults grew up in a world with the Internet and are generally already technology savvy. In summary, they are comfortable with typical Internet uses such as search engines, interactive multimedia, content creation, multitasking in technology rich environments, and prefer collaborative work. Again, these characteristics may not only apply to those born after 1982, though Berk’s definition provides some insight into today’s traditional learner.

Berk’s (2010) population of digital natives, those born into a world with the Internet, represents a large number of people in the United States (U.S. Census Bureau, 2011). With over one-third of the population of the United States of America under the age of 24, the population of learners under the age of 30 is well over 100 million (2011). This group is also important as many have already ventured into online learning experiences. Regarding this, the Pew Research Center notes that while about one-fourth of college graduates have taken an online course and 46% of their respondents graduating since 2001 having taken an online course, college presidents predict at least a 35% growth by 2021 (Taylor, Parker, Lenhart, & Moore, 2011).

Gender

Some of the most reported quantitative measures include gender differences, but the research is not definitive. For instance, Bonanno and Kommers (2008) found that females had a less favorable attitude towards gaming and were skeptical of their educational value; males had favorable attitudes towards gaming in all dimensions. Moreover, males were less apprehensive and more confident with regard to gaming and gaming devices. Additionally, both genders perceived gaming as an intelligent and socially acceptable activity. Similarly, both agreed that gaming was an interesting, imaginative, and an efficient way to learn, although the two genders perceived games differently. Specifically, males saw games as something to be mastered while females saw games as a venue for production of work. Supporting the idea of inherent gender differences, Park et al. (2011) indicated that gender differences directly impact motivation when it comes to playing video games. Finally, from their study, Chen et al. (2010) concluded "respondents' attitudes about online gaming are not affected by age or by hours spent online daily, but by gender and prior game-playing experiences" (p. 82).

Attending to gender-specific needs supports the premises of accountable game design and UDL. While males may be inherently more comfortable with game-based learning, females have needs that can be addressed either within the game environment or the classroom (Bonanno & Kommers, 2008). Vogel et al. (2006) found females to show significant gains in learning and favored interactive simulations and game-based learning. Furthermore, Chen et al. (2010) supported this idea and the potential significance of digital game-based learning through their advice: "universities should consider how to encourage the acceptance of digital game-based learning among female students" (p. 83).

The literature provides suggestions to account for gender differences. In general, Bonanno and Kommers (2008) found that females need more direct assistance with navigation to help them feel comfortable and acclimate to the virtual environment. Additionally, females have a greater need to know about mistakes that can be made and understand what can be changed later. Furthermore, females may need additional support to build confidence with game mechanics. Bonanno and Kommers suggested customizable tutors and sequenced steps to help female players with in-game processes. Finally, Baker et al. (2008) suggested choice in problem selection to address gender differences. Although gender differences may or may not be significant, these needs must still be attended to when considering UDL and accountable game design premises.

Attitudes and Beliefs

Along with general characteristics of the digitally connected learner and gender, the literature also explores learner attitudes and beliefs, which have demonstrated an impact on learning (Artino, 2008; Cannon-Bowers et al., 2011; Childress & Braswell, 2006). First, attitudinal shifts can be seen in the literature addressing student perceptions of computer games and computer game-based learning. In their 2009 survey, Clark and Ernst found a majority of the respondents to their survey (77%) saw gaming as a form of entertainment with only 42% seeing games as a venue for learning. More recently, games are gaining ground in education and have demonstrated an increase in positive perception of educational value (Berk. 2010; Cannon-Bowers et al., 2011; Richards et al., 2013).

Additionally, the inclusion of digital learning environments may impact student attitudes positively. For example, Childress and Braswell (2006) added SecondLife to an online graduate level course to provide a collaborative environment, and found the HIVE added “a visual feedback element that serves to enhance the interaction between the participants” (p. 191). Furthermore, the visual environment and the enhanced collaborative experience improved perceptions of the course and increased class engagement through the addition of participatory elements.

On the other hand, several studies also noted negative perceptions and attitudes. In their study, Beylefeld and Struwig (2007) identified two negative responses: learning cannot happen from play, and play was a waste of time. Furthermore, Chen et al. (2010) found half of their sample of 30 young adults between the ages of 18 and 30 held negative perceptions of gaming noting “most of the students are philosophically against online gaming" (p. 82). However, this finding may have resulted from a cultural bias as the sample came from a private university in Taiwan and the small sample size (*n*=23) use in the final analysis. Although the authors noted that online gaming cannot replace a textbook, they acknowledge the importance of student satisfaction and attendance to a broad range of learners.

Nevertheless, negative perceptions extend beyond mere satisfaction, and the underlying causes may stem from an amalgamation of factors. For instance, perceived quality of instruction and self-efficacy may influence negative perceptions, yet the learner's ability to self-regulate often influences these factors (Artino, 2008). In addition, Kim et al. (2009) noted a common negative perception and misconception: the more entertaining a game is the less effective it is as a learning tool.

> In fact, the quintessential combination of entertainment and learning seems almost impossible to achieve. This ideal scenario comes from a natural mixture of both learning and game content. However, it is not easy to determine the intrinsic balance where both learning and gaming happen simultaneously. This has continued to be a contentious issue in the development of educational computer games. (Kim et al., 2009, p. 801)

Despite these negative perceptions, the benefits may outweigh the potential costs associated with negative perceptions.

The inclusion of educational gaming opens the door to another related area with counterproductive outcomes: gaming the system behavior. Gaming the system behavior is a conscious, subversive way students disengage from the work by using in-game features to get around solving the problems (Baker et al., 2008). Examples of typical gaming the system behaviors include repeatedly selecting the same answer until the system automatically intervenes and provides support or by systematically selecting each answer choice until the correct answer is found. Surprisingly, Baker et al. found that between 10-40% of students engage in gaming the system behavior at some point when working with game-based learning.

Following this further, Baker et al. (2008) involved a small sample of middle grades teachers (n=18) and a large sample of middle grades students (n=533). As a result, they found gaming the system behavior related to negative attitudes towards mathematics and the environment. Consequently, these studies show the need to support learner attitudes and the appropriate implementation of game-based learning technology, as game-based learning may not meet the needs of all learners, specifically those with negative attitudes towards gaming. In brief, negative perceptions and engagement in negative behaviors, such as gaming the system behaviors, demonstrates differences in participants of digital game-based learning.

Aside from those who choose to engage in digital game playing, a group exists who elect not to participate. Exploring this further, Chen et al. (2010) determined three classifications of why people choose not to engage in digital game play. First, "New Media Resisters" identified digital games to be a waste of time, reduced the time availability for studying, and had a negative effect on academics. Meanwhile, this group identified the social aspect as the only benefit to online gaming. Next, "Pajamasocializers" believed “the visualizations, 3D graphic design, and sound effects of motion pictures in online gaming are nice; the design of characters is cute; the design of the scenes is vivid and sophisticated” (2010, p. 78-80). Additionally, they also perceived that online gaming was common at the university, yet still ranked the statement “Playing online games is a waste of time" highly. Furthermore, this group disagreed with all other negative statements and represented half the sample. Finally, "Game Value Resisters" identified the potential of gaming through their recognition of the potential positive benefits and effects. However, they still identified gaming to be a waste of time and money.

Despite digital natives being comfortable in technology rich environments, being a member of this population is not enough to predict attitudes and beliefs. For instance, Anderson (2008) and Artino (2008) found that beliefs, such as task value, self-efficacy, and perception of the quality of instruction are the most significant predictors of positive perceptions of digital learning. Additionally, members of this population may still need support in game-based HIVEs. For example, students may develop anxiety if not accustom to learning in virtual environments (Palloff & Pratt, 2007). While the factors relating to comfort in technology rich environments are complex, complexity is no excuse for deepening understanding in this area (Anderson, 2008).

The Role of Affect

Design to support all learners through the principles of differentiated instruction, UDL, and accountable game design includes the necessity to attend to learner emotional states. Emotions are important as they may predict academic achievement (Pekrun et al., 2002; Tüzün et al., 2008), relate to motivation (Games & Squire, 2011), and influence perceptions of educational environments (Artino, 2008; Baker et al., 2008). Overall, learners in game-based environments almost always report the fun or enjoyment factor (Tüzün et al., 2008).

To illustrate the importance of emotions to learning, Pekrun et al. (2002) investigated the connection between emotions and academic performance in their four-part study. Notably, anxiety was often targeted as the significant negative contributor to academic achievement. Anxiety stems from feelings of shame and hopelessness, and as a coping mechanism becomes anger towards the learning experience. Additionally, anger interferes with metacognitive strategies like self-regulation, highlighting the need to attend to emotional states as suggested by UDL principles (CAST, 2011). In contrast, anger stemmed from task frustration and the intrinsic desire to outperform others (Pekrun et al., 2002). In other words, as negative emotions swell within the learner, they impact motivation and achievement negatively; positive emotions, such as enjoyment, hope, and pride, impact educational factors including achievement, self-regulation, and task engagement positively.

Equally important, many studies investigate the impact of anxiety on learning, self-regulation, and task engagement, though most ignore other negatively compounding emotions connected to the learning experience (Pekrun et al., 2002). In addition to anxiety, those who are uncomfortable in their learning environment can also experience boredom, reduced course satisfaction, and reduced self-regulation (2002). Furthermore, Pekrun et al. identified that ability related directly to boredom: students who perceived themselves as more capable experienced boredom during low levels of instruction.

Likewise, those who cannot keep up with the material also expressed boredom. Additionally, those who struggle with learning in online environments disengage. Therefore, attending to anxiety and boredom become important for learners to have a positive learning experience and authentic engagement. Moreover, emotional states have also demonstrated relationships to engagement (Shilling et al., 2002), a contributing factor to the flow-state.

Though many studies exist focusing on one emotion as a trigger, Pekrun et al. (2002) noted the importance of attending to multiple factors as the interrelationships are important and often missed when understanding of psychological constructs, such as emotion, comes from a single perspective. In the same manner, Tüzün et al. (2008) supported this idea noting that understanding the educational impact of emotions means attending to the whole educational context. However, the single construct of anxiety affects learners both positively and negatively (Pekrun et al., 2002). For example, anxiety impacts both intrinsic and extrinsic motivation in an unbalanced fashion (2002). Additionally, Pekrun et al. found boredom and the feeling of hopelessness prove to have the highest negative correlation to academic performance when investigating multiple emotional factors at once.

In general, emotional states have both a positive and negative impact on motivation, and research focusing on one emotion typically investigates one side of educational impact, producing a one-sided view (Bonanno & Kommers, 2008; Pekrun et al., 2002). In particular, Pekrun et al. (2002) noted that positive emotions, such as relief and relaxation, reduces motivation but makes later learning easier; negative emotions, such as anger, anxiety, and shame, reduce academic motivation yet increase motivation to deal with the situation. Though a dual impact of emotional state on academic performance exists, the benefits of positive emotional states outweigh the negatives (Pekrun et al., 2002). In fact, Pekrun et al. determined that positive emotions trigger flexibility, creativity, self-evaluation, and the use of metacognitive strategies; negative emotions, on the other hand, trigger use of rigid strategies and reliance on algorithm. Furthermore, both relaxation and boredom caused withdrawal yielding lower levels of cognition. Therefore, attending to individual learning and emotional needs, and providing learning experiences that foster engagement promotes happiness and positive perceptions that may alleviate a major educational problem in the United States.

In order to attend to negative learner emotional states, such as anxiety and boredom, Ally (2008), Anderson (2008), Simonson (2000), and Shilling et al. (2002) provided suggestions to create an engaging experience for online learning environments. First, Ally (2008) suggested the critical nature of the importance of real-world scenarios that allowed the learner to contextualize the information. Additionally, Anderson (2008) highlighted the importance of learner centered, knowledge centered, and community centered online learning environments. Furthermore, Simonson (2000) noted the key component to attending to learner needs begins with online learning experiences being equivalent to those experienced in a brick-and-mortar setting. Finally, Shilling et al. (2002) highlighted the importance stimulating appropriate emotional states. Though different, the four noted a level of equity as fundamental to online education, which Simonson (2000) identifies as equivalence theory.

Berk's (2010) research identified additional areas that must be supported in learners. For example, although traditional students tend to be technology savvy, they are not guaranteed to be “net savvy” meaning they may need assistance with locating, evaluating, and using information appropriately. Additionally, while comfortable with general search engines, learners were noted to struggle with those designed for academic research and viewed them as cumbersome. Furthermore, although content creation and active participation were highly valued by this group, these learners still need support with new technologies. Accordingly, the need for active engagement means that teachers must carefully consider experiences with simulations and games in order to prime learners to extend learning experiences beyond the game environment.

By the same token, being emotionally more open than previous generations (Berk, 2010), these learners also need direct emotional support; teachers, schools, and communities must be prepared to support these needs. For instance, factors identified to correlate engagement with technology include the ability to explore without repercussions, sufficient orientation, and perceived support (Buckenmeyer, 2010). Additionally, introductory components providing opportunities to be successful in a non-threatening environment allow for maintaining a student's sense of self and may alleviate anxiety (Palloff & Pratt, 2007; Pekrun et al., 2002). For these reasons, affording learners time to adapt and integrate, appropriate technical assistance, and emotional support all attend to accountable game design and UDL principles (Amory, 2010; CAST, 2011; Charoenying, 2010; Rose & Strangman, 2007). Similarly, attending to personality factors and patterns of gamer behavior support principles of accountable game design and UDL, as well as factors influencing engagement.

In support of the importance of the flow-state, Beylefeld and Struwig (2007) noted the importance of teachers making a conscious effort to foster enjoyment in learning to encourage flow-states. Hence, the significant positive impact on flow experiences demonstrates a benefit of using game-based learning. Pursuing this further, Beylefeld and Struwig used a focus on pleasure, a loss of sense of time, increased risk taking, increased sense of control, and reduced of fear of failure to evaluate change in flow-state. Their findings (n=109) suggested significant growth in 4 of the 5 subscales

- enthusiasm for content grew from 51% to 82%;
- participation in discussion grew from 28% to 83%;
- perception that content is suitable for small-group learning grew from 32% to 99%; and
- enhancement of knowledge grew from 18% to 95%.

The authors also indicated that 93% of their participants noted how easy it was to forget factual information, providing awareness of the ineffectiveness of rote memorization. Their research also supported the necessity of engagement and highlighted the benefits of appropriately developed game-based learning environments. As a result, positive attitudes fostered both motivation and enthusiasm, indicators of flow-states. However, though the fun factor of the game may have influenced the growth, the sample composed of only 3rd year medical students in a medical microbiology course. This factor may have influenced the growth as this sample may be more motivated to learn the content than a more typical college level student.

Baker et al. (2008) suggested emotional states impact how learners interact with the content and environment. In their four-part study, teachers (*n*=18) believed frustration was the number one reason students choose to engage in gaming the system behaviors. Student participants (*n*=533) noted disliking mathematics and frustration with the content to be the most significant reasons for engaging in gaming the system behaviors. Their results highlight the influence of negative feelings on engaging in gaming the system behaviors. Consequently, to garner a positive impact on mood, game-based learning experience must attend to learner frustration and emotion. Additionally, the premises of UDL support balancing problem difficulty in order to provide the appropriate amount of frustration (CAST, 2011). Thus, focusing on feedback provided to learners to develop help systems that attend to learner needs may reduce frustration (Baker et al., 2008). Furthermore, Baker et al. suggested that providing game-based learning in small chunks, by limiting the number of problems or lesson length, supports maximized learning experience through the attendance to learner frustration.

Therefore, learner emotional needs must be supported according to the principles of UDL (CAST, 2011; Rose & Strangman, 2007) and because of their relationship to engagement and flow-states (Csikszentmihalyi, 2000). Accordingly, games can attend to the emotional needs of learners by providing high levels of control (Beylefeld & Struwig, 2007) and interest (Shernoff et al., 2003). Additionally, Beylefeld and Struwig (2007) supported the importance of accommodating for learner anxiety in their study that found game-based learning impacted perceptions and attitudes towards medical microbiology positively. They concluded that game-based learning may alleviate negative emotions when learning new content. Namely, anxiety is triggered when the expectations imply failure (Pekrun et al., 2002); well designed digital games can reduce the sense of failure by automatically scaffolding material based on detected needs or provide on-demand remediation helping the student find success. In essence, emotional states and frustration relate to attitudes towards games and engagement in game playing behavior; they are explored further in the section on traits and behaviors.

From their study regarding attitudes towards educational games, Bonanno and Kommers (2008) stated "enthusiastic gamers show very positive to positive attitude to gaming, moderate gamers show positive attitude, while most non-gamers show neutral or negative attitude towards gaming" (p. 106). In particular, positive attitude gained from game-based learning enabled learners to process information at deeper levels (Beylefeld & Struwig, 2007, p. 933); negative feelings and attitudes impacted learning negatively as students may seek to pass rather than learn, a component of gaming the system behavior (Baker et al., 2008). Moreover, this is an area where game design becomes critical, reinforcing the ideas of the importance of UDL and accountable game design. In the same way, the research by Beylefeld and Struwig (2007) highlighted the need for game design to focus less on winning and more on positive feelings of achievement supporting the necessity of engagement and the principles behind UDL and accountable game design.

To support positive attitudes towards achievement, Baker et al. (2008) suggested giving the students the ability to select problems: "simply by providing an element of choice, even among limited and similar options, may give students just enough control over the environment that they're looking for" (p. 218). In short, game-based choices impact perceived control, thus support the principles of differentiated instruction and flow-theory (Csikszentmihalyi, 2000; Gregory & Chapman, 2007; Heacox, 2002; Shernoff et al., 2003). Furthermore, choices in game-based learning environments also supports learner self-efficacy needs (Pekrun et al., 2002), which relates to an increased usage of metacognitive learning strategies, satisfaction, and academic performance (Artino, 2008).

Personality Factors

The relationships between personality factors and learning are a popular research topic. Furthermore, personality theory is the underlying idea employed by Bartle's player type theory and Yee's motivations. Therefore, personality is not only central to the theoretical framework of this study it is also a significant component of learning. Personality factors have demonstrated many relationships to learning. Ahmed, Campbell, Affair, Balalaika, and Campbell (2010) found a relationship between personality and overall course grade in problem-based learning environments in their 2-year study (*n*=85). Kayaoğlu (2013) found a strong relationship between introversion and metacognitive strategy usage and preference in the participants. Furthermore, Hannon & McNaughton-Cassill (2011) found that personality factors accounted for 21.4% of the variance in SAT performance; however, they noted that the only significant predictor in this case (*n*=253) was test anxiety. Additionally, accounting for personality variations can attend to emotional needs (de Bruin, 2007) addressing premises of both differentiated instruction and UDL. Particularly, as personality factors can also interfere with learning (Hand & Puder, 1968), understanding the relationship between personality and learning becomes important when investigating learning in game-based HIVEs.

Personality factors have demonstrated strong relationships to learning in digital environments and digital games (Park et al., 2011). "Certain personality traits cause people to value certain attributes of gaming that result in the gratification they seek, which further fuels their motivation to play games" (Park et al., 2011, p. 747) therefore influences engagement. Moreover, personality factors, such as desire for socialization, influence motivation to engage in digital gaming (Bonanno & Kommers, 2008; Park et al., 2011). While some personality traits, like extroversion and agreeableness, have demonstrated a significant relationship to successful learning in technology rich environments, the ability to cross-apply findings to struggling students learning mathematics in game-based HIVEs is questionable.

As noted previously, sample characteristics are important as samples may contain underlying characteristics that limit generalizability (Frankfort-Nachmias & Nachmias, 2008). There is a fair amount of research relating learning to personality factors, though may not be generalizable to US remedial mathematics students learning in a game-based HIVE. Additionally, cultural differences represent a significant influence on learning (Chang et al., 2011; Mosalanejad, Alipor, & Zandi, 2010; Omidvar & Tan, 2012; Speece, 2012; Zhou, Lam, & Chan, 2012). Chang et al. (2011) noted a significant difference across three domains in East-West comparisons, making culture a critical component when making cross-cultural comparisons. For example, Park et al. (2011) found personality factors related to engagement in digital gaming, but their sample came from college students in Korea. Furthermore, other differences may also restrict generalizing to US students struggling in mathematics.

In another example, Ahmed et al. (2010) investigated the relationship between patterns of behavior and achievement and found a majority of their sample fell into four out of sixteen possible Myers-Briggs personality types. However, their sample came from fourth year undergraduate software engineering students at a university in The United Arab Emirates where a majority of the participants earned the highest marks. These students already persevered through to the end of a degree requiring some skill in mathematics, representing a very different type of student than one requiring remediation. Additionally, Kayaoğlu (2013) found introverted students used more metacognitive strategies and engaged in self-monitoring behaviors more frequently than extroverted students. However, the sample included 200 students enrolled in an English preparatory program at a Turkish foreign languages school. Participants in this study were enrolled in a foreign language learning program that began with a mandatory year of English; thus, the participants may have a propensity for language learning and extroversion. Additionally, while the 200 participants were selected from a pool of 1,640 students, no information was provided as to how those students were selected. With an unequal number of extroverted and introverted participants, it may be possible that the number of introverted students limited sample selection.

While many personality characteristics are measurable, they are often combined to form archetypes useful to tailoring digital learning (Niesler & Wydmuch, 2009). This allows for the reduction of the number of variations through the use of general groupings. Psychology provides a variety of archetypal systems, such as the Myers-Briggs Type Indicator and The Big Five (Ahmed et al., 2010; Niesler & Wydmuch, 2009). Specific to digital gaming, Bartle's (1996) player types model is often referenced, being one of the forerunners of research into gamer behaviors.

Results from research into learner traits highlight the need to investigate traits and behaviors of learners in game-based learning environments and their relationships to learning. For instance, Artino (2008) demonstrated that perceived task value strongly predicted satisfaction, yet noted feelings of interest and importance also increased satisfaction. These factors contribute to positive attitudes, engagement, and academic performance, all influenced by inherent traits of the learner (2008). Additionally, attitudes and engagement contribute to flow states (Charoenying, 2010; Csikszentmihalyi, 2000), and both differentiated instruction and UDL remind educators to attend to the emotional needs of learners (CAST, 2011; Gregory & Chapman, 2007; Heacox, 2002; Rose & Strangman, 2007). Thus, understanding characteristics of learners in game-based learning environments becomes critical to stimulating task engagement and supporting learner needs.

However, while some characteristics of the digitally connected nature of this population are known (Berk, 2010) and US classrooms have more access to technology than ever (National Center for Educational Statistics, 2013), teachers are using technology less in the classroom (Buckenmeyer, 2010). Many factors contribute to lack of classroom use including comfort, adequate support, and uncertainty of value. Though the reasons have evolved over the years as technology has diffused into society and costs have dwindled, the reasons are still complicated (Buckenmeyer, 2010). Therefore, knowing the traits and behaviors of learners that support development in technology rich environments not only helps educators understand underlying learner traits that contribute to success, but also becomes useful to identify students who may not benefit from learning in game-based HIVEs. Consequently, characteristics of learners may also be specific to the content area, in this case, mathematics.

Factors Influencing Mathematics Achievement

The many suggested factors that influence performance in mathematics makes achievement in mathematics a complex phenomenon. However, the research is not definitive, with some studies demonstrating contradictory results, but the majority of the literature demonstrates relationships between learner traits and environmental characteristics to academic achievement in mathematics. Furthermore, many classroom factors and pedagogical methods have demonstrated statistically significant relationships to academic achievement, specifically compared to when the element is not there (Hattie, 2009). For example, Hattie (2009) reported, from a meta-analysis of meta-analyses, that using simulations and games had an effect of 0.34, less than the baseline of 0.40. Hattie (2009) noted several commonly highlighted factors have greater than 0.40 effect sizes including instructional quality (1.00), home factors (0.67), appropriate challenge (0.52), and teacher professional development (0.46). However, Hattie's (2009) assumption of the 0.40 baseline implies that teachers are constantly questioning their teaching strategies and adjusting them to meet the needs of their students. These teachers are looking for new and innovative ways of educating students, which may not be the norm. While Hattie (2009) presented effect sizes of many classroom innovations in relationship to each other, individual studies have shown further relationships to factors that influence mathematics achievement.

In a two-part study, Shin, Sutherland, Norris, & Soloway (2012) found that games positively influenced learning of mathematics in second grade students (n=91). A control group used a paper-based game while the experimental group played a GameBoy game. After 5 weeks, the control group gained an average of 4% while the digital game group gained an average of 11%. However, after 13 weeks, the control group gained an additional 11% while the digital game group gained 1%, with an effect size of 2.06, indicating a large effect. Unfortunately, while this study showed somewhat equivalent gains between the two groups, there was no group learning in a more traditional method. The effect seen may be a factor of innovation (Hattie, 2009).

Awan, Noureen, and Naz (2011), Esezi Obilor (2012), and Skaalvik and Skaalvik (2011) each noted relationships between mathematics achievement, and mathematics self-efficacy and self-concept. Awan et al. (2011) found a significant ($p<0.01$) positive relationship between mathematics self-concept and achievement in 336 secondary school participants, accounting for 37% of the variance. Esezi Obilor (2012) found a similar result with 300 secondary students with a calculated $t=20.55$, greater than the critical $t=1.960$ at $p<0.05$. Skaalvik and Skaalvik (2011) investigated both middle grades ($n=246$) and high school ($n=484$) students. They found a strong correlation ($r=0.81$) between mathematics self-efficacy for middle grades students, though less ($r=0.65$) at the high school level. Louis and Mistele (2012) investigated data from the 7,377 US participants in the 2007 TIMMS report while Mohammadpour (2012) looked at 4,599 participants from Singapore. While both studies noted home, classroom, and school factors, they also noted the relationship between self-concept to mathematics achievement. However, it is important to note that data from the TIMMS report involves self-reported self-concept. Furthermore, isolation of groups may create natural cultural differences. On the other hand, these results support the need to attend to emotional needs of students.

However, many of these factors are not considered within the scope of this study. For example, previous experiences in mathematics and former learning environments are not explored because of the difficulty in collecting and analyzing the data quantitatively.

Teacher factors are also not considered as they would be difficult to assess from the student participants' perspectives. While mathematics content is a focus of this study, factors influencing achievement, aside from time-on-task, are beyond the scope of this study. However, beyond characteristics of the learning environment and traits of the learner, two factors are worth noting as they are potentially the most significant influencers of mathematics achievement when mathematics remediation occurs in a game-based HIVE.

Literacy

Larwin (2010) demonstrated the critical nature of attending to reading ability when considering mathematics achievement as her study of the Educational Longitudinal Study data demonstrated that 56% of variance in mathematics achievement can be attributed to reading ability. As the HIVE used in this study requires reading contextual problems, reading ability is a critical factor, though the game-based HIVE has an average reading grade-level equivalence of 6th grade (D. Cavitt, personal communication, 17 October 2013). As this is an environmental component of learning in the game-based HIVE used in this study, literacy is an important characteristic to note. Even with an average 6th grade reading level, the game-based HIVE, *The Lost Function*, currently does not provide support for struggling readers, though it is planned for future releases (2013).

Gender

Though gender was noted in the section on learner traits, it is also important to note as a factor influencing mathematics achievement. While the research on gender influences may not be comprehensive regarding impact, attention to gender differences is important as noted in the section on learner traits. As a further illustration, Biber, Tuna, Incikabi, & Yigit (2013) found that pattern recognition, an important skill related to mathematics achievement, was more related to gender than grade level. However, they suspected that this related to attention to detail and rushing to complete the task rather than a true gender difference. Additionally, in their analysis of TIMMS data of 8th grade students, Louis and Mistele (2012) found that girls perform better than boys in algebra, but the reverse was true for other domains and mathematics courses.

Conclusion

Today's traditional learners are not like the learner of 30 years ago, and educators must adjust to accommodate the needs of these digital natives. While digital game-based learning has become more commonplace in education (Richards et al., 2013), it is not necessarily the most appropriate pedagogical tool for all learners. Additionally, the underlying causes of the relationship between learner traits and academic qualities may not be definitive; however, the potential relationships and interrelationships are important as these traits contribute to learning. Consequently, matching the learner to the appropriate learning experience influences engagement and attendance to a learning task. Without a doubt, not only must educators understand learner traits to meet individual needs through pedagogical decisions, game developers must also understand these relationships for appropriate game design. Understanding relationships between learner and learning environment may provide insight into appropriately matching learners to the environment of game-based HIVEs. In order to maximize the potential of specific classroom technologies, research must uncover relationships between specific traits and specific learning environments that influence academic achievement.

The current problem of remediation in mathematics at the college level in the United States demonstrated the need for this study. Accordingly, understanding the importance of play, the significance of engagement to learning, and the need to support all learners provided the lens of this research proposal investigating one potential environment for remediation. Furthermore, the benefits of learning in game-based HIVEs and the market for educational digital games demonstrate the necessity of both educators and developers to pay attention to these learning environments. Therefore, as learners have different traits that may influence their engagement with learning in game-based HIVES, understanding the relationship between patterns of gamer-behaviors and academic achievement may allow for matching learners to their most appropriate learning environment. Of the broad field of researched learner traits, a subset pertinent to gaming behaviors may uncover relationships between gamer-behaviors and academic achievement in game-based HIVEs. However, while the potential benefits of game-based HIVEs are significant, a mismatch between the learner and the learning environment can negate any gains, reducing the game to a 21st Century worksheet.

In this chapter, I provided a conceptual and theoretical framework to define the role of play in learning, to outline the critical nature of engagement to learning, to illustrate the necessity to maximize support for all learners, and to demonstrate that patterns of gamer behaviors may allow for understanding of how learners engage in the digital environment. Next, a review of literature of learning in game-based HIVEs and learner traits provided the foundation for understanding the significance of the digital learning environment and characteristics related to engagement in digital game-based learning. As an example, I discussed MMORPGs in this literature review as a type of HIVE. Additionally, I included commonly researched learner traits related to game-based learning including gender, attitudes, and emotions. Finally, though not a focus of this literature review, I addressed some factors influencing mathematics achievement as these represent potential confounding variables that cannot be mitigated within the parameters of this study.

What is not known is the relationship between gamer behaviors and academic achievement from learning in game-based HIVEs for remedial mathematics students. This literature review provided the foundation for the position that academic achievement from learning in game-based HIVEs may not be uniform across different patterns of gamer behaviors. Consequently, understanding variations in academic achievement and their relationship to gamer traits and behaviors allows for informed pedagogical and design decisions to best match the audience to the learning environment. In final consideration, research into understanding the relationship between learner and learning environment is critical to support all learners and actualize the potential of game-based HIVEs. Therefore, the conceptual framework and theoretical foundation as well as relevant research into the learning environment, traits of the learner, and the content form an understanding of the research gap, its significance, and its timeliness. Chapter 3 provides information on how the gap of understanding the relationship between patterns of gamer behaviors and time-on-task when mathematics remediation occurs in a game-based HIVE was proposed to be addressed by this study.

Chapter 3: Research Method

Introduction

The purpose of this body of research was to examine the relationships between patterns of gamer-behaviors as categorized by Yee et al. (2012) and time-on-task for students using a game-based HIVE for remediation in mathematics. Furthering the understanding of matching the learner to the most appropriate learning environment supports the premises of maximizing support for all learners noted in Chapter 2. Chapter 3 begins with the research design and rationale for this study, then includes an explanation of the methodology, instruments employed in this study, the plan for data analysis, threats to validity, and the measures taken to ensure the study is conducted ethically providing the plan for addressing the research question in Chapter 1. Finally, a conclusion summarizes this chapter.

Research Design and Rationale

An exploratory correlational quantitative research design was selected to examine relationships between patterns of gamer-behaviors and time-on-task when mathematics remediation occurs in a game-based HIVE. Quantifying the relationships between patterns of gamer-behaviors and time-on-task provides a numerical perspective to understanding these relationships and the potential to generalize to a larger population. Therefore, correlational statistical measures were appropriate. Quantitative measures allow for complex calculations to uncover relationships between multiple independent variables (Simon, 2003, Statsoft, Inc., 2013). However, quantitative analysis measures generally involve extrapolation to the larger population for the purposes of prediction; the analysis of multiple cases may limit this generalizability.

The use of anonymous third party data provided by AT&LT limited analysis to quantitative measures. As demonstrated in Figure 1, the independent variables for this study are the patterns of gamer-behaviors provided by Yee et al. (2012) as achievement, immersion, and social motivations. As both gender and age have demonstrated relationships to patterns of gamer-behaviors and mathematics achievement, as noted in Chapter 2, they were considered control variables. The dependent variable for this study was time-on-task while participating in the game-based HIVE, *The Lost Function*, for mathematics remediation.

While the idea of flow-states was included as part of the theoretical framework, quantitatively measuring flow-states is difficult, especially within the context of the data used in this study. The Flow State Scale by Jackson and Marsh (1996) exists, though it was designed to measure flow states regarding athletics and has seen little application in other areas. Likewise, Payne, Jackson, Noh, and Stine-Morrow (2011) noted that generalized scales to measure flow states do not exist, and the Flow State Scale by Jackson and Marsh may have limited generalizability to other areas of study and populations. Other scales have had limited application and typically ask the participant to identify if they have experienced the characteristics of flow-states as identified by Csikszentmihalyi (2000). These include the study comparing flow-states to online game addiction (Chin-Sheng & Wen-Bin, 2006) and the study comparing personality characteristics to flow-states (Seger & Potts, 2012). At this time, the only potentially accurate measurement of flow-states may be through the use of biological factors, such as electrical impulses in the facial muscles used in the studies by Nacke and Lindly (2009), and Mauri et al. (2011). This type of measurement is beyond the scope of this study.

Many types of experiences influence flow states, and a portion of the population may never experience them (Csikszentmihalyi, 2000). The idea of the flow-state is included to demonstrate the critical nature of engagement, yet the ability to document actual engagement is impossible within the context of the data provided by AT&LT. Therefore, time-on-task was used as a proxy measurement to represent engagement in the game-based HIVE. Though not included within the scope of this study, there are many in-game factors that contribute to engagement and may facilitate flow-states including a sense of what must be accomplished to complete a task, immediate feedback, a balance of challenge and skill, and a sense of control (Csikszentmihalyi, 2000). Though not included as tested elements, these components of the game-based HIVE used in this study provide a comparison to elements from the conceptual framework, thus are detailed below.

The research design selected for this study was exploratory and quantitative, using data from multiple case groups. The research design involved investigating multiple cases using quantitative, correlational analysis methods to determine relationships between patterns of gamer behaviors and time-on-task. Since little quantitative research investigates specific types of digital environments with regard to learning, and no known research compares the individual patterns of gamer-behavior to time-on-task when mathematics remediation occurs in a game-based HIVE, exploratory research in this area is where one must begin in order to understand any relationships. The exploratory nature of this study opened the door to understanding the relationships between patterns of gamer-behaviors, specific digital gaming environments, and factors influencing academic achievement. Further understanding of these relationships supports the ideas of UDL and accountable game design by allowing educators to match the learner to the most appropriate learning environment and game designers target the appropriate audience through game design. Researchers noted the importance of understanding the traits of players in relationship to serious games in order to actualize the potential of game-based learning (Gee, 2011; Park et al., 2011; Shute & Kim, 2011; Yee et al., 2012). While games may lead to learning, how the learner interacts with the game was a significant contributor to learning and transfer (Artino, 2008; Childress & Brasswell, 2006; Gee, 2011; Shute & Kim, 2011).

As third party data were used in the analysis there were inherent limitations on the data accessible. For example, as the information provided was anonymous, it was impossible to follow up with participants, inhibiting digging further into implementation and use strategies. There was no way to determine the amount of time allotted to students to use the product. It was unknown in each of the case studies how many reminders were provided to students to complete the game as well as other external motivating factors noted in the Limitations section of Chapter 1.

While studies investigating patterns of gamer-behaviors have been conducted, the extrapolation of these traits to other areas including game-based learning has been limited and was noted to be an important next step (Gee, 2011; Park et al., 2011; Yee et al., 2012). Exploratory research in this area could lead to subsequent research, including true experimental designs, to determine the influence of these learner traits on academic achievement. The research design chosen for this study was supported by both the intent of the research and the available data. While the concept of player motivations have been applied to commercial games, they have had no known application to serious games, thus the need for exploratory research. The nature of third party numerical data lends itself to quantitative analysis, and the specifics of investigating the relationship of multiple factors on a single dependent variable lends itself to using multiple regression.

While this research may not be considered an intervention study because of the lack of a control group, the context in which data were collected is undeniably an intervention: the participants in each pilot group were determined to require remediation in pre-algebra skills. *The Lost Function* by AT&LT was selected to be the intervention for each of these groups. For the purposes of this study, *The Lost Function* was selected as the game to investigate because it was the only game-based HIVE on the market specifically designed for mathematics remediation with a comprehensive grade-band curriculum targeting algebra readiness skills necessary for college algebra. According to E. P. Harvey (personal communication, 28 January-22 September 2014), CEO of AT&LT, *The Lost Function*

- is an adventure-style video game set in a three-dimensional open world;
- has a story that was written by Lee Sheldon, a noted writer, producer, and designer of television shows, books, and other video games;
- contains all algebraic content generally required to be successful in a traditional initial high school or college algebra courses;
- is aligned to Common Core State Standards as well as standards from other states not adopting the initiative;
- allows for self-paced instruction with immediate feedback;
- includes an intelligent tutoring agent to help pinpoint skill deficiencies in mathematics including both instruction as well as guided practice; and
- contains over 300 lessons in video or narrative format, approximately 1000 guided practice problems, and over 5000 assessment questions.

The mathematics content is presented in a linear fashion, with foundational material in the earlier levels and advanced concepts in later levels. If the game is played linearly as suggested by AT&LT, foundational skills must be mastered before the player is allowed to move forward in the game. AT&LT defines mastery within the game to be at least 80% correctness on the assessment questions for each skill or concept. The discussion below regarding aspects of accountable game design included in *The Lost Function* provides the rationale for this design choice.

Additionally, *The Lost Function* includes many facets considered important within the scope of this research noted in Chapters 1 and 2. First, the importance of providing learners with appropriate challenge and choices is an element of differentiated instruction (Gregory & Chapman, 2007). Appropriate level of challenge is addressed through the self-paced nature, the linear curriculum presented within the level designs, and the intelligent tutoring agent that provides lesson and practice materials. Learner choice is accommodated in many different areas of the game including avatar selection, choice in media format for lessons, method of travel within the game environment, quality of graphical display, and content addressed through the level selection tool. While learner choice was not available regarding the product used in each case group, *The Lost Function* supports learner needs through choices that support a variety of learning preferences along with control over some aspects of the environments.

Next, *The Lost Function* addresses the premise of UDL of allowing for maximum access by intentional design. Mathematical concepts are broken down into sub-skills so that the intelligent tutoring agent can identify specific areas where the student is struggling. Like differentiated instruction, UDL advocates for providing content using multiple means of representation (CAST, 2011), which are included within the game lesson designs. *The Lost Function* supports pattern recognition networks through NPC conversations that connect concepts, narrative and video lessons that identify connections to previous content, and guided practice problems with hints reminding the learner of previous concepts. These support pattern recognition by assisting students to see connections and patterns between and within concepts. The game-based HIVE also supports strategic networks through the guided practice problems by helping students construct meaning of the problem and develop a plan to arrive at a solution. Finally, the game-based HIVE supports affective networks through the environment and story, the freedom to explore, and socialization with NPCs. Supporting these areas, according to UDL, influences engagement and motivation (CAST, 2011; Rose & Strangman, 2007).

E. P. Harvey (personal communication, 28-30 January 2014) noted many facets of *The Lost Function* that factor in principles of accountable game design. The game's intended audience is students who need remediation in skills necessary to be successful in an entering high school or college level algebra course, which also defines the learning goals. The learning goals, or skills to be mastered, are identified in the quest name, in the assessment problems, and within the tablet interface such that each skill is provided by name to the player. The game identifies progression through the skills within each quest at the bottom of the screen, so the player always knows how many questions have been answered and how many questions remain for each concept. This feature allows the learner to know where they are in relationship to achieving the learning goals. At the conclusion of each quest, the game revisits the learning goals and provides a percent correct for each skill. Regarding group dynamics, the game was intentionally designed to be single-player in order to avoid monitoring player conversations for situations such as digital bullying. However, *The Lost Function* supports the social aspect through the use of many NPCs, some of whom are threaded throughout the storyline.

The rules are designed to be simple, and the user is provided a tutorial at the beginning of the game to assist with navigation and location of the next quest. Simple rules along with an orientation were included in the game design to reduce as many external negative influences because members of the target audience may already have a negative perception of mathematics (Baker et al., 2008). The game-based HIVE includes chance and surprises in the game's "brain breaks", or mini-games where mathematics ability is not a component, such as running through a maze or collecting chickens in a given time. The self-paced nature supports those on both ends of the skill spectrum (Charoenying, 2010). Students who have mastered a particular concept will move quickly through the level while those who are struggling with the content are provided more interventions. The criteria for success is set at 80% for each subskill, though the learner must correctly answer the real-world final challenge problem at the end of each quest. AT&LT decided that 80% correctness was sufficient for mastery of the content in order to reduce frustration for struggling students, yet still incorporate a balance of challenge and skill. Pedagogical agents and NPCs redirect learners when they are not successful and reward learners when they achieve success. During the assessment problems, the progress bar at the bottom shows the learner the number of skills addressed as well as how many must be correctly answered, providing a visual cue as to when success has been achieved.

The protocol for interaction is real-time, but the mathematics problem solving is turn based, with no time limitation. Similar to complexity of rules, this choice was made to support the target audience, the struggling mathematics student. As pressure and anxiety may result because of time constraints as well as impacting a player's ability to meet the criteria for success (Charoenying, 2010), *The Lost Function* takes a turn-based approach during the assessment problems. Finally, the particular format of the game, a native application game-based HIVE, accommodates those without Internet access and those with limited bandwidth. AT&LT made this decision to reduce the necessary bandwidth when the game is employed in a school or classroom setting. Under the principles of accountable game design, intentional choices were made in the design and development of *The Lost Function* to meet the needs of the target audience.

The additional factors noted by Amory (2010) were also important. In order to produce a game that would be suitable for middle grades students, *The Lost Function* avoids actions and ideas that may be contradictory to the expectations for a learning tool appropriate for school use, such as violence and theft. Additionally, items that are important for the player to interact with are identified on the in-game map; non-essential items can be located by mousing over them and looking for a change in the mouse pointer. Amory (2010) also noted the importance of NPCs and their role in assisting the player. While Schroeder and Adesope (2014) noted that research into pedagogical agents as NPCs demonstrated mixed results, when compared to other digital learning environments without pedagogical agents, learners with access to this type of NPC generally reported being more satisfied, more motivated, and felt that the pedagogical agent positively influenced success. In *The Lost Function,* pedagogical agents are provided not only through NPCs in the game world, but also through the tablet interface and the intelligent tutoring agent.

However, while offering many advantages, *The Lost Function* was not a perfect match to all premises underlying this research. With flow-theory underlying the argument of the importance of the engagement (Csikszentmihalyi, 2000), it is worthwhile to note that games in general, this particular game, the genre, or the environment of a HIVE will not appeal to all users; therefore, any one digital game will not be the most suitable educational solution for all students. Next, the significance of the balance between challenge and skill was also noted in the literature (CAST, 2011; Charoenying, 2010; Gregory & Chapman, 2007; Inal & Cagilay, 2007; Rose & Strangman, 2007; Vygotsky, 2004), and while the game does not automatically adjust problem difficulty, pedagogical agents direct learners to the tablet interface for assistance. The tablet interface provides choices in the forms of narratives, videos, and interactive problems; however, there is a limited number of each. Learners may have access to only one practice problem, one video, and one narrative for a particular concept; thus, learners may not have enough opportunity to master the topic through the intervention system.

The Lost Function is a single-player game without a built in player-to-player communication system, yet premises of UDL support the need for both collaboration and discourse (CAST, 2011; Rose & Strangman, 2007), as does accountable game design (Charoenying, 2010). The National Council of Teachers of Mathematics (2010; 2014) noted the importance of mathematical discourse as it allowed learners to create meaning rather than accept it from another. Another area where *The Lost Function* may differ from the underlying theoretical premise of accountable game design is the target audience. While a target audience was specified, this is still a broad population, and while Charoenying (2010) noted that the game must be instructionally appropriate, it also must be developmentally appropriate. Narrowing the target audience and focusing the lesson materials to age groups may be more appropriate. As the initial design of *The Lost Function* targeted graduating seniors preparing for college placement exams, yet subsequent alignment to Common Core State Standards and a few non-participating states demonstrated the game content typically fell into middle grades mathematics curricula, AT&LT expanded the target audience for marketing purposes (D. B. Cavitt, personal communication, 23 May 2014). For example, imagine the differences between middle school students using the game in a classroom prior to promotional exams versus adult students entering college for the first time preparing for mathematics placement exams. While both groups may need remediation in pre-algebra concepts, there will be many differences in interests, maturity, and motivation alone that should be reflected in the game to foster engagement. However, that is not to say that *The Lost Function* appeals to a particular group by age or circumstance more than another.

Although impossible to meet the needs of every learner within one environment, *The Lost Function* offers players a unique environment and a mystery themed story to facilitate remediation of middle grades mathematics skills. The environment, a game-based HIVE, is similar to those which many traditional learners are already familiar.

Game-based HIVES have the potential to foster engagement, promote learning and transfer, allow for exploration, and support learner needs (Chatham, 2011; Charoenying, 2010; Chee & Tan, 2012; Chen et al., 2012; Csikszentmihalyi, 2000; Games & Squire, 2011; Rose & Strangman, 2007; Richter & Livingstone, 2011; Tamim et al., 2011). Therefore, they may provide an environmental alternative to traditional face-to-face classes. Thus, game-based HIVEs are a significant digital environment to which to attend.

Methodology

Population

The theoretical target population stems from the social problem forming the backbone of this research: the number of students entering college unprepared to enter a credit-bearing mathematics course. Nationally, almost 2 million students enter two-year colleges and universities representing between 20 to 50% of those enrolling in post-secondary institutions (Complete College America, 2012). While current data was not available for the 2012 or 2013 school years regarding non-selective colleges, the National Center for Public Policy and Higher Education (2010) noted approximately 75% of those enrolling in these colleges require remediation in reading, mathematics, or both. Furthermore, a recent report regarding U.S. high school seniors by the National Center for Educational Statistics (2014) noted that only 26% are considered proficient or better in mathematics and predicted that only 39% are prepared for entry-level college mathematics. However, the accessible population, defined by the data available from

AT&LT collected during pilot studies and marketing events used in this study, may not be generalizable to the population as a whole, only representing the included case groups.

Sampling and Sampling Procedures

Prior to describing specifics regarding each case group, some general commonalities are necessary to note. First, AT&LT provided all information regarding the case groups and their associated data. Sample information will be provided for each of the groups below including why the students were identified as needing remediation. While each case group may represent a sample, random selection did not occur. Each case group stemmed from a preexisting group representing convenience sampling. As a result of using third party data, information regarding recruitment and participation may not be available, though will be included in the case group description when known as well as in Table 2 as a summary of the information from the case groups.

Power Analysis

As this study used third party data, I calculated the optimal sample size using two different effect sizes, providing a range for the optimal sample size from medium to large effect sizes. I used the A-priori Sample Size Calculator for Multiple Regression (Soper, 2014) to calculate the two optimal sample sizes. Park (2010) noted an a-priori analysis is appropriate to determine sample size; however, as this study uses third party data, there was no way to control for sample size. This calculator required an anticipated effect size for f^2, desired statistical power level, number of predictors, and probability level. For anticipated effect size, 0.35, or a large effect was used as was 0.15 for a medium effect size (Soper, 2014). The large and medium values were selected as Yee et al. (2012) noted the three categories account for the majority of the variance (59.3%) within the 12 statements as well as being highly consistent (all Cronbach $\propto > 0.70$). Additionally, significant relationships between the self-reported values when compared to in-game metrics, with all p-values less than 0.01 (Yee et al., 2012), meant that a medium or large effect was most appropriate. Furthermore, a small effect size was noted to be useful only when careful investigation is employed to find potentially negligible differences (Institute for Digital Research and Education, n.d.; Walker, 2008).

Next, for desired statistical power level, I selected 0.80, representing the minimum power useful to detect a desired effect (Soper, 2014) to narrow the range of determining if the effect is significant (Park, 2010). For the number of predictors, I used five to represent the three patterns of gamer-behaviors noted by Yee et al. (2012), gender, and age. For probability level, I selected 0.05 to provide for statistical significance (Park, 2010). Using the tool by Soper (2014), these values provided a minimum sample size of 43 for a large effect and a minimum sample size of 91 for a medium effect. As the data related to multiple case groups, a sample size range allowed for discussion of how each group's sample size related to the suggested optimal sample sizes for large and medium effects.

Procedures for Recruitment, Participation, and Data Collection

The use of third party data limited available information regarding recruitment and participation; however, each case group description includes what was known about the groups, and Table 2 provides a summary of the information for each case group. Recruitment was conducted by AT&LT through marketing events. Participation is noted in each of the case group descriptions. The following information regarding data collection occurred in all case groups with specifics for each case group provided in the individual descriptions.

Informed consent occurred in two ways depending on if the case group was considered a pilot study or not. For pilot groups, a representative from each pilot group site consented to anonymous use of their data as a component of participating in a pilot study. College level students consented through the purchase and use as indicated in the end-user license agreement (EULA) for *The Lost Function* as well as accepted a reiteration of the "consent to share information" clause of the EULA. AT&LT provided free licenses to all pilot case groups, including both high school groups and one college level case group in this study. College participants in the other college level case group were not afforded this opportunity.

Data collection for the pilot groups occurred the same in the same manner. According to S. S. Convery (Personal communication, 21 May 2014), the Deployment Specialist for AT&LT, all pilot groups included in this data set received an on-site orientation. During the orientation, students completed a survey using Google Forms (see

Appendix A), which included an adapted version of the online gaming motivations scale by Yee et al. (2012). The 12 Likert-type questions were adapted for clarification purposes for participants who do not play many digital games or play other game formats, such as puzzle games. Four statements were modified:

- "being part of a guild" was changed to "being part of a guild or other long-term/permanent group"
- "grouping with other players" was changed to "grouping or playing with other players"
- "learning about stories and lore of the world" was changed to "learning about stories and lore of the game"
- "exploring the world just for the sake of exploring it" was changed to "exploring the game just for the sake of exploring it"

Additionally, AT&LT's Deployment Specialist was on hand at each pilot orientation to answer questions and provide clarification during the survey. Each of the high school groups received the same orientation through the use of a group facilitated scavenger hunt (see Appendix B). Each participant in the pilot completed the scavenger hunt to learn navigation, quest completion, accessing resources, tutoring agent interventions, and other game mechanics to ensure that each participant was comfortable in the game environment and to give each participant a consistent orientation experience. The college level pilot groups received an orientation similar to that provided to secondary schools.

While the college level student survey included different information than that of the high school survey, such as major, the college student survey contained the same 12 Likert style questions from the gamer motivations scale.

Time-on-task was collected by the game-based HIVE and included the sum of the time spent answering assessment questions and time in the tutoring interface. The game-based HIVE collects and reports progress, amount of time spent on each topic, the average amount of time spent in remediation, and the total amount of time spent in the environment. It is important to note that the time collection feature of the game pauses if the user moves to another application, providing a more realistic view of time-on-task. This is a critical game feature as it would be impossible to discern if a student was actively engaged in problem solving and remediation, or has deviated from the task by surfing the Internet, checking email, or other computer-based distractions from the task. However, as noted in the Limitations section of Chapter 1, the system does not pause during periods of inactivity while the student is engaged in an assessment question, as long as the game window remains active. Using data provided by a corporation, and the need for individual as well as group privacy meant that some data were not available. Finally, no debriefing or follow up procedures were noted with the case groups included, though students were asked to complete an additional survey after completing the game for game improvement purposes. E. P. Harvey, the CEO of AT&LT (personal communication, 28-30 January 2014) provided permission to access the data set, with no formal permissions requested by the company. The following information was taken from conversations with S. S. Convery, the Deployment Specialist for AT&LT (Personal communications, 10 January 2014 to 15 August 2014). An overview of the case groups is provided in Table 2.

Case Group A

This group was a pilot group from a private liberal arts university located in the southeastern United States. The college has a population of less than 5000 undergraduate students. Case Group A consisted of pre-service elementary teachers, all members of two methods of teaching mathematics courses designed for elementary teachers. The instructor of the course determined the need for remediation and further development of pre-algebra skills prior to students taking the state's teaching exam, a nationally recognized educator licensing assessment. This group consisted of 33 participants, smaller than the recommended sample size of 43 for a large effect size (f^2=0.35). While all other pilot groups consist of a mixture of genders, this case group consisted of all female participants (n=33, 100%). This case group was provided approximately three months to complete the game outside of class time. Students were expected to complete the game as part of the curriculum, though no known class credit or grades were assigned for completion.

Case Group B

The second group came from the same university as Case Group A. However, participants in Case Group B included 25 in-service teachers participating in a science-technology-engineering-mathematics (STEM) summer program from neighboring school districts, though only 18 completed the survey and participated in the game. While most of the teachers were elementary teachers, some identified themselves as middle grades teachers (*n*=6). Participants of this group were given both a pre and post assessment aligned to the content of *The Lost Function*, and they were afforded two weeks to complete the game, though the assessment data were not used in this study. This group was also smaller than the recommended sample size of 43 for a large effect.

Case Group C

The third group was a pilot involving a public high school of approximately 2000 students located in a coastal city in a mid-Atlantic state. The 55 high school participants were in two regular American Government classes taught by the same instructor. The instructor determined that these two groups needed remediation in pre-algebra skills prior to taking high school exit, college placement, and/or military assessments. Three participants were removed from the sample as they did not provide complete information. While the sample size falls between the recommendations for large and medium effects, 43 and 91 participants respectively, the number of included participants is closer to the recommended sample size for a large effect. Therefore, data from this group may only reveal relationships when the effect is large. Of the 52 participants, 25% (*n*=13) were male. Students in this pilot group were only afforded three class periods to play the game, though students were allowed to play outside of class time. The amount of unstructured time was unknown for this case group as participants may have had differing abilities to access to the game outside of class.

Case Group D

The fourth group came from a public high school of approximately 2000 students located in a coastal city in a mid-Atlantic state. All participants of this pilot group were dual enrolled in an algebra readiness courses as well as a traditional Algebra I type course. The high school used performance data from 8th grade in order to determine need for remediation and placement into the algebra readiness course. While 8 sections of students were enrolled in the pilot, some sections did not use the program at all while other students had limited computer access. While time data were provided for 33 participants, only 11 completed the survey information to be included, substantially below the recommended sample size for a large effect.

Table 2
Case Group Overview

Case Group	Number of Participants	Grade Band	Recruitment Procedure	Additional Case Group Characteristics
A	33	College	Required - By instructor	Students in two methods of teaching elementary mathematics courses for pre-service teachers taught by the same instructor
B	18	College	Required – Participation in STEM Academy	Participants from a STEM summer academy for in-service teachers.
C	52	High School	Required - By instructor	Students in two regular education American Government classes taught by the same instructor
D	11	High School	Required - By instructor	Students dual enrolled in an algebra readiness course and a traditional entry algebra course

As three of the four sample sizes were below the recommended value for a large effect, the data from two college groups were combined as well as the two high school groups.

Instrumentation and Operationalization of Constructs

Advanced Training & Learning Technology, LLC collected and provided all data used in this study. AT&LT used Google Forms to collect data including demographic information and the online gaming motivations scale by Yee et al. (2012). Demographic information included questions requesting each participant's age and gender. Written permission was obtained to use AT&LT's product and data (E. P. Harvey, Personal communication, 11 March 2013) and is included in Appendix C. N. Yee provided written permission to use the online gaming motivations scale (Personal communication, 8 August 2013), with the email requesting permission included in Appendix D. While patterns of behavior may be assessed through a variety of instruments, the scale by Yee et al. (2012) is specific to gaming motivation. Using gamer traits researched by others including Bartle (1996), Yee (2006), Park et al. (2011), and Chiang et al. (2011) provide for reliability in the independent variables (Fabrigar, Wegener, MacCallum, & Strahan, 1999).

The online gaming motivations scale by Yee et al. (2012) was developed using a large cross-cultural random sample (n = 1000) and was designed to provide predictive validity from the study by Yee (2005), which formed the scale's foundation. The scale consists of 12 statements using a Likert-type scale using the following notation:

1. *not important at all;*
2. *slightly important;*
3. *somewhat important;*
4. *very important; and*
5. *extremely important*

in order to rate each participant in three domains: achievement, immersion, and social. Achievement was measured using four statements including “competing with other players.” Immersion was measured using four statements including “having a background story or history for your character.” Social was measured using four statements including “chatting with other players.” The initial study by Yee (2005) used a large sample (n=3,200) of World of Warcraft players and was based on Bartle's (1996) study investigating patterns of gamer-behavior and player archetypes. Refining the scale in the subsequent study by Yee et al. (2012), the reliability coefficient of Cronbach’s alpha was 0.74 for achievement, 0.75 for immersion, and 0.77 for social, all above the recommended value of 0.70 for high internal reliability (Creswell, 2013; Institute for Digital Research and Education, n.d.; Yee et al., 2012). Furthermore, in the study by Yee et al. (2012), they also investigated the relationship between the self-reported values compared to actual in-game metrics. Yee et al. demonstrated the three patterns of gamer-behaviors have high correlations to in-game behaviors, each significant with at minimum $p<0.01$. Therefore, along with the validity and reliability provided by the studies themselves, it has been noted that reliability can be achieved by building upon existing works (Fabrigar et al., 1999). Table 3 summarizes the constructs for this proposal.

Operationalization

Table 3 provides the constructs and operational definitions for the five variables included in this study.

Table 3

Variables in this Study

Construct Name	Construct Definition	Operational Definition	Measure
GENDER	The self-identified gender of the participant.	Defined by the participant's response to the survey prompt "Gender" with two options: male or female.	Categorical
AGE-BAND	Whether the participant is in high school or college.	Defined by the case group.	Categorical
ACHIEVEMENT	The pattern of behavior indicating the level of motivation derived from achievement-focused factors within a game environment.	The sum of the participant's self-rating on the four achievement factors as identified by Yee et al. (2012). Scores will range 4-20 where higher scores represent a greater relationship between motivation to play and achievement factors.	Interval
IMMERSION	The pattern of behavior indicating the level of motivation derived from immersion-focused factors within a game environment.	The sum of the participant's self-rating on the four immersion factors as identified by Yee et al. (2012). Scores will range 4-20 where higher scores represent a greater relationship between motivation to play and immersion factors.	Interval
SOCIAL	The pattern of behavior indicating the level of motivation derived from social-focused factors within a game environment.	The sum of the participant's self-rating on the four achievement factors as identified by Yee et al. (2012). Scores will range 4-20 where higher scores represent a greater relationship between motivation to play and achievement factors.	Interval
TIME-ON-TASK	The amount of time a participant spends engaged in the mathematics in the game-based HIVE.	The sum of the time, recorded by the game-based HIVE, spent in solving mathematics assessment problems and within the tutoring agent for skill remediation.	Ratio

Data analysis plan

Statistical analysis was conducted using SPSS 21.0. Descriptive statistics including measures of central tendency and standard deviation will be used for group descriptive purposes, to check for outliers, and ensure there were no coding errors. Gender was coded as 0 = male and 1 = female. Grade band, which was reported as high school and college level, was coded as 0 = high school and 1 = college. Participants lacking all required data were removed from the pool prior to analysis.

The population in the study by Yee et al. (2012) consisted of only *World of Warcraft* players. While the study included a cross-cultural validation and predictive validity, the population of *World of Warcraft* players may be inherently different from those in the case groups in this study. Therefore, a confirmatory factor analysis was planned to compare the fit of the three factors identified in the study by Yee et al. to the data gathered. Confirmatory factor analysis provides validation when a pre-existing scale is applied to a different population (Harrington, 2008; Suhr, 2006). Additionally, Cronbach's alpha was computed to evaluate the scale reliability (Creswell, 2013; Institute for Digital Research and Education, n.d.; Yee et al., 2012) and further compare this study's application to the initial scale use by Yee et al..

In order to answer the research question of "what are the relationships between patterns of gamer behaviors to time-on-task when mathematics remediation occurs in a game-based HIVE?", I used the following hypotheses:

$H_0$1: There is no relationship between patterns of gamer behaviors to time-on-task in students requiring remediation in mathematics when learning in game-based HIVEs when gender and age-band are considered control variables.

H_a1: There is a relationship between patterns of gamer behaviors and time-on-task in students requiring remediation in mathematics when learning in game-based HIVEs when gender and age-band are considered control variables.

Multiple linear regression was selected as the most appropriate statistical method as it can handle multiple independent variables that influence a single dependent variable (Riecke, 2014; Simon, 2003; StatSoft, Inc., 2013). While multiple regression is typically used for prediction purposes, it is important to note that generalizability for prediction purposes may be limited because of the nature of analysis of historical, third-party data.

Multiple regression has many assumptions that must be met for the model to be most informative (Starkweather & Herrington, 2014). The lack of multicollinearity is one of the most important assumptions when employing multiple regression (Cook, 2010; Davis, 2011; Starkweather & Herrington, 2014). Yee et al. (2012) demonstrated this lack of multicollinearity between the three patterns of behavior in their study. However, SPSS will be used to produce a correlation matrix to determine if any of the variables exhibit multicollinearity (Cook, 2010; Starkweather & Herrington, 2014). Furthermore, multiple regression is noted to work best when linear relationships exist and is easily influenced by outliers (Starkweather & Herrington, 2014), identified through exploring descriptive statistical values provided by SPSS. Outliers were planned to be removed from each case group to prevent potential negative influences to the outcomes. Finally, after generation of the regression equation, determine of significance was planned at $\propto = 0.05$. As most of the individual samples were below the recommended sample size, an aggregated sample was used.

Threats to validity

The results of a study are only as good as the ability to interpret the results with accuracy and confidence, however both internal and external validity may interfere (Trochim, 2006). While threats to internal validity concern whether the results of a study can be attributed to the relationship between the independent and dependent variables, external validity deals more with generalizability to the population (2006). There are several potential threats to both internal and external validity because of the nature of using third-party data.

First, a potential threat to internal validity came from the lack of random assignment to groups. Each case group was selected because of a site-determined deficiency in mathematics skills addressed in *The Lost Function.* While measuring academic achievement includes the potential for many threats to internal validity, such as the practice effect, focusing on a quantitatively measured factor, time-on-task, that relates to both engagement and achievement, may reduce some threats to internal validity. Time-on-task can be measured fairly accurately within the game environment as noted in the “Data Collection” section of this chapter.

Furthermore, extraneous variables, such as the amount of time participants were allowed to use *The Lost Function,* may pose a threat to validity (2006). However, analyzing each case group independently may reduce this threat as participants in each case group were allotted approximately the same amount of time. On the other hand, this is an unresolved threat to internal validity if data in the case groups were combined as some groups were provided several months while other case groups may have only had a few weeks to use the game.

While internal threats such as the effects of history, maturation, and testing may not apply to this particular study, mortality was an unmitigated threat to internal validity. Mortality presents a problem as participants may give up on using *The Lost Function* prior to the end of the intervention period. While patterns of gamer-behaviors may lend themselves to differing amounts of time-on-task, there was no guarantee due to the nature of using third-party data. For example, in each pilot group, there was no known amount of reminders, incentives, or other external motivators implemented.

Potential threats to external validity also come from the study design. As this study investigated separate case groups, there is an inherent possibility that the results apply only to the case groups themselves and may not be generalizable to the population of students requiring remediation in skills required to be ready for a traditional algebra course. Population validity may be difficult to account for in any study (Trochim, 2006) and using third-party data that lacks random sampling and a control group adds to this issue. Therefore, population validity represented an unmitigated issue that cannot be accounted for due to the nature of the data used in this study. These potential threats to validity are also noted in the Limitations section of Chapter 1.

Ethical Procedures

While any research involving humans must consider ethical treatment of participants, the use of anonymous third-party data reduces the potential harm to the participants. All data used in this study was historical data, already collected by AT&LT, and was not collected by me for the purposes of this study. For data associated with middle and high schools, AT&LT entered an agreement with someone at each site. These pilot programs, according to AT&LT, required permission at the site level to include the use of data anonymously. At the college level, consent to use the data is included in the end user license agreement (EULA) which must be accepted in order to install the software and create an account (S. S. Convery, Personal communication, 15 May 2014).

While no follow up was provided by AT&LT, follow up in each case group may include subsequent mathematics courses, whether non-credit bearing, developmental courses, or credit-bearing courses. All data were anonymous and were provided with no personally identifiable information. As AT&LT provided data, they already have access to the data, including unshared personal information. Game servers owned by AT&LT stored all game metrics. Data shared for the purposes of this study will be deleted upon completion of the data analysis, though will still be maintained by AT&LT.

Summary

Chapter 3 outlined the proposed design and methodology of the method of inquiry to be used to investigate the research questions and address the hypotheses. The research design selected for this study was exploratory using quantitative correlational methods. This study was based on the online gaming motivations scale by Yee et al. (2012) and applied the concept of connecting learner traits to a factor reflecting engagement. Data from multiple case groups was analyzed using multiple regression to determine the relationship between multiple independent variables (achievement, immersion, and social dimensions along with gender and age) to a single dependent variable (time-on-task). AT&LT provided all data, which was analyzed using SPSS software. Third-party anonymous data facilitated the ethical treatment of human participants. Chapter 4 will provide the results as well as discussion to interpret the results of the data analysis process.

Chapter 4: Results

Introduction

The purpose of this quantitative study was to explore the relationships between the patterns of gamer-behaviors of social, immersion, and achievement motivations to time-on-task for students using a game-based HIVE for remediation in mathematics. The quantitative research design chosen for this study was correlational, using historical data from four case groups. All participants received mathematics remediation using the same game-based HIVE, *The Lost Function: Episode 1: Sum of the Forgotten Minds* by Advanced Training & Learning Technology, LLC. The independent variables of this study were the three motivational patterns of gamer behaviors identified by Yee et al. (2012): social, immersion, and achievement motivations. As other studies noted relationships between age and gender to pattern of player behavior, they were included as control variables. The dependent variable for this study was time-on-task while learning in the game-based HIVE. The model representing this study was provided in Figure 1.

The research question of this study was: Is there a significant relationship between patterns of gamer behaviors and time-on-task as a result of mathematics remediation in a game-based HIVE for US students when controlling for gender and age-band? The following hypotheses were investigated in this study

$H_0 1$: There is no relationship between patterns of gamer behaviors to time-on-task in students requiring remediation in mathematics when learning in game-based HIVEs when gender and age-band are considered control variables.

H_a1: There is a relationship between patterns of gamer behaviors and time-on-task in students requiring remediation in mathematics when learning in game-based HIVEs when gender and age-band are considered control variables.

Chapter 4 includes a section on data collection, including discrepancies between the expectations in Chapter 3 and the provided data used in Chapter 4. This section will include baseline descriptive statistics and demographics for each of the four case groups. Furthermore, descriptive statistics and demographics will be provided for the two age-band groups as well as the combined sample of the four case groups. Next, the results section will include the statistical assumptions along with the results for the combined sample of all four case groups. Chapter 4 will conclude with a summary to answer the research question and transition to Chapter 5.

Data Collection

I used historical third-party data collected between January 2012 and June 2014 provided by AT&LT in order to examine the effectiveness and gather feedback on their game-based HIVE *The Lost Function.* AT&LT collected all data at face-to-face site-based orientations and through in-game metrics. In addition to the data noted in Chapter 3, including gender, age-band, responses to the 12 statements regarding patterns of gamer behaviors, and total time spent in problem solving in *The Lost Function* for each participant, AT&LT provided additional data for all participants: the number of hours per week each participant spent playing digital games and the preferred genre or digital game.

Upon approval from Walden University's IRB (#10-02-14-0080972), IBM's SPSS Statistics version 21.0 was used to conduct all data analysis. In order to facilitate data analysis the following data transformations were used on the original data set to facilitate analysis. The two control variables were changed from text to numeric values. First, each case group was assigned a number: Case Group A =1, B = 2, C = 3, and D = 4. Then, gender was coded numerically, with participants identifying themselves as male coded as 0 and those identifying themselves as female coded as 1. An additional variable, HSvsCol, was created to code the age-band groups of high school as 0 and college as 1. The total time in the system, representing time-on-task, was converted from hour:minutes:seconds format to a numeric value of time in minutes. The responses to the twelve statements representing patterns of gamer behaviors were left as whole numbers ranging from 1 to 5.

I used the a priori Sample Size Calculator for Multiple Regression (Soper, 2014) to calculate two optimal sample sizes for large and medium effects as a small effect on time in minutes may not be useful when looking at time-on-task with regard to remediation. Given an anticipated effect size of 0.35 for a large effect, a probability of error of 0.05, a power of 0.80, and five predictors resulted in a recommended minimum sample size of 43. Using 0.15 for a medium effect, with all other parameters the same as used in the large effect, resulted in a recommended minimum sample size of 91. The effect sizes used were recommended by Soper (2014) when conducting multiple regression. As the data are historical and third-party, there was no way to account for sampling strategy for each case group; however, a range between medium and large effect sizes allows for comparisons to benchmark values. The next section provides basic demographics and sample size comparisons to the benchmark sample size suggestions for medium and large effects.

Baseline Descriptive and Demographic Characteristics of the Sample

Case Group A consisted of 33 participants, smaller than the recommended sample size of 43 for a large effect size (f^2=0.35). Case Group A consisted of undergraduate college level, pre-service elementary teachers, all female (*n*=33, 100%).

Case Group B included 25 in-service teachers participating in a college level science-technology-engineering-mathematics (STEM) summer program; however, only 18 completed the survey as well as used the game and were included in this study. This group was also smaller than the recommended sample size of 43 for a large effect. Case Group B included 2 male (11.1%) and 16 female (88.9%) participants.

Case Group C consisted of 55 high school participants; however, I excluded three participants as all required information was not provided. The sample size fell between the recommendations for large and medium effects, 43 and 91 participants respectively; the number of included participants was closer to the recommended sample size for a large effect. Of the 52 participants, 13 (25%) were male, and 39 (75%) were female.

Case Group D consisted of 33 participants; however, only 11 completed the survey information. This sample size is substantially below the recommended sample size for a large effect. In Case Group D, 9 participants (81.8%) were male, and 2 (18.2%) were female.

Combined Case Groups

Combining Case Groups A and B provided aggregated information regarding the participants identified as college level. The college level combined group consisted of 51 total participants of whom 2 (3.9%) were male, and 49 (96.1%) were female. The combined college level group was slightly above the recommended sample size for a large effect. Combining Case Groups C and D provided aggregated information regarding the participants in high school. The high school combined group consisted of 63 total participants of which 22 (34.9%) were male, and 41 (65.1%) were female. The combined high school level group was also above the recommended minimum for a large effect. Combining all four groups into one sample yielded a total of 114 participants, of which 24 (21.1%) were male, and 90 (78.9%) were female. The total combined sample was sufficient in size to detect a medium effect.

For all individual Case Groups, except for D, the sample was predominantly female. In the combined grade band groups, both the college level and high school level groups were mostly female. The gender imbalance was also reflected in the combined total of the four groups with nearly four out of every five participants being female. A summary of the demographic data is provided in Table 4.

Table 4

Demographic Data for Participants

	Male		Female	
	Number	%	Number	%
Case Group A	0	0	33	100
Case Group B	2	11.1	16	88.9
Case Group C	13	25	39	75
Case Group D	9	81.8	2	18.2
College Grade Band	2	3.9	49	96.1
High School Grade Band	22	34.9	41	65.1
Combined Total	24	21.1	90	78.9

Each group was identified as needing remediation in algebra readiness concepts by an external entity. Moreover, each group existed prior to the adoption of AT&LT's *The Lost Function*. The participants may not represent the population as a whole, noted in Chapter 1 as a limitation. Though each group was unique in composition of participants, selection of the group, and usage of the game-based HIVE, the orientation process was uniform detailed in Chapter 3. All survey information was collected during the orientation sessions. The sample was predominantly female (Table 4), which may not represent the population of students requiring remediation, nor those of game players. The U.S. Department of Education (2014) NAEP data from the 2013 administration shows 72% of males and 76% of females scored at or below proficient, demonstrating a relatively balanced ratio of males to females. The participant data used in this study included more females than males in all case groups except Case Group D. The combined age-band groups and the total group data demonstrate a greater number of females in the data for this study as shown in Table 4. The study by Yee et al. (2012) consisted of approximately 34% female participants. However, as the participants in this study were identified as needing remediation by a site-based entity, the justification of need and importance is there even if the gender distribution is atypical. Participants in the study by Yee et al. were self-selected players of one online game resulting in data that may not represent typical students or typical game players. Age was noted to have a significant relationship to the three patterns of gamer behaviors noted by Yee et al.; high school students represented 55% (*n*=63) of the total participants in this study. As the total number of participants was just over the recommended sample size to detect a medium effect, the results section only regards the total combined sample of all four case groups.

Results

The sample used in this study was different than the sample in the study by Yee et al. (2012) in two critical areas. First, a gender difference existed and has been noted to influence perceptions of digital games and serious games (Bonanno & Kommers, 2008; Chen et al., 2010; Park et al., 2011; Vogel et al., 2006). Next, the samples used in the study by Yee et al. comprised of self-selected players of a single MMORPG, *World of Warcraft*. On the other hand, the data used in this analysis, included players of other types of games as well as those who do not play digital games. While not anticipated and discussed in Chapter 3, AT&LT provided responses to two additional questions: "how many hours, on average, do you spend playing digital games" and "what type of digital game do you prefer to play". Not a single participant identified *World of Warcraft* as their favorite game and only two identified role-playing games as a preferred genre.

Beylefeld and Struwig (2007) and Chen et al. (2010) noted that a portion of the whole population was opposed to game playing or had negative perceptions of game playing. Table 5 summarizes participant self-reported game-playing time. Case Group A had a range of 0 to 4 hours with $\bar{x} = 0.27$ and $\sigma = 0.801$, Case Group B had a range of 0 to 3 hours with $\bar{x} = 0.47$ and $\sigma = 0.931$, Case Group C had a range of 0 to 60 hours with $\bar{x} = 6.71$ and $\sigma = 13.381$, and Case Group D had a range of 0 to 54 hours with $\bar{x} = 10.23$ and $\sigma = 15.526$.

Table 5

Participant's Responses to the Number of Hours Playing Digital Games

	Descriptives		Responses of Zero	
	Mean $\bar{x}$	Std. Deviation σ	Number	%
Case Group A	0.27	0.801	28	85
Case Group B	0.47	0.931	12	81
Case Group C	6.71	13.381	21	40
Case Group D	10.23	15.526	2	18

Additionally, 28 participants (85%) in Case Group A provided an answer of zero hours when responding to the question "how many hours, on average, do you spend playing digital games. Furthermore, 12 participants (81%) of Case Group B, 21 participants (40%) of Case Group C, and 2 participants (18%) of Case Group D reported spending zero hours per week playing digital games as shown in Table 5. Therefore, a total of 63 participants (55%) reported zero hours of play per week. Furthermore, of the 114 total participants, 16 participants specifically reported zero hours of play with the additional responses of "none" "N/A", or "I don't play" to the statement "what type of digital game do you prefer to play". These responses may indicate that some participants align with what Chen et al. (2010) labeled as "New Media Resisters" or "Game Value Resisters". These inherent differences between the sample and previous research into patterns of gamer behaviors, such as the study by Yee et al. (2012), suggest that additional statistical testing should occur prior to the main analysis comparing patterns of gamer behaviors to time-on-task.

Exploratory Factor Analysis

As there are inherent differences between the sample used in this study and those who participated in the study by Yee et al. (2012), exploratory factor analysis (EFA) was employed to examine if the same factors identified by Yee et al. appear in this sample. Confirmatory factor analysis typically is used in situations where one has prior knowledge of the relationship between variables and confirms that the dataset aligns with which is already known (Suhr, 2006); however, there were discrepancies between the sample used in this study and the population addressed in the study by Yee et al. to warrant EFA. EFA helps identify covariances within the dataset (Field, 2013), thus was used to see if the 12 patterns of gamer behavior statements reduce to the same three factors noted by Yee et al.. Conducting EFA allowed for comparisons between a priori knowledge regarding a different population and the sample used in this study.

According to Field (2013), Nimon (2012), and Suhr (2006), as with all linear modeling techniques, EFA has assumptions

- The data are normally distributed, and there are no significant outliers;

- The dependent variable is of at least interval type;
- The observations are independent;
- The variables are multivariate normal; and
- The sample is taken randomly;

The EFA includes two additional assumptions: there is some interaction between independent variables that may be reduced into factors, and the sample size is sufficient (Field 2013; Suhr, 2006). However, there is some disagreement in what constitutes a sufficient sample size for EFA, as noted by Field (2013). For 12 components, Field highlighted literature that a sample of anywhere from 60 to over 1000 is required for generalizability. The suggested range is huge, but includes the combined sample (*n*=114) in this study. While some may consider this to be a limitation with this study, I considered this to be within standards proposed in in the literature as to appropriate sample sizes for EFA. Therefore, for the purposes of the EFA run, I used a combined sample comprising of all 114 participants.

Table 6 contains descriptive statistics for each of the 12 statements. Assuming the data were normally distributed, the mean ($\bar{x}$) represents the center of the five-point Likert type scale ($\bar{x} = 3$); thus, the expected standard deviation (σ) should be less than 2 and closer to 1. The mean and standard deviation for each statement were close to a perfectly normal distribution, with all $\bar{x} \approx 3$ and $\sigma \approx 1$ representing a normally distributed dataset with no outliers. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy was 0.895, which Field (2013) noted indicated a great fit for EFA, and Bartlett's Test for Sphericity is significant at $p<0.001$; therefore, according to these measures, the sample was appropriate for exploratory factor analysis.

Table 6

Descriptive Statistics for Patterns of Gamer Behaviors

	Mean $\bar{x}$	Std. Deviation σ	*N*
Chatting with other players	2.12	1.345	114
Being part of a guild or other long-term or permanent group	2.16	1.301	114
Grouping or playing with other players	2.59	1.381	114
Keeping in touch with your friends	3.45	1.357	114
Learning about stories and lore of the game	2.61	1.340	114
Feeling immersed in the world	3.00	1.297	114
Exploring the game just for the sake of exploring it	2.76	1.339	114
Having a background story or history for your character	2.77	1.370	114
Becoming powerful	3.07	1.368	114
Acquiring rare items	2.86	1.388	114
Optimizing your character as much as possible	3.06	1.391	114
Competing with other players	2.99	1.360	114

In order to dig a little deeper into the data, exploratory descriptive statistics were calculated for each statement separated by case group. Case Group A had means for most items within ±0.5 and below the means of the aggregated sample. The mean comparison value of 0.5 was selected because it represents the halfway point between two elements on the Likert-type scale used to rate each of the 12 statements. The participants in Case Group A, on average, rated “chatting with other players” ($\bar{x} = 1.55$) substantially below the aggregated sample. Furthermore, “keeping in touch with your friends” ($\bar{x} = 3.48$) and “learning about stories and lore of the game” ($\bar{x} = 2.33$) were above the aggregated means. The standard deviations for each statement in this case group were below the aggregated sample and within 0.2 except for "keeping in touch with your friends" ($\sigma = 0.971$). The other college sample, Case Group B demonstrated substantial differences in means, but, like Case Group A, had standard deviations similar to the aggregated sample. All means for Case Group B were below the means of the aggregated sample. The following statements were more than 0.5 below the aggregated mean:

- Grouping or playing with other players ($\bar{x} = 1.94$);
- Keeping in touch with your friends ($\bar{x} = 2.67$);
- Learning about stories and lore of the game ($\bar{x} = 2.06$);
- Exploring the game just for the sake of exploring it ($\bar{x} = 2.11$);
- Having a background story or history for your character ($\bar{x} = 2.17$);
- Becoming powerful ($\bar{x} = 2.17$);
- Acquiring rare items ($\bar{x} = 2.06$);
- Optimizing your character as much as possible ($\bar{x} = 2.00$); and
- Competing with other players ($\bar{x} = 2.11$).

Of the 12 statements, 9 had differences in mean greater than 0.5 from the aggregated sample. These substantial differences may indicate that this case group represents those who do not value games, though this group represented the oldest group of participants.

When looking at the high school groups, differences were also notable. In Case Group C all items had means above the aggregated total and standard deviations within 0.2. Though all statements were rated higher than the aggregated means, none had means greater than 0.5 from the aggregated sample. Finally, Case Group D had means for all statements above the aggregated sample. The following statements had means 0.5 or more from the aggregated sample:

- Chatting with other players ($\bar{x} = 3.73$);
- Being part of a guild or other long term/ permanent group ($\bar{x} = 3.00$);
- Grouping or playing with other players ($\bar{x} = 3.09$);
- Exploring the game just for the sake of exploring it ($\bar{x} = 3.64$);
- Having a background story or history for your character ($\bar{x} = 3.27$);
- Acquiring rare items ($\bar{x} = 3.36$);
- Optimizing your character as much as possible ($\bar{x} = 3.73$); and
- Competing with other players ($\bar{x} = 3.55$).

Similar to Case Group B, 8 of the 12 statements were at or beyond the 0.5 difference. Case Group D represented the youngest group of participants. These differences between the four case groups demonstrate that each group may not be normally distributed; however, each case group is below the recommended minimum (Field, 2013) for EFA. These differences may be attributable to sample differences, though any judgments in this area are pure speculation without additional information. However, with that being said, it appears that younger participants, on average, rated the 12 statements higher than older participants.

Though the aggregated sample may be statistically appropriate for EFA, Flora, LaBrish, and Chalmers (2012) noted that Likert-type scales are not the most suited for EFA; however, as it was conducted in the study by Yee et al. (2012) to reduce the statements to three factors, it was employed in this study for sake of consistency and comparison. As the data used in this EFA run was collected only during the initial orientation for each case group, the data met the independence assumption. In order to determine if the sample met the assumption of multivariate normality, I used the explore command in SPSS with the parameters of displaying outliers. Analyzing the stem-and-leaf plots and box plots revealed:

- Left skewed items: chatting with other players; being part of a guild or other long-term/permanent group; learning about stories and the lore of the game;
- Centered items: feeling immersed in the world; and
- Right skewed items: keeping in touch with your friends.

The remaining statements were approximately evenly distributed:

- grouping with other players;
- exploring the game just for the sake of exploring it;
- having a background story or history for your character;
- becoming powerful; acquiring rare items;
- optimizing your character as much as possible;
- competing with other players

The Mahalanobis distance demonstrated that the probability density is close to the mean. With Mahalanobis distance representing the spread of the data and the data with only five possible values as well as means between 2.12 and 3.45 ($\Delta = 1.33$) and standard deviations between 1.297 to 1.391 ($\Delta = 0.094$), as shown in Table 6, it is to be expected that the data were compacted around the mean. However, Field (2013) noted discrepancies in the literature regarding cut scores for Mahalanobis distances with three predictors. It was noted that sufficient sample size allows for the assumption of multivariate normality to be broken if there is a large amount of consistency (Flora et al., 2012). As the sample size and consistency conditions were met and, as noted earlier, EFA was used in the study by Yee et al. (2012), the assumption of multivariate normality was held for the purposes of conducting this EFA run.

Even if all other assumptions were met, the assumption of random sampling cannot be ignored. However, Berk and Freedman (2012) noted that when the dataset is treated as the population, analysis is appropriate, but generalizability is limited. Generalizability of this study was noted in the Scope and Delimitations, and the Limitations sections of Chapter 1. While it is possible to apply the convenience sample used in this study to an imaginary population (2012), it is important to note that many factors of this study make it difficult to generalize to any population as the data regards a specific game-based HIVE. While possible to generalize to similar implementations of *The Lost Function*, these samples are still unique entities complicating replication and generalizability.

Additionally, Berk and Freedman (2012) noted that violating statistical assumptions was common in social science research employing convenience sampling, and means comparisons to other samples become important in all research within the domain of comparing traits and behaviors to any factor influencing academics. Furthermore, the noted literature alludes to flexibility with each assumption of EFA, but can create Type I and II errors (Berk & Freedman, 2012; Field, 2013; Nimon, 2012). Violation of an assumption may be critical or negligible dependent on its relationship to any study compared to it. Thus, with leniency, all assumptions of EFA can be assumed; however, it is important note this assumption implies that generalization should only be made to another sample with careful examination of differences. Additionally, this assumption was made because this study used the scale by Yee et al. (2012), in which EFA was integral.

EFA was conducted using SPSS 21.0 using principal axis factoring extracting Eigenvalues greater than 1. A direct oblique rotation was used to account for the inherent relationship between psychological constructs (Field, 2013; Flora et al., 2012). Before extraction, SPSS identified 12 factors, which Field (2013) noted as normal as the number of factors should equal the number of variables. After extraction and rotation, SPSS identified three primary factors with Eigenvalues greater than 1, accounting for 65.6% of the variance as shown in Table 7. Additional analysis of the scree plot also indicated three factors.

Table 7

Total Variance Explained for the Combined Sample

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Factor	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.541	54.509	54.509	6.218	51.815	51.815
2	1.298	10.817	65.326	.987	8.229	60.044
3	1.041	8.673	73.999	.670	5.584	65.628
4	.765	6.379	80.378			
5	.444	3.701	84.079			
6	.400	3.336	87.415			
7	.378	3.148	90.564			
8	.307	2.558	93.122			
9	.262	2.185	95.307			
10	.229	1.904	97.212			
11	.179	1.491	98.703			
12	.156	1.297	100.000			

Table 8 shows the pattern matrix resulting from the EFA. Primary factor loadings were bolded, and values between -0.1 and 0.1 removed for clarification. The pattern matrix resulted from principal axis factoring as the extraction method and Oblimin with Kaiser Normalization used as the rotation method, converging at 21 iterations. The statements creating factor 1 corresponded to the *immersion* motivation as noted by Yee et al. (2012). Factor 2 corresponded to the *social* motivation as noted by Yee et al.; however, the statement “keeping in touch with your friends” appeared with the statements corresponding to the *achievement* motivation, represented by factor 3 in the pattern matrix. The factor loadings corroborate the ideas of Yee et al. that three main factors exist, providing support for their three-factor theory. While the data did not provide a rationale as to why “keeping in touch with your friends” loaded with the items identified as the achievement pattern of gamer-behavior, it is worth noting that the statement cross-loaded with the social factor with at 0.319. This may indicate that an unidentified interaction exists such as participants of this study engaged in game play with and against their friends, thus a relationship may exist between social and achievement patterns of behavior identified by the values of the cross loadings as shown in Table 8.

Table 8

Pattern Matrix for the Combined Sample

	Factor		
	1	2	3
Having a background story or history for your character	**0.839**		
Exploring the game just for the sake of exploring it	**0.689**		0.146
Learning about stories and lore of the game	**0.630**	0.265	
Feeling immersed in the world	**0.425**	0.201	0.251
Being part of a guild or other long term permanent group		**0.820**	
Chatting with other players	0.217	**0.755**	
Grouping or playing with other players		**0.698**	0.182
Acquiring rare items	0.151		**0.774**
Becoming powerful	0.156		**0.749**
Optimizing your character as much as possible	0.361	-0.131	**0.744**
Competing with other players			**0.663**
Keeping in touch with your friends	-0.198	0.319	**0.497**

Along similar lines, the statement “optimizing your character as much as possible” cross-loaded with immersion with a load factor of 0.361. These discrepancies may indicate that the statements are perceived by this sample differently than those in the study by Yee et al. (2012). Furthermore, when comparing the pattern matrix and the variance to the study by Yee et al., there are additional similarities and differences. In contrast, the factors in the study by Yee et al. loaded into the factors of social, immersion, and achievement corresponding to the percent of variance accounted for in highest to lowest order.

Also displayed in Table 8, similar to the study by Yee et al. (2012), a majority of the factor loadings were above 0.60. In the study by Yee et al., the statements “keeping in touch with your friends”, “exploring the world just for the sake of exploring it”, “creating a background story and history for your character”, and “competing with other players” had factor loadings below 0.60. The data used in this study, however, resulted in only two statements with factor loadings below 0.60: “feeling immersed in the world” and “keeping in touch with your friends”. Unlike in the results noted by Yee et al., five statements had cross loadings greater than 0.20, two of which are above 0.30. The cutoff point of 0.30 is noted to be important as this value indicates a possible statistically significant factor loading (Costello & Osborne, 2005).

Finally, the inter-factor correlations were low in the study by Yee et al. (2012), all falling below 0.25, while this sample exhibited correlations between the achievement factor to the social and immersion factors at 0.557 and 0.556 respectively, and social was correlated to immersion at 0.387, also displayed in Table 8. In order to determine if the differences were contained with the two statements with the highest cross loadings, EFA was run again but with the statements "optimizing your character as much as possible" and "keeping in touch with your friends" removed. Running the same analysis with the removal of the two statements resulted in the Kaiser-Meyer-Olkin Measure of Sampling Adequacy 0.877, and Bartlett's Test for Sphericity was significant at $p<0.001$; however, the EFA resulted in only two factors with Eigenvalues greater than 1 and a third at 0.902. An Eigenvalue of 1 was noted to be somewhat arbitrary (Field, 2013); therefore, the EFA was run a third time specifying a result of exactly three factors. Table 9 is the resulting pattern matrix with values less than ±0.1 removed.

Table 9

Pattern Matrix after Accounting for High Cross Loadings

	Component		
	1	2	3
Learning about stories and lore of the game	**0.780**	0.194	
Feeling immersed in the world	**0.745**		
Exploring the game just for the sake of exploring it	**0.799**		
Having a background story or history for your character	**0.918**		
Chatting with other players	0.169	**0.824**	
Being part of a guild or other long term permanent group		**0.873**	
Grouping or playing with other players		**0.820**	0.252
Becoming powerful	0.416		**0.606**
Acquiring rare items	0.398		**0.619**
Competing with other players	-0.119	0.172	**0.887**

Removing the two statements with factor cross-loadings above 0.30 resulted in three factors, accounting for 76% of the variance (see Table 7) as opposed to 65% in the study by Yee et al. (2012). Next, 16 participants were considered for removal from the sample who responded with both 0 hours per week and a written response of "none"

"N/A", or "I don't play" to the statement "what type of digital game do you prefer to play" were explored. While there was no evidence suggesting that participants providing this pattern of response are opposed to digital game playing, studies by Chen et al. (2010) and Kim et al. (2009) demonstrated the importance to account for these individuals. However, these participants were not removed for the purposes of this study. If all participants with these responses provided the extreme value of 1 for each statement, then the removal may be defendable, but all of these participants responded with other values. Furthermore, some who responded with 0 hours but no written response provided all 1's for the 12 statements. Therefore, there was no justification to rerun the EFA excluding participants, and the dataset was analyzed as a whole; however, Field (2013) noted this practice is not uncommon. Subsequent analysis will include the three statements as social and the five statements as achievement instead of the evenly distributed arrangement by Yee et al. (2012).

The exploratory factor analysis indicated that three predominant factors existed in the sample: immersion, social, and achievement. However, the statements from the Motivations to Play Online Games by Yee et al. (2012) do not completely meet the behaviors of a wider population of including those who play games of different genres and those who do not play digital games. This misalignment may be the cause of the differences in the data in this study, further detailed in Chapter 5. While misalignment existed, there was enough statistical significance in the existence of the three dimensions to analyze their relationship with time-on-task when mathematics remediation occurs in the game-based HIVE, *The Lost Function*.

Regression Analysis

As the literature noted that gender may influence attitude towards digital games (Bonanno & Kommers, 2008; Chen et al., 2010) and motivation to engage (Park et al., 2011; Yee et al., 2012), gender was explored as a moderator variable prior to conducting the regression analysis. Like the EFA, all analysis of moderators was conducted using SPSS 21.0. First, the three independent variables representing the immersion, social, and achievement factors were created as the sum of the scores from the associated statements. As there were four, three, and five statements for each of the respective factors, the total for each factor was normalized by taking the mean for each participant retaining the 1 to 5 scale.

Next, simple linear regression was run using PROCESS for SPSS (Hayes, 2014) to determine if gender was a moderator variable. As PROCESS can test up to 76 different models, Field (2013) suggested using model 1, representing simple moderation. At the 95% confidence interval, the interaction between gender and immersion was insignificant ($F<0.001$, $p=0.993$). Additionally, the interaction between gender and social was also insignificant ($F=0.801$, $p=0.777$) as was the interaction between gender and achievement ($F=0.558$, $p=0.457$). As no interaction was found between the three factors representing patterns of gamer behavior, gender does not appear to be a moderating variable for the dataset used in this study. With the aggregated dataset, this result was contrary to what was noted by previous researchers such as Yee et al. (2012). This result may be due to the greater proportion of female to male participants in this study, displayed in Table 4.

The same regression process was used to determine if age-band, representing approximate age, was a moderating variable. While the interaction between age-band and immersion was insignificant (F=0.188, p=0.665) as was the relationship to social (F=1.165, p=0.283), the relationship between age-band and achievement was significant at the 95% confidence interval (F=4.208, p<0.05). Additionally, there was a statistically significant positive relationship between students in the college level groups between age-band and statements identified as achievement factors: b=222.626, 95% confidence level, [-68.821, 376.431], t=2.869, p<0.01. Table 5, indicating the differences in hours played per week, made some of these relationships predictable. This relationship may be explained by a number of factors, including differences in motivations between college level and high school level students; however, without follow-up data, this is speculation.

To answer the research question "is there a significant relationship between patterns of gamer behaviors and time-on-task as a result of mathematics remediation in a game-based HIVE for US students" multiple linear regression was selected, as noted in Chapters 1 and 3. The PROPHET StatGuide (BNN Corporation, 1997) noted eight assumptions of multiple regression including:

- The lack of unaccounted for independent variables;
- The observations are independent, with Y's independent;

- The slopes of the linear models are essentially the same (multicollinearity);
- There are no significant outliers;
- The dependent values are nonnormal;
- The variance in the dependent variable is consistent (homoscedasticity);
- The individual models are linear; and
- The independent variables are fixed and continuous.

These eight assumptions are critical to accurate calculation of minimal linear regression and the associated power to generalize. Examining this list after performing the EFA illuminated violations of the assumptions of multiple regression.

First, as noted by Field (2013) and Yee et al. (2012), social science research inherently includes inter-relationships between factors as well as the prevalence of unaccountable factors, such as those noted in Chapter 2 with regard to factors influencing learning mathematics. Furthermore, as the scale was developed to investigate behaviors of gamers, the three factors may not account for all possible independent variables, and it is impossible to guarantee the lack of unaccounted independent variables. Additionally, as participant data used in this study came from pre-existing case groups, there is an inherent hierarchical nature to the data. Thus, the data inherently fails the assumption of unaccounted independent variables, and the violation of this assumption cannot be mitigated. The idea of measuring social science constructs, which cannot be fixed as they are dependent on the participant, also violated the assumption of fixed independent variables. Field (2012) noted that a violation of this assumption creates bias in the regression coefficients.

Analysis of the dataset as well as basic descriptive statistics demonstrated the presence of outliers and its left-skewed nature, as shown in Table 10. According to the Empirical Rule, 95% of the data should fall within 2σ from the mean, yielding a maximum time of 1827.173 minutes or 30.5 hours. Furthermore, another common method of determining cutoff points for outliers is one and a half times the interquartile range (1.5 x IQR). The IQR for time was 550.54 minutes; therefore, the value for determining what is considered an outlier when working with box-and-whisker plots is 825.81 less than the first quartile and greater than the third quartile. With the first quartile at 15.925 minutes, all lower end values are within the normal range; however, as the third quartile is 566.467 minutes, the cutoff for higher values is 1,392.277 minutes or 23.2 hours. The time data for seven participants would be considered outliers, with each participant in a college level case group, with four in Case Group A and three in Case Group B.

Table 10

Descriptive Statistics Relating to Time-on-Task (in minutes)

	Minimum	Maximum	Mean ($\bar{x}$)	Std. Dev. (σ)
Aggregated Total	0.00	5312.52	422.155	702.509
Case Group A	0.00	5312.52	987.793	964.921
Case Group B	0.00	2302.63	754.611	699.136
Case Group C	0.00	266.28	37.609	55.704
Case Group D	128.38	434.08	269.073	101.582

However, as the range for the dataset was large, analysis of the mean, median, or other related statistics may not be representative. From the dataset, 42.1% of the dataset played less than 60 minutes, 50% played less than 2.5 hours, with approximately 75% who played less than 10 hours. The distribution of the amount of time participants used *The Lost Function* demonstrated that a substantial portion of the sample spent a relatively small amount of time engaged in the game: less than 60 minutes.

Finally, while linearity was tested in preparation for the multiple regression runs, linearity in the individual case groups was difficult to ascertain without removing outliers. Removing outliers would create a discrepancy between the tested sample and the true sample, potentially polluting the results of this study regarding the sample as a whole. However, as outliers were identified when the assumption of normality in distribution was checked, scatter plots were generated with outliers removed to determine if a linear relationship existed between each pattern of game behavior and time-on-task. The linear relationship between each of the three patterns of gamer behavior (IVs) and time-on-task (DV), one of the most critical assumptions of multiple regression, was impossible to verify for the combined sample and the individual case groups because of the distribution and range of the dependent variable. While the removal of outliers assisted with this analysis, the number of students in each group who used the product for less than one hour skewed part of the data making it appear non-linear. It is possible that by removing those who used *The Lost Function* for less than one hour may attend to this violation, but removal of approximately 45% of the sample would not represent the dataset. Therefore, a linear relationship could not be determined as it is unknown if the statistical outcomes were attributable to violations of statistical assumptions, the range and distribution of the data, or the number of students engaged for less than one hour.

On the other hand, if the assumptions only impacted generalizability, this study helps the understanding of relationships between the learner to specific game-based learning characteristics, in this case, the relationship between personality factors related to gamer behaviors and the user experience in *The Lost Function*, a game-based HIVE. Additionally, Simon (2003) noted that some studies conduct multiple regression in order to determine if a relationship exists without regard to the assumptions. Berk and Freedman (2003) proposed the idea of an "imaginary population and imaginary sampling mechanism" (p. 4) for addressing some violations of statistical assumptions.

Therefore, with no intent for generalization along with the knowledge that Type I and II errors will influence any hypothesis acceptance, the following results of multiple regression are presented. The data analysis assumed the following equation:

$$y = constant + (influence\ of\ gender\ and\ age\ band) + b_1(Achivement) + b_2(Immersion) + b_3(Social) + \varepsilon$$

where the influence of gender and age-band represent the respective control variables, *b* represents a slope for each factor, and ε represents the error. As noted by Simon (2003), statistical noise exists in all studies within the social sciences. Table 11 shows the correlations when related to time-on-task.

Table 11

Pearson's r and Significance for the each Factor in Relationship to Time-on-Task

	Immersion	Social	Achievement	Gender	College vs. HS
Pearson Correlation	-0.128	-0.063	-0.047	0.172	-0.547
Significance (1-tailed)	0.087	0.254	0.310	0.033	< 0.001

The Pearson correlations demonstrate that most factors have an insignificant relationship to time-on-task; however, a moderate relationship exists to age-band, with those in a college tending to spend more time-on-task ($p<0.001$) as well as females spending more time-on-task than males ($p<0.05$). Additionally, while not significant at the 95% confidence level, the immersion factor has a mild negative correlation to time-on-task at the $p<0.10$ level. Table 12 illustrates the model summary with Table 13 showing the excluded variables for the stepwise multiple regression run. However, as noted earlier, not only does this information only pertain to this sample, interpretation and application of the reported correlations should only be done with caution because of violations of the statistical assumptions and sample representativeness noted previously.

Table 12

Regression Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.547[a]	.299	.293	590.78054
2	.578[b]	.334	.310	583.54424

a. Predictors: (Constant), HSvsCol

b. Predictors: (Constant), HSvsCol, Social, Immersion, Achievement

c. Dependent Variable: Time

Table 13

Regression Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation
1	Gender	-.040[b]	-.467	.642	-.044
	Immersion	.029[b]	.354	.724	.034
	Social	.089[b]	1.086	.280	.103
	Achievement	.165[b]	1.980	.050	.185
2	Gender	-.034[c]	-.391	.696	-.038

a. Dependent Variable: Time

b. Predictors in the Model: (Constant), HSvsCol

c. Predictors in the Model: (Constant), HSvsCol, Social, Immersion, Achievement

The stepwise method of multiple regression was selected to determine the influence of the control variables and the three patterns of gamer behaviors on time-on-task when engaged in a game-based HIVE for mathematics remediation. At step 1 of the regression analysis age-band entered into the regression equation and was related to time-on-task $F(1,112)=47.73$ at $p<0.001$. The multiple regression coefficient, noted in Table 12, was 0.55 representing approximately 29.9% of the variance in time-on-task from age-band. All other variables did not enter the regression analysis at step 1, noted in Table 13. At step 2, the three patterns of gamer behavior entered the regression equation along with age-band. With $F(4,109)=13.69$ at $p<0.001$, the multiple regression coefficient was 0.58 accounting for 31% of the variance in time-on-task. The difference between in the significance and the accounted variance once the three gamer-behaviors were included, as noted in Table 12, was $\Delta R=0.031$ with an increase in the variance accounted for an additional 3.5%.

The normal P-P plot of regression (Figure 6) demonstrated that the normality assumption was met, as the display represented a non-normal distribution when compared to expected values of a linear relationship and resembles a cubic function. However, in parent cubic functions, a tangent line drawn at the origin yields a slope of zero, representing a mathematical change in direction, also known as a critical point. The P-P plot indicated that the actual values of the dependent variable, time-on-task, did not match the theoretical values of a linear model demonstrating the non-normality of the aggregated dataset with regard to the dependent variable.

Additionally, analysis of the Q-Q plot (Figure 7) may indicate a non-linear function. The shape of the Q-Q plot is similar to a right translated radical function. The Q-Q plot demonstrated that the linear model may not be a good fit for the dataset. Taken with the shape of the P-P plot, a bi-modal dataset may exist, and analysis using a linear model may not be appropriate. While not a component of the multiple regression run and the analysis presented here, the data in Table 5 regarding the amount of time spent playing games may support the idea of a bi-modal dataset based on age-band. In order to explore this idea further, the dataset was split into two groups representing the two age-bands for post-hoc analysis. Testing for non-linear models was not performed because of the nature of the anonymous third-party dataset, including that the combined dataset represented four unique groups having differing amounts of access, information not included with the data.

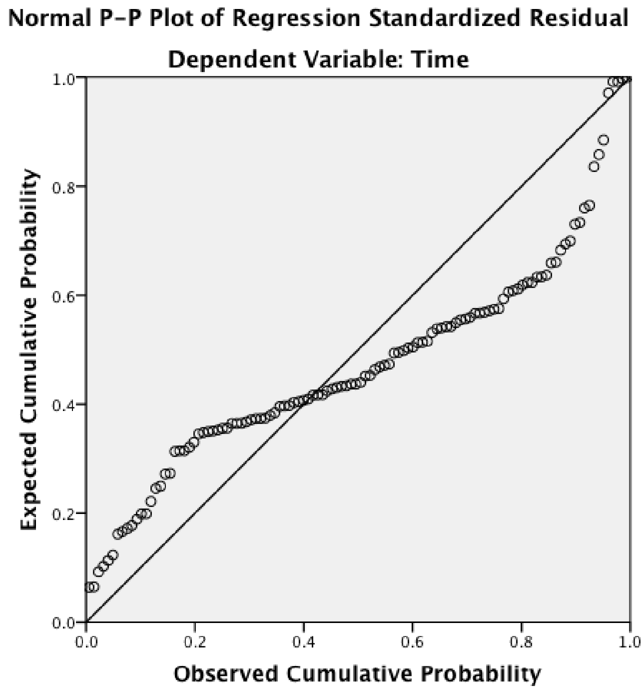

Figure 7. Normal P-P Plot of Regression for the combined dataset.

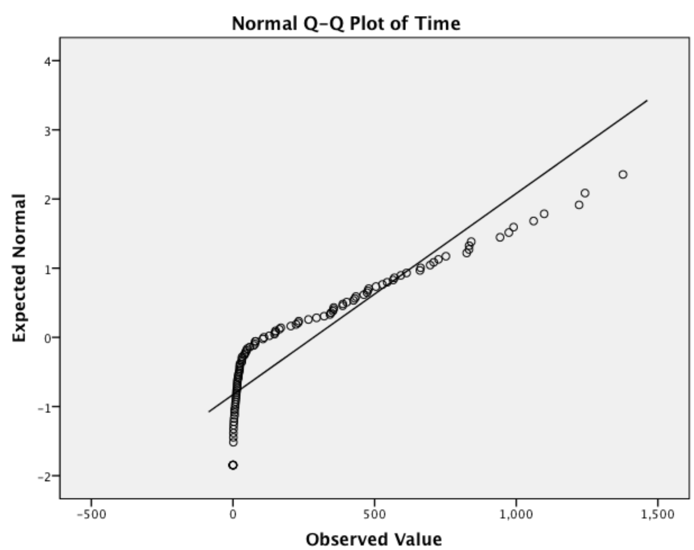

Figure 8. Q-Q Plot for the dependent variable for the combined dataset.

Post-Hoc Analysis

Splitting the data set into groups seemed logical through the previous analyses as well as understanding that the case groups are pre-existing structures. However, each case group was not randomly sampled and may not represent any population except when the sample is taken as the population. However, Field (2013) noted that all linear statistical models assume the independence of errors and lack comorbidity in residual scores. Each case group could be analyzed independently, though the sample sizes fall below the recommended sample size for detecting a large effect. However, looking at age-band groups may provide useful information, though the statistical assumptions were still violated.

The Q-Q plots for both the college age group and high school age group demonstrated non-normality in the datasets. Additionally, the Shapiro-Wilk test was significant at the $p<0.001$ level for both groups, indicating that the datasets were not normal. While the multiple regression results should only be investigated with caution, some Pearson correlation coefficients were significant. However, as the assumptions of Pearson's r are similar to those of linear regression (Field, 2013), the following results in Table 14 and 15 should not be generalized beyond the age-band groups of this study, nor should the significance or correlation coefficients be deemed as representative.

At the college level (n=51), time-on-task was mildly correlated with the achievement domain (0.266, $p<0.05$). The immersion factor correlated with the social factor (0.632, $p<0.001$) and the achievement factor (0.771, $p<0.001$). Additionally, the social factor correlated with the achievement factor (0.454, $p<0.001$). Finally, gender correlated with the immersion factor (0.259,$p<0.05$) and the achievement factor (0.264, $p<0.05$).

Table 14

Significant Pearson's r for College Groups

	Time-on-Task	Immersion	Social	Achievement	Gender
Time-on-Task				0.266 *	
Immersion			0.632 **	0.771 **	0.259 *
Social		0.632 **		0.454 **	
Achievement	0.266 *	0.771 **	0.454 **		0.264 *
Gender		0.259 *		0.264 *	

Note: Correlations not significant at the 95% level or better were removed for clarity
* Significant at $p<0.05$
** Significant at $p<0.001$

Similarly, the high school group (n=63) demonstrated correlations under Pearson's r. First, time correlated with gender (-0.425, $p<0.001$). The immersion factor correlated with both the social factor (0.526, $p<0.001$) and the achievement factor (0.615, $p<0.001$). Additionally, the social factor correlated with the achievement factor (0.604, $p<0.001$). Gender correlated with all three factors at at least the 95% confidence interval: immersion (-0.225), social (-0.231), and achievement (-0.207).

Table 15

Significant Pearson's r for High School Groups

	Time-on-Task	Immersion	Social	Achievement	Gender
Time-on-Task					-0.425 **
Immersion			0.526 **	0.615 **	-0.225 *
Social		0.526 **		0.604 **	-0.231 *
Achievement		0.615 **	0.604 **		-0.207 *
Gender	-0.425 **	-0.225 *	0.231 *	-0.207 *	

Note: Correlations not significant at the 95% level or better were removed for clarity
* Significant at $p < 0.05$
** Significant at $p < 0.001$

In an effort to be thorough, though three of the four case groups fell below the minimum sample size for a large effect, the data file was split to analyze each case group independently. Unfortunately, as with the combined groups, each case group fails the independence of sampling assumption (Nimon, 2012), as no group represents a random sample. This method, however, reduces the influence of the independence of observations, though, again, there is an inherent grouping. As with all social science research, it is difficult to guarantee the independence of dependent variables (2012). In addition to small sample sizes, none of the case groups included normal distributions of data nor were the residuals normally distributed. Q-Q plots demonstrated violations of the assumptions of normality and are provided in Appendix E for reference.

An additional post-hoc EFA analysis was conducted on the 12 statements for each of the four case groups for exploration using the same parameters of the original EFA run. It is important to note that all four case groups had sample sizes below the minimum recommendation of Field (2013) of 60. However, EFA was run on each case group independently to determine if any notable differences appeared. The following discussion may not useful for extrapolation or generalizability and is presented for exploratory purposes.

The 12 statements loaded into 4 factors for Case Group A with the fourth factor accounting for 9.6% of the variance. While most of the factors loaded similarly to those from the aggregated sample, “feeling immersed in the world” loaded with the social factors at 0.71. Additionally, “keeping in touch with your friends” and “competing with other players" loaded into the fourth factor with absolute values greater than 0.4. Case Group B, on the other hand, resulted in three factors; however, factor one, labeled as immersion in the aggregated sample, included the initial four factors as well as "becoming powerful", "acquiring rare items", "optimizing your character as much as possible", and "competing with other players" with absolute values of 0.6 or greater. Factor two, labeled as social in the aggregated sample, only included the statement "keeping in touch with your friends" loading at 0.76, though it accounted for 12% of the variance. Factor three included the items initially loading into the social factor. There was no distinctive achievement factor as those statements loaded with the statements labeled as immersion. The factor loadings for the two college age groups are displayed in Table 16 along with the aggregated factor loadings. Primary factor loadings were bolded, and values between -0.1 and 0.1 removed for clarification.

Table 16

Pattern Matrix for Case Groups A and B with Aggregated Sample for Reference

	Aggregated Sample			Case Group A				Case Group B		
	1	2	3	1	2	3	4	1	2	3
Having a background story or history for your character	**0.839**			0.374		**-0.701**		**0.912**	-0.103	
Exploring the game just for the sake of exploring it	**0.689**		0.146		0.337	**-0.734**	0.203	**0.680**		0.201
Learning about stories and lore of the game	**0.630**	0.265		**0.702**	0.396	0.156		**0.531**		0.488
Feeling immersed in the world	**0.425**	0.201	0.251		**0.705**	-0.253	0.232	**0.727**	0.513	
Being part of a guild or other long term permanent group		**0.820**		-0.192	**0.845**		-0.197			**1.036**
Chatting with other players	0.217	**0.755**			**0.799**	-0.191		0.132		**0.813**
Grouping or playing with other players		**0.698**	0.182	0.387	**0.547**	0.328				**0.985**
Acquiring rare items	0.151		**0.774**	**0.931**			-0.215	**1.002**		
Becoming powerful	0.156		**0.749**	**0.901**	-0.110	-0.121		**1.009**		-0.105
Optimizing your character as much as possible	0.361	-0.131	**0.744**	**0.957**	-0.111			**0.981**	-0.233	
Competing with other players			**0.663**	**0.625**	-0.245	-0.158	0.415	**0.588**	-0.169	0.416
Keeping in touch with your friends	-0.198	0.319	**0.497**	0.257	**0.545**	0.449	0.467	0.154	**0.761**	0.281

Differences also existed with the high school groups. Case Group C also resulted in four factors accounting for 77% of the total variance. The factors resulting in the EFA run for Case Group C aligned with the initial study by Yee et al. (2012); however, the initial third factor was distributed between factors 1 and 2, as well as a fourth factor composed of the statements “acquiring rare items” and “competing with other players”. The fourth factor accounted for 7.8% of the variance. Furthermore, 9 of the 12 statements loaded into factor 3 with absolute values above 0.1, yet none had factor loadings whose absolute value was above 0.5. Finally, the EFA run for Case Group D resulted in only two factors accounting for 89% of the variance in the sample. All statements loaded into the first factor between 0.61 and 0.97; however, “chatting with other players” loaded into both factors above 0.6 and was the only statement that loaded into the second factor. The factor loadings for the two high school age groups are displayed in Table 17 along with the aggregated factor loadings. Primary factor loadings were bolded, and values between -0.1 and 0.1 removed for clarification. The differences between the initial EFA run using the combined sample and each case group most likely resulted from the sample sizes well below the recommended minimum, though this cannot be guaranteed. For example, differences may be attributable to different ages or other sample characteristics, yet cannot be explored further due to limitations of using anonymous third-party data. Rationale for differences is further explored in Chapter 5.

Table 17

Pattern Matrix Case Groups C and D with Aggregated Sample for Reference

	Aggregated Sample			Case Group C				Case Group D	
	1	2	3	1	2	3	4	1	2
Having a background story or history for your character	**0.839**			**0.930**	0.105		0.166	**0.940**	-0.219
Exploring the game just for the sake of exploring it	**0.689**		0.146	**0.879**	-0.201		-0.139	**0.947**	0.206
Learning about stories and lore of the game	**0.630**	0.265		**0.926**		-0.228	0.115	**0.865**	-0.294
Feeling immersed in the world	**0.425**	0.201	0.251	**0.708**		0.141	-0.117	**0.947**	0.206
Being part of a guild or other long term permanent group		**0.820**		0.106	**0.742**	-0.258	0.132	**0.882**	0.125
Chatting with other players	0.217	**0.755**		0.256	**0.595**	-0.434	-0.181	0.609	**0.651**
Grouping or playing with other players		**0.698**	0.182		**0.424**	-0.397	-0.132	**0.925**	0.261
Acquiring rare items	0.151		**0.774**	0.259	0.119	0.380	**-0.516**	**0.904**	-0.244
Becoming powerful	0.156		**0.749**	0.298	**0.564**	0.418		**0.939**	
Optimizing your character as much as possible	0.361	-0.131	**0.744**	**0.585**		0.256	-0.490	**0.884**	0.136
Competing with other players			**0.663**	-0.135			**-0.960**	**0.967**	
Keeping in touch with your friends	-0.198	0.319	**0.497**	-0.190	**0.892**	0.262		**0.954**	-0.104

Summary

An exploratory quantitative research design was used to uncover any relationships between patterns of gamer-behaviors and time-on-task when mathematics remediation occurs in a game-based HIVE. Though multiple regression is generally used to uncover relationships between multiple independent variables and to allow for generalization to a larger population (Field, 2013; Simon, 2003, Statsoft, Inc., 2013), the dataset used in this study violated all statistical assumptions of multiple regression. The multiple regression run demonstrated that most factors had an insignificant relationship to time-on-task, except for a moderate relationship to age-band. The nature of the historical, third-party data used in this study limited analysis to exploration only. Therefore, any statistical results should be interpreted with caution and should not be applied to other groups without careful consideration.

The aggregated sample of the four case groups demonstrated similar results from the exploratory factor analysis run when compared to the study by Yee et al. (2012) with the data reducing to three factors. While some differences in factor loadings are to be expected between different samples, the statement "keeping in touch with your friends" loaded into the achievement factor as opposed to the social factor from the study by Yee et al.. Further investigation lead to transformations to account for higher than expected cross-loadings yet resulted in a similar outcome. However, though the results of EFA were similar to those in the study by Yee et al., it is prudent to note that the data violated the assumptions of exploratory factor analysis and may not be accurate beyond describing the dataset as its own population.

Next, the differences exposed between the two age-bands and the shapes of the P-P (Figure 6) and Q-Q plots (Figure 7) possibly represented two normally distributed groups within the data. In post-hoc analysis, I split the data into groups by age-band to determine if the apparent bi-modal distribution demonstrated statistical significance in the separate groups. The post-hoc multiple regression analysis demonstrated that the bi-modal distribution was not attributable to age-band.

Also in the post-hoc analysis, EFA was run on each case group for further exploration, though none of the case groups met the minimum sample size recommended by Field (2013). While the results of this post-hoc analysis should only be extrapolated to another group with care, the results demonstrated differences in the number of factors and degree of factor loading (see Tables 16 and 17). Interpretation of the EFA results are provided in Chapter 5. Chapter 5 concludes this dissertation by providing an interpretation of findings, implications, and follow-up questions from the data analysis in Chapter 4.

Chapter 5: Summary and Conclusions

Introduction

The purpose of this quantitative study was to explore the relationships between the patterns of gamer-behaviors of social, immersion, and achievement motivations to time-on-task for students using a game-based HIVE for remediation in mathematics. The quantitative nature chosen for this study was correlational, using historical data from four pilot studies conducted by AT&LT. This study was conducted in order to determine if a relationship existed between the independent variables of this study, the three motivational patterns of gamer behaviors identified by Yee et al. (2012) as social, immersion, and achievement motivations, and the dependent variable for this study, time-on-task while learning in a game-based HIVE.

The key finding from this study was that the data provided inconclusive results when generalized to a larger population. However, if the sample is taken as a population, many of the assumptions may be ignored (Field, 2013; Simon, 2003). Violations such as independence, existence of outliers, and normality create too much statistical noise (Field, 2013; Nimon, 2012). While each assumption may be accounted for, accounting for all assumptions overly modified the dataset to provide viable data, still limiting any statistical analysis to the dataset as a population; therefore, all statistical results may decrease power and/or impact the significance of the results. However, the study still resulted in interesting information.

Interpretation of the Findings

Chapter 2 began with the conceptual framework that included the importance of play, the role of engagement, and the necessity of adequate support for the learner. While making comparisons to these three domains was difficult because of the nature of the data provided by AT&LT, the data did not discount the importance of the three domains noted in the theoretical framework. However, analysis demonstrated some correlations to time-on-task, a proxy for engagement. Violations of the assumptions of multiple regression meant that any correlations and their associated probabilities should only be applied to other groups with care, though. While time-on-task may be a proxy variable for engagement, there is no way to determine if the correlations to time-on-task related to engagement with the content, aligning with the difficulties for exploring engagement noted in the literature.

Taking these limitations into account, the multiple regression run demonstrated a statistically significant relationship between time-on-task and age-band, with those in the college level groups engaging more. From the initial scale by Yee et al. (2012), the immersion factor mildly related to time-on-task as was gender, significant at $p<0.1$ and $p<0.05$ respectively. Contrary to the literature, the immersion factor was negatively correlated to time-on-task. While this may have been a result of violating statistical assumptions or sample characteristics, the data do not lend themselves to conclusions regarding this relationship. In order to test the importance of play or the importance of learner support, an experimental design involving controls and treatment groups would be necessary for investigation. Without pre and post assessment data, it would be difficult to see direct academic impact.

The messiness of the statistics resulting from violations of the statistical assumptions demonstrated an important problem when working with third-party data. While the data used in this study were collected through uniform orientations provided by the same person and the in-game metrics were collected in the same manner, the dataset violates important assumptions of multiple regression including independence, multicollinearity, the existence of outliers, and the fixed nature of the independent variables. These assumptions become critical and are easily violated when combining data from multiple sources.

The resulting methodological issues identified in this study are significant to the outcomes of this study and are relevant today. One area where statistical assumptions may cause issues is the idea of big data. Big data are the aggregation of data from a variety of sources that can sense, collect, and pass on information resulting in hundreds of thousands to billions of data point (IBM, 2014; Lohr, 2012). According to Gartner's *2014 Hype Cycle of Immerging Technologies*, a yearly report graphically displaying the progression of an innovation through the adoption process, big data crested the *Peak of Inflated Expectations* and is moving into the *Trough of Disillusionment.* The idea is that with a large enough number of data points regarding the same piece of information may allow for accurate predictions. However, the data points could come from many different and unrelated collections with no guarantee of overlap.

For example, many websites track which advertisements are clicked on and how often users navigate to the advertised service. Organizations collect information on TV viewing habits and viewer preferences for advertisements. While these two pieces of data may represent the same construct, they are collected in different manners, under different circumstances, using different methodologies, and from different populations. Uncontrolled differences, similar to the case groups in my study, result in violations to statistical assumptions making any generalization or extrapolation questionable. While violations of the statistical assumptions may be mitigated by transforming the data or removing the offending data points (Berk & Freedman, 2003; BNN Corporation, 1997; Field, 2013), the results may not represent the population expected. The repeated transformations and the removal of data that does not fit the model takes away from the purity of the statistical model and may yield disingenuous results. As noted by researchers such as Berk and Freedman (2003), Nimon (2012), and Simon (2003), transformations and data cleaning are often performed to account for violations of assumptions and to create a better fit of the data to expected models. However, these processes reduce the generalizability and the trustworthiness of the findings. Therefore, this study reiterates cautionary notes regarding blind acceptance of findings of any study that violates statistical assumptions for which the analysis of big data has the potential.

The Lost Function includes many components aligning with supportive elements noted in the conceptual framework; however, no one product is perfect. There are differences between what would be optimal and reality. For example, enabling a voice over component would accommodate those with limited English proficiency or those who read below a 6th grade level. Features increasing appeal to the social domain may facilitate participation for some learners, even though *The Lost Function* includes many pedagogical agents.

The theoretical framework encompassed the idea that responses to statements regarding behaviors can be measured and will reduce down to measurable factors that may provide insight into patterns of gamer behaviors. Using the premise of Yee et al. (2012) that game players exhibit behaviors that fall into three predominant factors of achievement, immersion, and social, and these factors account for the majority of variance in a sample, this study attempted to apply the same theory to students using a game-based HIVE for mathematics remediation. The results confirmed the idea of Yee (2005) that the factors are independent of each other and that people may be high or low in each of the factors. While the 12 statements used by Yee et al. still reduced to three factors, "keeping in touch with friends" loaded into the factor termed achievement instead of the factor termed social in this study. Though this study did not explore reasons behind this phenomenon, it is possible that players of other types of games, beyond *World of Warcraft* may play socially. For example, console games may be played cooperatively or competitively with friends. This is the same with other types of games and genres. One example of this are games found on Facebook, many of which are social, requiring either cooperation or competition to move forward. While no comparisons were made in this study to other personality factors, such as those noted in the Big 5, relationships to gender and age-band were found, similar to those in the literature. Further investigation with the elimination of two statements from the initial list of 12 statements that both fell under what Yee et al. termed the achievement factor resulted in finding two additional statements under the same factor having cross-loadings above 0.30.

The differences between the initial EFA run using the combined sample and each case group (see Table 16 and 17) most likely resulted from the sample sizes well below the recommended minimum, though this cannot be guaranteed. For example, differences may be attributable to different ages or other sample characteristics. While beyond the scope of this study, it is possible the statements may not represent the idea of achievement for the sample used in this study. It is also possible that these statements may not be appropriately worded to have meaning to a wider population than *World of Warcraft* players. For example, players of puzzle games like *Candy Crush* may not be able to relate to statements like “becoming powerful”, yet a statement such as “advancing to the next level or challenge, or becoming more powerful” may encompass a broader spectrum of digital game players. With many similarities and differences found between the original EFA conducted by Yee et al. (2012), the combined sample in this study, and the individual case groups, the additional EFA runs support the idea that the 12 statements reduced to general factors. While the combined sample supports the idea of the three-factor model of achievement, immersion, and social patterns of gamer-behaviors, analysis of individual case groups may not. Although the post hoc analysis did not uncover relationships behind the appearance of a bimodal dataset, the additional EFA runs supported the idea behind distinctive patterns of gamer behaviors. Furthermore, analysis of the individual case groups suggests that the 12 statements may not have the same meaning across different sample characteristics because of differences in factor loadings, shown in Table 16 and 17, though additional research would need to be conducted to support or refute this claim.

One important difference existed between the studies noted in the theoretical framework and the data used in this study: studies in the literature investigating player motivation used players of digital games. The studies by Graham and Gosling (2013), Yee (2005), and Yee et al. (2012) used self-selected players of *World of Warcraft*. Jeng and Teng (2008) included only students with online game experience in their study using the Big 5 personality traits. Park et al. (2011) did not provide information about non-gamers. Konert et al. (2013) included secondary students and looked at a variety of personality factors, but only looked at correlations between different personality factors of different inventories, though Konert et al. did not specify if participants were selected because of digital game experience. However, similar to this study, Konert et al. found some relationships but was inconclusive overall. In line with similar studies, this study found the existence of personality factors representing patterns of gamer behaviors, but strong relationships between the three patterns of gamer behaviors to engagement could not be determined in this study. Furthermore, similar to the study by Park et al. (2011), correlations were found between the patterns of behavior to gender and age-band.

Additionally, inter-relationships are possible between the three factors, similar to what Yee et al. (2012) noted. Although the results show a statistically significant relationship between the immersion factor and time-on-task, the findings do not lead to any concrete information regarding the relationship between patterns of gamer behaviors and time-on-task when mathematics remediation occurs in a game-based HIVE.

Limitations of the Study

Riddled with statistical assumptions that were violated by the nature of the dataset, there should be little generalizability from the data and analysis (Nimon, 2012) representing the greatest limitation. While some assumptions were easily managed, such as using oblique rotation to accommodate data with potential interrelations, statistical transformations create noise and may lead to Type I and Type II errors (Nimon, 2012). The sample sizes estimated from the a priori sample size calculator for multiple regression (Soper, 2014) required estimated effect sizes for calculation. Though values were provided for small, medium, and large effects, these values are recommendations and may not accurately allow for comparisons regarding sample sizes. Though the literature provides a large range of participants for exploratory factor analysis and I accepted the total sample size as within the bounds provided, it should still be noted as a limitation as the sample size was small. For hierarchical data, as was used in this study (students in classes, in schools, violating independence), hierarchical or multilevel modeling may be used, but they have many of the same assumptions as those without nesting (Nimon, 2012), therefore a change in statistical methodology would not mitigate all assumption violations. Repeated application of transformations move the data further away from the original dataset, contaminating the results and lead to improper or unreliable results (2012).

One limitation to this study was the number of participants who played *The Lost Function* for less than 60 minutes. The substantial number of students using the game-based HIVE in this limited fashion may reflect a normal population distribution with regard to serious games used for remediation purposes. However, it is plausible that this phenomenon may be an emergence of the mortality threat to validity: students who struggle with math and may have a negative perception, must do more math. However, Type I or Type II errors may occur with the acceptance of either hypotheses due to external threats such as of failure of the teacher to adopt the program or a resource limitation. Furthermore, many internal threats existed because of the violation of statistical assumptions.

Anonymous third-party archival data is also a limitation to this study. With no control over methodological factors, such as sample selection, as well as access to historical data regarding one game-based HIVE, many generalizations may not be made. While results were reported from analysis of the data, the results should only be considered applicable to this dataset, and there is a high chance that the results are skewed as all assumptions were violated (Nimon, 2012).

Research Recommendations

Future research projects into the educational potential of game-based HIVE would benefit from some of the outcomes of this dissertation. While methodological changes may eliminate or reduce the influence of statistical assumptions, this may not be the solution to all problems. First, the optimal quantitative methodology would be a true experiment with randomly selected participants; however, this is difficult to accomplish in social science. In reality, control and treatment groups of statistically sound sample size from the same site may allow for some control, but still violates the independence assumption. Next, research should continue into patterns of behaviors when engaging in specific educational activities in order to understand their impact. Understanding the relationships between patterns of gamer behaviors and how the relationship influence achievement when using digital games is critical for efficacy research as well as meeting the needs of the intended audience.

Multiple case groups should be considered for future studies to allow for broader understanding of mathematics remediation using a game-based HIVE; however, the samples at each site need to fall between the minimum recommended sample size for large and medium effects. On the same note, sample sizes for each case group should be at least 60 representing the minimum sample size for EFA (Field, 2013). While sample sizes provided are recommendations, they may be sufficient to detect a large effect as well as allowing for comparing EFA results. Optimally, it would be useful to have a large enough sample size to allow for comparisons between groups who played digital games for different amounts of time. This would be especially interesting if the group who noted they played less than 1 hour could be compared to the remaining portion of the sample as well as follow-up anecdotal data regarding those who identified playing zero hours per week.

The means for the following statements with less than 0.25σ of 3, represented "somewhat important" on the 5-point Likert-type scale (see Table 6):

- feeling immersed in the world;
- exploring the game just for the sake of exploring it;
- having a background story or history for your character;
- becoming powerful;
- acquiring rare items;
- optimizing your character as much as possible; and
- competing with other players.

Furthermore, "feeling immersed in the world" had a mean of 3, with the smallest distribution according to the standard deviation ($\sigma = 1.297$). It is unknown if some statements were neither important nor unimportant, or if the statements, as written, were inappropriate for a general population of learners.

The differences that appeared from EFA should be a future topic of research. This could potentially span a large range of studies including determining if a more appropriate set of statements would accommodate differences in game-playing preferences. Additionally, it may be worth understanding if different scales representing the differences in genres of digital games would be appropriate for matching learners to digital learning environments, or if a unified scale could be created to accommodate all learners. Finally, understanding the difference in the factor loading of the statement “keeping in touch with friends” and its movement to the statements loading into the achievement factor are worth exploring. Is this shift due to a change in the types of games available, a shift to inexpensive games through mobile devices, an emergence of a social cooperative-competitiveness where players still want to win, but will help friends, or some other unknown factor?

The data provided by AT&LT used in this study was archival. While companies in the serious gaming industries may consider studies with larger sample sizes, the statistical assumptions remain. For example, even a large-scale study conducted at a single site with a sample of 1,000 participants means generalizability may still be limited to the sample studied. Future research should also investigate areas some of the irregularities within the dataset. For example, the college level case groups were either pre-service teachers or in-service teachers and predominantly female (96%), while the sample as a whole was 79% female. Would the results be more evenly distributed with a wider variety of adult users requiring mathematics remediation? Bonanno and Kommers (2008), Chen et al. (2010), and Park et al. (2011) noted gender significantly related to perceptions of games and/or motivations to engage in playing digital games. While the scale used in this study was developed from studies conducted using *World of Warcraft* players, none of the participants noted it as their favorite game and only two noted role-playing games as their favorite genre. With this difference, would changing the language of the scale by Yee et el. (2012) so that each construct would be meaningful to players of all digital games strengthen the study? In addition to changing the language, it is also prudent to determine if digital game based learning is appropriate to the sample, as this study included 55% who noted spending zero hours per week playing digital games.

As noted in Chapter 4, games in general, this particular game, the genre, and the environment of a HIVE will not appeal to all users of serious games. This leads to understanding ways to accommodate differences in environmental needs. Future studies should continue to investigate specific digital game-based learning environments designed to maximize learner access per guidelines such as UDL and accountable game design. Moreover, under the idea noted in Chapter 1 that any one type of digital game will not be the most suitable educational solution for all students, understanding the learner that maximizes academic gains when learning in a game-based HIVE is an important step in identifying this population of learners. Therefore, understanding relationships between the learner and digital learning environments are still important for future research.

Finally, future research should investigate the nature of the population within the context of this study. For example, over 46% of the combined sample played *The Lost Function* less than one hour; the phenomenon of limited and non-use should be understood. Was the lack of use attributable to the game-based HIVE, traits of the users, or were there unknown factors influence the amount of usage? Also, none of the participants noted playing *World of Warcraft*, one of the most popular game-based HIVEs; we should understand the dynamic of game playing behaviors between genres of games as the software industry has revenues in the billions. Furthermore, we need to understand why “chatting with other players” is different than “keeping in touch with your friends”, even in mean score across the whole sample ($\bar{x} = 2.12$ and $\bar{x} = 3.45$ respectively), as well as its factor-loading.

These recommendations lead to an important continuation in understanding if the idea of a gamer-behavior scale could be applied to the population of learners. First, as noted above, the scale itself may need to be reworded in order to account for a larger variety of digital games played. Next, a larger sample representative of the population of learners should be included. Field (2013) noted the discrepancy in sample size recommendations for exploratory factor analysis. A large sample of over 1000 participants would encompass the range noted by Field. Finally, analysis should compare all participants to those who play digital games and those who do not. Not only would this allow for the development of a better tool, but it would also allow for a deeper understanding of the population of learners and relationships to digital gaming.

Corporate Recommendations

After working with AT&LT’s *The Lost Function* for this project, I have the following recommendations for the company regarding their product based on my experience with their product and with the data from this study:

- First, as noted in Chapter 3, the game-based HIVE meets many of the guidelines of both UDL and accountable game design; the supports that make this possible should be continued.
- Define then understand the intended audience and accommodate them using the advantages of the HIVE, including the ability to engage in activities not possible in traditional classrooms.
- If this sample is representative of their intended audience, more supports for female players need to be in place as the sample is female heavy (79%), such as understanding what influences game play, such as those noted in Chapter 2. One current example is that when you exit a quest in the middle, the player must start the question line over again.
- Discern why a sizable portion of the sample played less than 60 minutes to engage this group. What internal and external factors relate to the low amount of engagement for these students, and how can these influences of adoption can be mitigated?
- As more than 65% of the variance in the responses to the 12 statements regarding patterns of gamer behaviors; therefore, in-game mechanics need to support the achievement, immersion, and social needs of users. Examples might include a selection of badges or rewards for completing levels and other tasks, customization of some features including the avatar

because of the importance of attending to learner control, as well as increasing the social interaction capabilities.

Implications for Positive Social Change

While the results of this study did not provide conclusive evidence to support either hypotheses of this research project, this study illuminated factors relating to mathematics remediation using game-based HIVEs for students in the United States. First, this study as a whole reminds us that there are gender differences that create needs that can be accommodated by using game-based HIVEs. Baker et al. (2008), Bonanno and Kommers (2008), and Chen et al. (2010) provided suggestions on accommodating inherent gender differences in game knowledge, noted to often be a determinant of success or failure (Charoenying, 2010). Attending to needs from gender differences supports the ideas of UDL and balances the learning opportunities each gender can attain from digital game-based games. This study supported previous studies by highlighting a statistically significant difference in time-on-task from gender.

Next, solutions to the mathematics remediation issue must be investigated, and no one digital solution is going to meet the needs of every learner; however, understanding the needs of this population is critical to support their mathematics education. Not only is a foundational mathematics ability important to function in society, a need for students to enter STEM fields requires a solid foundation in mathematics. For example, understanding algebra and matrices is important within computer programming while understandings of calculus are critical for engineering and some hard sciences such as physics. Furthermore, developmental mathematics courses at the college level have had a long history of being gateway courses with failure to complete them preventing degree attainment (Bailey, 2009; Bailey & Cho, 2010; Complete College America, 2012). Preventing learners from progressing in their college certificate or degree track removes these individuals from the workforce before they have had a chance to start.

Moreover, this study reinforces the need to match learners with the most appropriate environment, and though the data did not support the idea of differences related to time-on-task, the literature supported the relationship through the ideas of motivation, need satisfaction, and increased engagement. Pedagogical ideas of universal design for learning and accountable game design help developers and educators make appropriate choices in digital game design and selection of products to include in the curriculum. As noted earlier, increasing engagement and motivation may lead to a reduction in the need for remedial courses at the college level, and while it will not eliminate the need for developmental courses at the college level, it may substantially reduce the number of learners that need remediation as well as make the hurdle of developmental courses surmountable.

Finally, this study demonstrated the importance of statistical assumptions and their role in the analysis process, arguing that too many violations of statistical assumptions leads to both Type I and Type II errors. While each assumption can be mitigated through transformations and data cleaning, too many adjustments to the dataset may lead to deceitful results. While researchers like Berk and Freedman (2012) and

Simon (2003) noted that violations of statistical assumptions are common practice, it is important to both researchers and scholar-practitioners attend to the ramifications of violating statistical assumptions. Furthermore, understanding the plausibility of statistical noise and its impact should be carefully considered when extrapolating results.

Conclusion

The purpose of this quantitative study was to explore the relationship between the three patterns of gamer behaviors by Yee et al. (2012) and time-on-task when mathematics remediation occurs in a game-based HIVE for students in the United States when gender and age-band are controlled. One goal was to determine if the "Motivations to Play Online Games" scale (2012) could be applied to a serious game in an educational setting. While the data used in this research study could not answer the research question with the proposed methodology using the available third-party dataset, studies into this area are critical, especially with the growth of the serious game industry and its inclusion in the US classroom. Additionally, while not definitive, gender was reiterated as having relationships to factors relating to engagement, as well as those relating to academic achievement. This study generated more questions than it answered, opening the door to future research into the relationship between patterns of gamer behaviors and academic achievement in order to address the nationwide mathematics remediation problem. Most importantly, the methodological issues in the analysis component of this study remind us that we can more easily measure interactions between things, than those within people.

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Appendix A: Sample Student Survey

Page 1 of 2

Middle School Student Survey - Pi and the Lost Function

We are interested in your opinions and experience with digital games. Please answer the questions below. Thank you!

Personal Information

Last Name

Student ID*

School Email address (if available)

Interests/Activities outside of School - check all that apply

- ☐ Organized sports (on a team)
- ☐ Recreational Sports
- ☐ Work/Job
- ☐ Family Life (Church, babysitting, etc)

Gender*

- [ ] Male
- [ ] Female

Age

Grade level

How many hours do you play digital games per week?

What type of digital game do you prefer to play? If you are unsure, provide the name of an example of your favorite digital game.

Video Game Survey

We are interested in your opinions about your experience when you play a digital game. Indicate how important each item is to you. Use 1 for "not important at all", 2 for "slightly important", 3 for "somewhat important", 4 for "very important", and 5 for "extremely important".

Chatting with other players*

	1	2	3	4	5	
Not Important at All	○	○	○	○	○	Extremely Important

Being part of a guild or other long-term/permanent group*

	1	2	3	4	5	
Not Important at All	○	○	○	○	○	Extremely Important

Grouping or playing with other players*

	1	2	3	4	5	
Not Important at All	○	○	○	○	○	Extremely Important

Keeping in touch with your friends*

	1	2	3	4	5	
Not Important at All	○	○	○	○	○	Extremely Important

Learning about stories and lore of the game*

	1	2	3	4	5	
Not Important at All	◯	◯	◯	◯	◯	Extremely Important

Feeling immersed in the world*

	1	2	3	4	5	
Not Important at All	◯	◯	◯	◯	◯	Extremely Important

Exploring the game just for the sake of exploring it*

	1	2	3	4	5	
Not Important at All	◯	◯	◯	◯	◯	Extremely Important

Having a background story or history for your character*

	1	2	3	4	5	
Not Important at All	◯	◯	◯	◯	◯	Extremely Important

Becoming powerful*

	1	2	3	4	5	
Not Important at All	◯	◯	◯	◯	◯	Extremely Important

Acquiring rare items*

	1	2	3	4	5	
Not Important at All	◯	◯	◯	◯	◯	Extremely Important

Optimizing your character as much as possible*

	1	2	3	4	5	
Not Important at All	◯	◯	◯	◯	◯	Extremely Important

Competing with other players*

	1	2	3	4	5	
Not Important at All	◯	◯	◯	◯	◯	Extremely Important

Appendix B: Samples From the Orientation Scavenger Hunt

Getting Started

PLEASE REMEMBER TO KEEP ALL OF YOUR RESOURCES IN "WINDOWED" MODE. MINIMIZE THE GAME, THE WEBSITE, THE SCAVENGER HUNT FORM, AND "MISSION:RECON" AS YOU PROGRESS THROUGH THE HUNT. DO NOT CLOSE ANY WINDOWS!

THE LOST FUNCTION

Login to the game and website using the username and password provided.

Follow the directions in this scavenger hunt and explore "The Lost Function - Episode 1!" Check out the math content, instructional resources, and teacher support tools.... have fun!

After logging into the game, select "Start New Game." How many choices do you have besides "Start New Game"?

How many female avatars are available to choose from?
Select your avatar after answering the question. Remember, your selection does not impact game-play. You also earn the ability to change your outfit when you complete lessons and challenges.

After the title page, answer the question based on the initial dialogue. What is the name of the town that Pi and Ben are talking about?

Once the dialogue is finished, a student would have the option to complete the tutorial to find his/her way to the town and to learn more about the story. Since you have already seen the tutorial in our demonstration, you should click "Skip Tutorial" to continue the scavenger hunt.

How do you speed up conversations?

Ask for help if you are not sure.

- ◯ Click the left mouse button
- ◯ Push the space bar
- ◯ Push the escape key
- ◯ Hold down the shift key
- ◯ Tell your computer nicely to hurry up

Appendix C: Email From E.P. Harvey Regarding Data Usage

Edward Harvey <ed.harvey@verizon.net> 3/11/13

to me, David

Marvin,

I let Dave know we (ATLT) are committed to helping you in any way we can on your Ed.D research. Just let us know what you need and we will see that it happens.

NOTE: The remainder of the email falls within my non-disclosure agreement with AT&LT and is not provided here

Appendix D: Email From N. Yee Regarding Permission to Use the Scale

Marvin Fuller <marvin.fuller@waldenu.edu> 9/8/13

to contact

Hi Nick,

My name is Marvin Fuller, a PhD student at Walden University. I would like your permission to use the inventory presented in your paper Motivations of Play in MMORPGs. I am comparing learner traits to academic achievement in a game-based highly interactive virtual environment (HIVE). Some questions will be modified to fit the context of the study.

Your permission would be greatly appreciated.

Cordially,

Marvin G. Fuller
Student: Ph.D. Program, Educational Technology
912.675.5408 (EST)

Nick Yee <contact@nickyee.com> 9/8/13

to me

Hi Marvin,

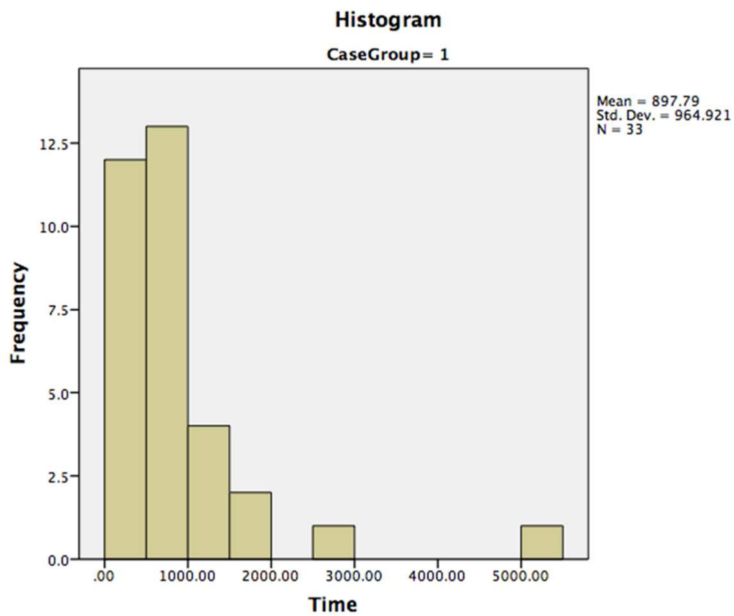
In case you hadn't seen, there's also a more recent and shorter scale that directly measures the 3 high-level factors:
http://nickyee.com/pubs/2012%20CHI%20-%20Motivations%20Scale.pdf

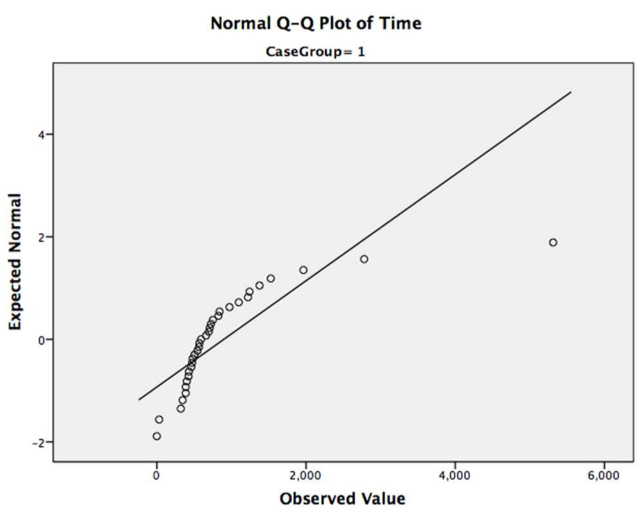
Please feel free to use either scale, whichever is more appropriate for your project. And all the best with your research!

Nick

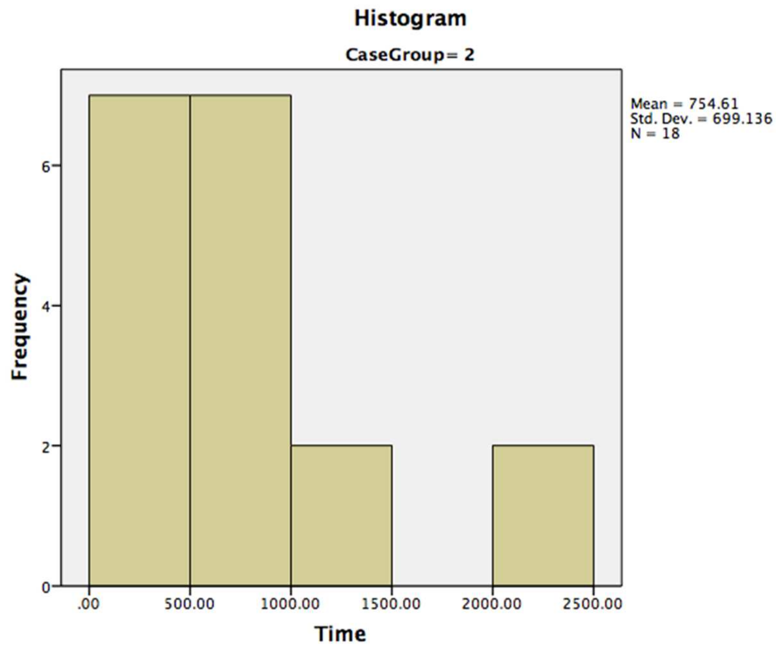
Appendix E: Distribution and Q-Q Plots for Time-on-Task (DV) for Individual Case Groups

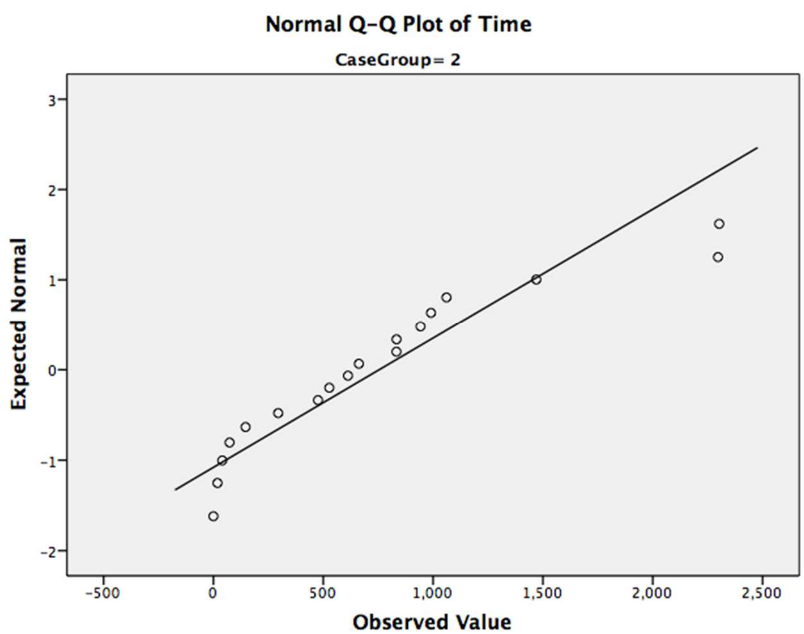
Case Group A (n = 33)



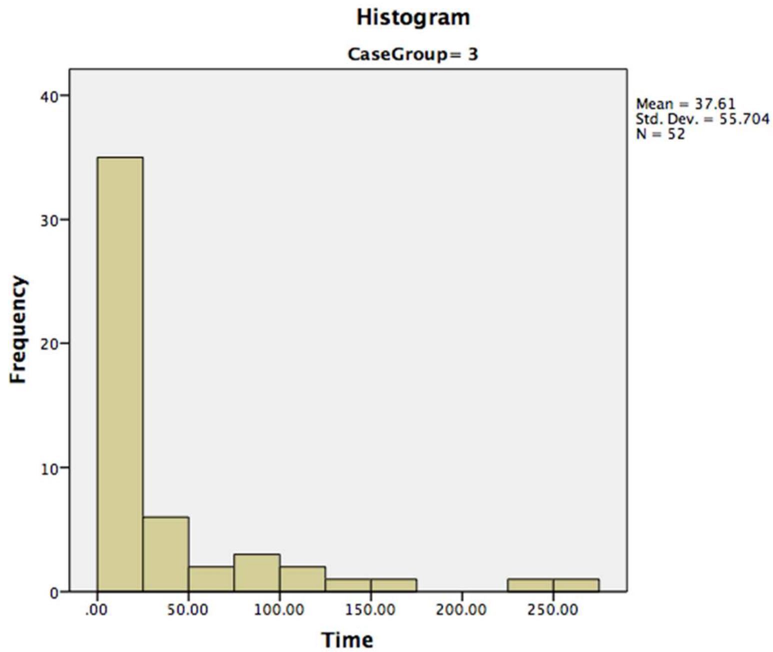


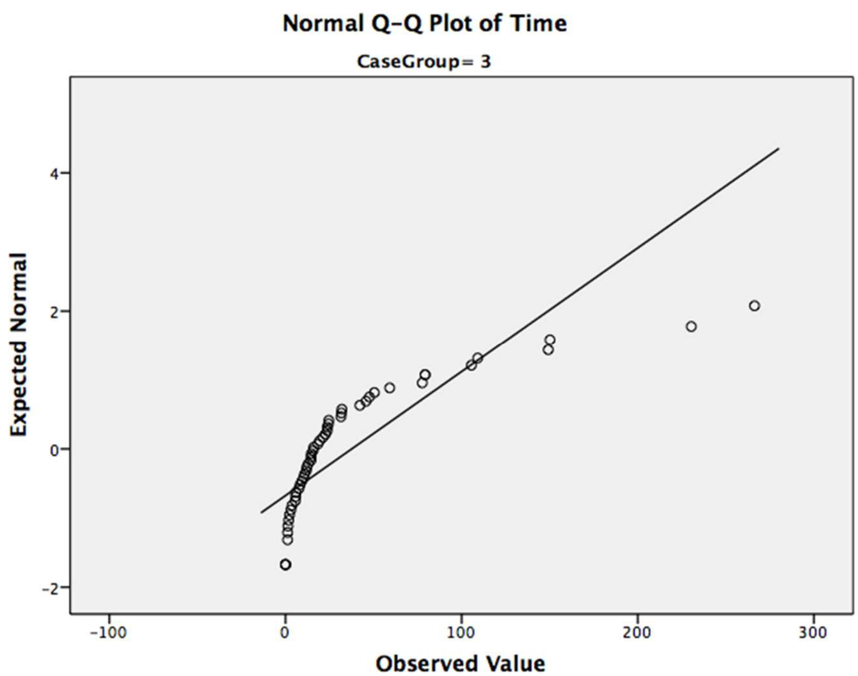
Case Group B (n = 18)



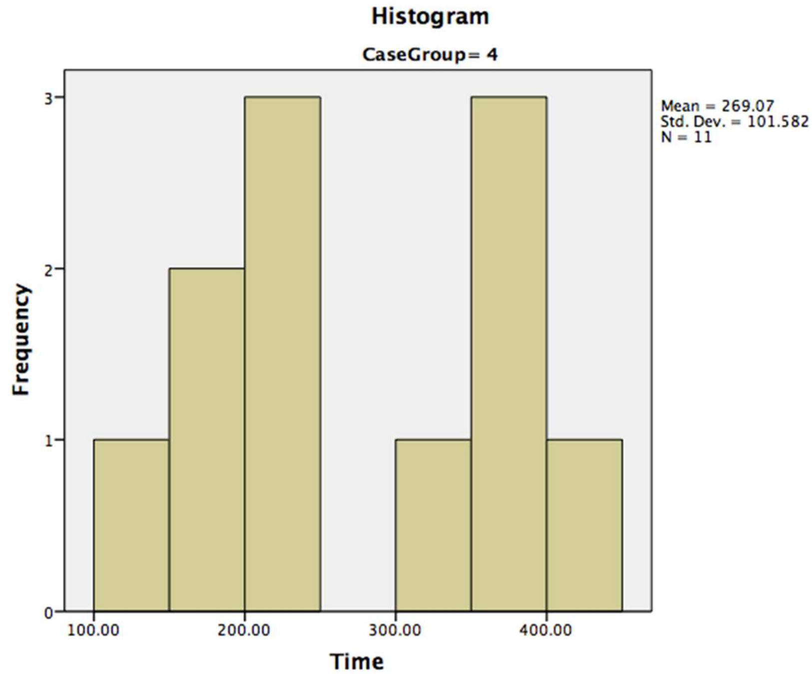


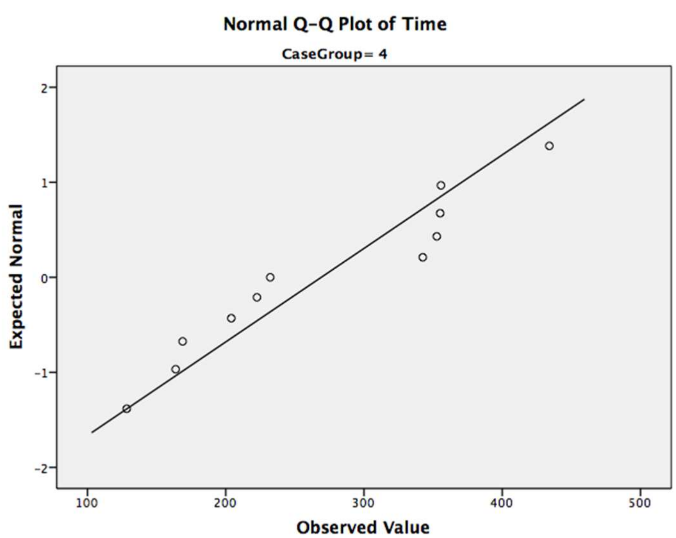
Case Group C (n = 52)





Case Group D (n = 11)





Curriculum Vitae

Marvin G. Fuller

misplaceddecimal@gmail.com

marvin.fuller@waldenu.edu

EDUCATION

- Ph.D. in Educational Technology, Walden University (in progress - anticipated graduation January 2015)
- Masters of Arts in Education - Adams State College (2003)
- Masters of Arts in Counseling - Webster University (1998)
- Bachelors of Science in Psychology - Missouri University of Science and Technology (1997)

RELATED EXPERIENCE

- Developed and implemented a middle grades STEM curriculum including video game design, 3D design and 3D printed solutions, robotics, and research
- Consultant with companies and educational institutions to develop game-based learning tools
- Evaluation and analysis of game-based virtual learning and assessment environments

- Developed and implemented a virtual professional learning platform for K-12 mathematics teachers for a medium-sized public school district
- District level mathematics coach / trainer
- Developed assessments for the State of Georgia
- 11 years as a classroom 6-12 mathematics educator
- Executive director of a non-profit agency supporting law enforcement and victims of violent crime

RECENT SPEAKING ENGAGEMENTS

Georgia Educational Technology Conference (GaETC) - 2013

- Edmodo as a Professional Development Delivery Platform
- Game Based Learning in Highly Interactive Virtual Environments (HIVEs)

Georgia Mathematics Conference - 2013

- Edmodo as a Professional Development Delivery Platform
- Game Based Learning in Highly Interactive Virtual Environments (HIVEs)
- Using Thinking Blocks to Explore Bar Modeling in Middle Grades

Savannah Regional Educational Technology Conference - 2013

- Introduction to Animoto
- Common Core Look Fors (CCL4s) for Administrators
- Introduction to Prezi

Numerous individual, small group, and 30 person workshops focusing on Common Core mathematics, the Standards for Mathematical Practice, manipulatives (physical and digital), and technology integration in the classroom for teachers, administrators, and para-professionals

ORGANIZATIONS & DISTINCTIONS

- Nominated for the 2014 “Most Innovative Implementation of Technology in Education” award through the Florida Educational Technology Conference
- Certified Edmodo Trainer
- International Baccalaureate MYP Certified - Mathematics
- International Baccalaureate DP Certified - Psychology
- Executive Board Member - Georgia Council of Teachers of Mathematics
- Board Member - Georgia Council of Supervisors of Mathematics
- Member - International Society for Technology in Education