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THE EFFECTS OF A PROBLEM BASED LEARNING DIGITAL GAME ON CONTINUING MOTIVATION TO LEARN SCIENCE

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THE EFFECTS OF A PROBLEM BASED LEARNING DIGITAL GAME ON CONTINUING MOTIVATION TO LEARN SCIENCE

by

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Dedication

To my wife!

Acknowledgements

My dissertation committee!

THE EFFECTS OF A PROBLEM BASED LEARNING DIGITAL GAME ON CONTINUING MOTIVATION TO LEARN SCIENCE

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Chapter 1: Introduction

For lest it be forgotten, attitudes are enduring while knowledge often has an ephemeral quality. The price of ignoring this simple fact and its implications is the potential alienation of our youth and/or a flight from science – a phenomenon that many countries are now experiencing. There can, therefore, hardly be a more urgent agenda for research. (p. 1074)

- Osborne, Simon, and Collins (2003)

The following dissertation reports on a mixed-methods, design-based research study of continuing motivation to learn science for sixth graders. Continuing motivation will be promoted by playing a problem-based learning digital game, called *Alien Rescue III*, which presents a complex problem that requires scientific knowledge and skills to solve.   This study will be conducted using self-report questionnaires, a science knowledge test, classroom observations, and interviews. The remainder of this chapter presents background, the significance of this study, the statement of problem, the overview of methodology, limitations, and definitions of terms.

SIGNIFICANCE OF THE STUDY

Recently, the National Science Board's (NSB's) Commission on Precollege Education in Mathematics, Science and Technology assessed the U.S. precollege mathematics and science education and found that compared to our peers internationally our most advanced students performed at or near the bottom by the time they reached senior year in high school (National Science Board, 2006). In another study reported by NSB, American 15 year old students were recently assessed in math and science knowledge and application, and compared to students in participating nations of the Organization for Economic Co-operation and Development (OECD), the U.S. students were at or near the bottom. There has also been a steady long-term decline in U.S.

students completing natural science and engineering degrees relative to other countries, and we now rank 14th in baccalaureate attainment among 19 tracked countries. Yet, scientific and engineering occupations are expected to continue to grow rapidly (National Science Board, 2006). Moreover, performance disparities in mathematics and science students from disadvantaged U.S. populations lagged even farther behind than their American peers. Because of these findings, the NSB recommended that effective instructional materials to support the development of mathematical and scientific skills for the growing English as a second language learners population need to be created (National Science Board, 2006).

The National Science Board also proclaimed that America's long-term prosperity and security depends on its remaining a world leader in science and technology (National Science Board, 2006). We are dependent on a high level of scientific and technological expertise and, thus, the lack of students taking mathematics and science, and negative attitudes toward these subjects, are significant threats to our society's prosperity (Osborne, Simon, & Collins, 2003). According to an article in Reader's Digest (Wallace, 2005), "America's Brain Drain Crisis", the author calculated that scientists and engineers create 50% of the U.S. Gross Domestic Product (GDP), though they make up less than 5% of the population. At both a personal and societal level, science has become increasingly significant in contemporary life (Osborne, Simon, & Collins, 2003). Unfortunately, research has indicated that the general population is ignorant of science and at times have a negative perception of science (Osborne, Simon, & Collins, 2003).

This negative perception of science often begins to develop at an early age. Frequently, American students lose interest for science in middle school, and this lack of involvement has led to shortages of native-born scientists and engineers, and perhaps the loss of the competitive edge of the U.S. (Stake & Mares, 2001). The middle school years

are critical for the development of interest and positive attitudes toward learning science, which then leads to educational and career choices in science and engineering (Singh, Granville, & Dika, 2002).

Unfortunately, in middle school, instruction in school is often boring and dull, and students' motivational and attitudinal problems to learn quickly appear: "In a variety of settings and using a variety of measures, investigators have found children's reported intrinsic motivation in school to decrease steadily from at least third grade through high school" (Cordova & Lepper, 1996, p. 716). That is, results have clearly shown that students' interest on average in any subject decreases over time in school (Krapp, 2002). Intrinsic motivation can be defined as the innate interest in learning and mastery of an activity or subject for its own sake, and not for extrinsic reasons (Graham & Weiner, 1996). Having intrinsically motivated students pursue activities and learning goals independent of formal instruction is an ultimate goal for educators (Hidi & Harackiewicz, 2000). Unfortunately, motivational problems or lack of effort is a primary explanation for unsatisfactory academic performance (Hidi & Harackiewicz, 2000).

The problem of motivating students is particularly acute when the subject matter is science (Tuan, Chin, & Shieh, 2005). Studies have shown that as children become older, their intrinsic motivation to learn science, interest in science, and attitude toward science declines (Eccles & Wigfield, 2002; Gottfried, 1985; Krapp, 2002; Lepper, Corpus, & Iyengar, 2005; Stake & Mares, 2001), particularly from age 11 onwards— from the point of entry to secondary school (Osborne, Simon, & Collins, 2003). This decline in motivation as children get older has been attributed to the deterioration of perceived value beliefs of content, tasks, and activities related to most school subjects (Krapp, 2002).

In contrast to how many students perceive science instruction, digital gaming is considered to be intrinsically motivating and an interest of the general population in the U.S., as indicated by the sales of 221 million copies that were worth $6.9 billion of digital games in 2002 (IDSA), and digital games are becoming ever more popular. The youth, those under 18 years old, are major players of digital games accounting for between 30-38% of the most frequent game players (IDSA). Besides the popularity of digital games in our society, accordingly to Garris and Ahlers (2002), there are two primary reasons why researchers and educators should be interested in the development of digital games for education (pp. 441-442):

- The shift from the traditional didactic instructional model to a student-centered active learning model, and

- Empirical evidence suggesting that digital games can be effective tools for enhancing and understanding of complex subject matter (Cordova & Lepper, 1996; Ricci, Salas, & Cannon-Bowers, 1996).

In addition, there is one more important reason to research digital games; they have been found to be highly motivational (intrinsically) to play, based on numerous research findings (Malone, 1981; Randel & Morris, 1992; Rosas, Nussbaum, & Cumsille, 2003; Russell, 1994). Given these benefits, it is unfortunate that there are few studies of the use of digital games in classroom settings, and if instructional designers are to leverage the motivational power of digital games, more studies are critically needed (Squire, Barnett, Grant, & Higginbotham, 2005). In this study, it is hoped that the intrinsic motivation experienced by playing digital games can improve attitude to science, increase interest in science, and promote continuing motivation to learn science—all of which are highly related constructs to describe the way people desire to continue to engage and learn about science.

Continuing motivation is important for the following reasons. First, in our ever increasingly complex world, learning is continuous and not confined to school. Thus, it is not only important to learn academic subjects, such as science, but also to have the willingness to engage in the subject matter again in the future, outside of school. Second, summative assessment of students is "probably significantly affected by the degree to which the student chooses to reconfront the school task outside of the school context" (Maehr, 1976, p. 444). That is, performance on assessments is probably influenced by the degree to which the student is willing to learn outside of the classroom. Finally, Pascarella, Walberg, Junker, and Haertel (1981) argue that continued motivation, interest, and engagement in science activities fosters the scientist, rather than solely mastery of science content. Unfortunately, educational researchers seldom study the motivational outcomes of learning (Maehr, 1976; Small, Bernard, & Xiqiang, 1996).

One way of promoting continuing motivation to learn science may be to leverage the motivational affordances of digital games. In general, the use of computer-based learning environments and tools have provided opportunities for students to think like a scientist and to grow scientific knowledge, as well as been shown to positively affect cognition, self-esteem, and behavior (Soderberg & Price, 2003). The computer-based learning environment that will be used in this study is called *Alien Rescue*.

Alien Rescue II is a stand-alone problem-based learning (PBL) software program based on the science curriculum for 6th grade in Texas and is designed in accordance with the National Science Education Standards and the Texas Essential Knowledge and Skills (TEKS) guidelines (Liu, Williams, & Pedersen, 2002). *Alien Rescue II* presents a complex problem for scientific investigation and decision-making by children (University of Texas at Austin, 2002). Studies on previous versions of *Alien Rescue II* have shown it to provide an effective learning environment for gaining science knowledge and problem-

solving skills (Bera & Liu, 2006; Liu, 2004, 2006), and to promote intrinsic motivation (Liu, 2004; Liu, Hsieh, Cho, & Schallert, 2006; Pedersen, 2003; Toprac, 2006). However, students, on average, did not significantly (p = 0.0517) improve their attitude toward science by using *Alien Rescue II* (Liu, 2004).

Also, as would be expected, not all students have been successful using *Alien Rescue II*. In a study by Bera and Liu (2006), they found that low achieving students, as measured by a factual and applied knowledge test, exerted less mental effort and experienced difficulty in seeking information and self-monitoring. Liu (2004) found that on average students did not find homes for all six aliens (the goal of *Alien Rescue*), with talented and gifted (TAG) students finding homes for five aliens, regular education (RegEd) students finding homes for four aliens, and English as a second language/learning disability (ESL/LD) students finding homes for three aliens. In addition, she found that the ESL/LD students felt that *Alien Rescue* was considerably less educationally valuable compared to TAG and RegEd students. Liu attributed her findings to the "large quantity of information to be sifted through and large amount of reading involved, which makes it more challenging for the ESL/LD students" (Liu, 2004, p. 373). Motivationally, RegEd and ESL students may need additional intrinsic motivational affordances in order to enhance persistence while engaged with *Alien Rescue*. In addition, improving intrinsic motivation may promote continuing motivation to learn science beyond engaging with *Alien Rescue*.

In order to improve motivational and cognitive scaffolding of *Alien Rescue*, additional elements were identified by using a set of heuristics on educational game design (Malone & Lepper, 1987). The design of the new version, called *Alien Rescue III,* adds various gaming features with the result that it could clearly be considered a digital game, based on definitions of games from game researchers and theorists.

In conclusion, science is important to the progress of mankind. Unfortunately, one of the leading countries in scientific research, the U.S., has fallen behind in attracting the interest of students to learn about science and is not producing enough graduates to fulfill demand in science and science-related occupations. It is important that science education becomes more motivating for students in order to attract and retain their interest in learning science in the classroom. Moreover, with the increasing complexity of society and science itself, it is important that students attain a high level of continuing motivation to learn beyond school. This critical continuing motivation to learn science may be promoted through the use of digital games. Unfortunately, both digital games in the classroom and continuing motivation are seldom researched.

PROBLEM STATEMENT OF THE STUDY AND RESEARCH QUESTIONS

The purpose of this study is to investigate whether digital games can motivate students to continue learning academic subjects, after instruction has ended. In particular, this is a study about motivating students to continue learning science from playing a digital game that presents a complex problem requiring scientific knowledge and skills to solve. That is, the focus is on how a problem-based learning (PBL) digital game may be able to promote continuing motivation to learn science. Thus, there are three aspects to this research that come together in a meaningful way: digital games, problem-based learning, and continuing motivation to learn science. The following are the research questions for this dissertation:

1. Can playing a problem-based learning game in science, *Alien Rescue III,* promote continuing motivation to learn science? Does continuing motivation to learn science change over time after completion of instruction?

2. Is continuing motivation subject, domain, or task specific?

3   What are the psychological dimensions of continuing motivation? Is there a relationship between the knowledge gained during instruction and continuing motivation?

4   Does continuing motivation to learn in future classroom instruction differ from continuing motivation to learn outside of the classroom?

It is anticipated that students' continuing motivation to learn science will be discernible when students finish using *Alien Rescue III* at the end of their learning unit and that this continuing motivation will dissipate as students are reengaged in regular classroom activities in science.

OVERVIEW OF METHODOLOGY

Design-based research (DBR) is the research paradigm used in this study. DBR is aligned with pragmatic philosophy, where the validity of a theory is its ability to explain phenomena and produce change in the world (Barab & Squire, 2004; Dewey, 1938b). Thus, DBR inquiry does not claim Truth as is advocated by objectivists, nor does it claim no truths as asserted by subjectivists, but instead claims that truths are theories that 'fit', in the Darwinian sense (Davis, 2004), in our current context of the world and can produce work in the current generation of the world. In this way, DBR can be considered trustworthy, credible, and useful, which goes beyond the positivistic view of generalizability (Barab & Squire, 2004; Schoenfeld, 1992).

The research methodology used in this study is mixed methods, which combines quantitative and qualitative approaches during different phases of the research process to create a product that is aligned with the pragmatic paradigm (Tashakkori & Teddlie, 1998). Many researchers in motivation recognize the benefit of using mixed methods approaches to provide a more full and in depth explanation of student motivation (Walker, Pressick-Kilborn, Arnold, & Sainsbury, 2004).

Both quantitative and qualitative methods will be used to gather data in order to address the research questions. Using the triangulation mixed methods design (Creswell, 2005) quantitative and qualitative datasets will carry equal weight, priority, and consideration. The results of the quantitative and qualitative analysis will be compared and to the extent possible, integrated. The resulting triangulated results could show convergence, inconsistency, or be complementary (Creswell, 2005). The quantitative results will provide the opportunity for generalizabiliy, while the qualitative result will provide a better understanding of the context and meaning (Creswell, 2005).

LIMITATIONS OF THE STUDY

The intent of this study is to design and develop a computer-based learning environment, in the form of a digital game, that not only adds to the research literature on the theory of continuing motivation, but also is valuable to teachers and students in schools. That is, the intent is not only to show the complexity of one particular context, but also show relevance to other contexts. This type of generalization has been referred to as a *petite generalization* (Stake, 1995). As such, petite generalizations have limitations.

One limitation is the need to draw boundaries around the study where the "contexts of the implementation are nested" (Barab & Squire, 2004, p. 12). That is, there is a need to draw boundaries in classrooms that are nested among teachers in a school within a school system and so forth. Thus, these boundaries constrain not only our understanding of pedagogy, including students' motivation, but also the generalizability of research findings. Researchers must draw a boundary between a set of humans within nested systems of people in order to practically accomplish its goal. Otherwise, time and resources would run out before the results could be determined. The tradeoff is that this artificial boundary means that the whole system of events and relationships are not taken

into account. Consequently, as detailed as we might want our research, it necessarily has to omit data and findings that would improve the generalizability and usefulness of the results.

Furthermore, as John Muir, a prominent environmentalist, writer, and scientist about a century ago, stated, "When we try to pick out anything by itself, we find it hitched to everything else in the universe" (Wikipedia, 2006c). In the case of this study, the intention is to pick up the concept of continuing motivation in order to understand its existence and properties. However, an individual's motivation is interconnected to his or her cognitions, emotions, and physiological state. And this interconnection goes beyond the individual's mind to the interconnectiveness of mankind's consciousness that is the human experience. As a result, any research on humans arbitrarily must create boundaries around the human experience, and our constructs to explain it, in order to study it with the limited resources and time available. This limitation again constrains the generalizability and usefulness of the results.

What's more, there is a limitation of the instruments used to measure the human consciousness. There is often an assumption in social sciences that an individual is of one mind. However, an individual's consciousness is part of another system. This system is not even fathomable to the individual. Humans have the capacity to "think" that we will behave one way but to actually behave in another. This can be seen not only in intentional hypocrisy, but also in the dissonance that often resides in our heads when it comes to predicting our own behavior. Thus, self-reports, though often used reliably, can be suspect when asking people to predict their actions in the future. In addition, often people forget or exaggerate their past behavior. Researchers hope that these issues average out when examining a group of individuals. Given the small sample size of this study, this must be taken in consideration, and may impact the validity of the findings.

This problem of instrument accuracy and interpretation becomes more acute when the instrument is the researcher. Particularly, when the investigator, while performing qualitative research, is observing the actions of others and trying to interpret them. Not only does the interpretation of behavior of others reduce the validity of the findings, but also the prejudgments and filtering that occurs even before the observer is able to consciously detect these limitations (Gadamer, 1977; Warnke, 1987). Limitations due to measuring and interpretation extend to quantitative findings and validity, as well. Cronbach (1982) wrote "Validity is subjective rather than objective: the plausibility of the conclusion is what counts. And plausibility, to twist a cliché, lies in the ear of the beholder" (p. 108). Thus, the "construction and assessment of validity is an act of interpretation" in itself (Bell, 2004, p. 250).

These limitations are clearly true of the results of this study. Yet, the hope is that the readers will find that the research was performed with enough rigor so that the results seem plausible. And the hope is that the reader finds the results useful in his or her endeavors. If so, this study will be a success.

DEFINITIONS OF KEY TERMS

Attitude toward science is a vague and ambiguous construct with no agreed definition among researchers, but is often defined as our like or dislike of science and/or science-related activities and content.

Continuing motivation is the tendency to return to and continue working on tasks in a non-instructional context that was initially confronted at an instructional context (Maehr, 1976), or the desire to reengage in the same or similar tasks in the future that are in instructional contexts.

Design-based research is a series of approaches used to produce "new theories, artifacts, and practices that account for and potentially impact learning and teaching in

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naturalistic settings" (Barab & Squire, 2004, p. 2) that is aligned with the pragmatic paradigm.

Digital games are rule-guided activities with one or more players that have goals, constraints, and consequences (Dempsey, Lucassen, Haynes, & Casey, 1996).

Individual Interest is a relatively stable, enduring positive disposition toward a content or object (Pintrich & Schunk, 2002) that influences a student to desire to learn more about a content over an extended time.

Mixed methods is the combining quantitative and qualitative approaches during different phases of the research process to create a product that is aligned with the pragmatic paradigm (Tashakkori & Teddlie, 1998).

Pragmatic paradigm of research uses multiple methods of data collection and analysis to determine what works in practice (Creswell & Clark, 2007).

Praxis is the connection between theory and practice, where the two inform each other to the point of becoming indivisible (Guerro, 1998).

Problem-based learning is an "instructional approach that exemplifies authentic learning and emphasizes solving problems in rich contexts" (Liu, 2004, p. 358).

Techne is knowledge on how to perform everyday practices.

Theory is a proposed construct that it is used to predict the future.

The following section elaborates on the theories of continuing motivation, interest, and attitude toward science. Additionally, the following section discusses digital games and design-based research.

Chapter 2: Review of Literature

If students come out of school as proficient test takers who hate school, math, or Shakespeare, then the school will have failed. (p. 19)

- Collins, Joseph, & Bielaczyc (2004)

There are large bodies of literature on digital games, problem-based learning environments, continuing motivation, interest, attitude toward science, and design-based research. Written discourse on these topics were found through searches in Academic Search Premier, ERIC, and PsychInfo, as well as other online databases at the University of Texas at Austin, and the Internet using Google. In addition, readings from classes and relevant books were searched for any pertaining information. The remainder of this chapter will examine both the theoretical foundations and empirical studies of what was found.

OVERVIEW OF DIGITAL GAMES

A common view of digital games defines them as rule-guided competitive activities with one or more players that have goals, constraints, and consequences (Dempsey, Lucassen, Haynes, & Casey, 1996) on an electronic computing device. However, there is little consensus by philosophers and researchers on the definition of games and how they differ from simulations (Garris & Ahlers, 2002; Martens, Gulikers, & Bastiaens, 2004). One of the most influential philosophers of the 20th century, Ludwig Wittgenstein, argued that there are no common characteristics among all games and that games only bear a 'family resemblance' to one another (Garris & Ahlers, 2002; Wikipedia, 2006d). After reviewing attempts by educational researchers, such as Lepper, Malone, and others, to define games, Garris and Ahlers (2002) concluded that digital

based learning games have six broad dimensions: fantasy, rules/goals, sensory stimuli, challenges, mystery, and control, as shown in Table 1. Yet, even these characteristics of the dimensions of digital games do not clearly distinguish them, since many of these same dimensions can be used to describe other learning environments.

Table 1: Educational Game Dimensions

	Fantasy	Rules/ Goals	Sensory Stimuli	Challenge	Mystery	Control
Descriptors	Imaginary or fantasy context, themes, or characters	Clear rules, goals, and feedback on progress toward goals	Dramatic or novel visual and auditory stimuli	Optimal level of difficulty and uncertain goal attainment	Optimal level of informational complexity	Active learner control
Related research	Cordova & Lepper, 1996; Driskell & Dwyer, 1984; Malone, 1980, 1981; Malone & Lepper, 1987; Parker & Lepper, 1992	Driskell & Dwyer, 1984; Lepper & Chabay, 1985; Malone, 1980, 1981; Ricci, Salas, & Cannon-Bowers, 1996; Schloss, Wisniewski, & Cartwright, 1988; Thurman, 1993	Hereford & Winn, 1994; Lepper, 1985; Malone, 1980, 1981; Rieber, 1991; Surber & Leeder, 1988; Thurman, 1993; Wishart, 1990	Elliot & Harackiewicz, 1994; Lepper, 1985; Lepper & Chabay, 1985; Lepper, Woolverton, Mumme, & Gurtner, 1993; Malone, 1980, 1981; Thurman, 1993; Whitehall & McDonald, 1993; Wishart, 1990	Day, 1982; Lepper, 1985; Loewenstein, 1994; Malone, 1980, 1981; Malone & Lepper, 1987; Terrell, 1990; Thurman, 1993	Cordova & Lepper, 1996; Hannafin & Sullivan, 1996; Kinzie, Sullivan, & Berdel, 1988; Reigeluth & Schwartz, 1989; Simons, 1993; Steinberg, 1989; Wishart, 1990

Note: From "Games, motivation, and learning: A research and practice model," by R. Garris and R. Ahlers, *Simulation & Gaming*, 33(4), p. 447. Copyright 2002 by Sage Publications.

For instance, computer simulations have a close resemblance to digital games (Leemkuil, de Jong, & Ootes, 2000). Computer simulations are open-ended programs involving situations with many interacting variables that attempt to model (simulate) a

system (de Jong & van Joolingen, 1998). Yet, SimCity and the plethora of similar programs are considered to be digital games, but still fall under this definition of computer simulations. Thus, the distinction between many digital games and simulations is not clear-cut, and they are often referred under the interchangeable terms of 'game simulation' or 'simulation game' (Leemkuil, de Jong, & Ootes, 2000). In fact, as Martens, Gulikers, and Bastiaens (2004) pointed out, it is not easy to define the difference between educational games and simulations, or, even, any other authentic learning environment. They concluded that these learning environments could not be "sharply distinguished from each other" (p. 370). Instead, they focused on common features found in educational simulations, games, and other learning programs and categorized all of these applications as 'Authentic Learning Programs' (Martens, Gulikers, & Bastiaens, 2004).

Non-educational game and play researchers provide another perspective on the definition of games. Salen and Zimmerman (2004) compared game definitions from notable play and game historians, designers, and researchers, such as David Parlett, Clark C. Abt, Johann Huizinga, Roger Caillois, Bernard Suits, Chris Crawford, Greg Costikyan, Elliot Avedon, and Brian Sutton-Smith, and found no consensus, though all of them except Costikyan include rules as a key aspect of games (see Table 2 below). Ultimately, Salen and Zimmerman defined games as "a system in which players engage in artificial conflict, defined by rules, that results in quantifiable outcome" (p. 80). In their definition, artificial refers to the artificial space that separates games from "real life". Conflict is considered a contest of some kind between players or players and the game. That is, there is a challenge from other players or the game, or both, that must be overcome. And quantifiable outcome means the player has either won or lost, or received a numerical score.

Table 2: Game Elements

Elements of Games	Game and Play Researchers							
	Parlett	Abt	Huizinga	Caillois	Suits	Crawford	Costikyan	Avedon/ Sutton-
Constricting rules	X	X	X	X	X	X		X
Conflict or contest	X					X		X
Goal/outcome oriented	X	X			X		X	X
Activity, process, event		X			X			X
Decision-making		X				X	X	
Playful and absorbing			X					
No extrinsic reward			X	X				
Artificial/Safe			X	X		X		
Creates social groups			X					
Voluntary				X	X			X
Uncertain				X				
Make believe				X		X		
Inefficient					X			
System of parts						X	X	
A form of art							X	

Note: Adapted from *Rules of Play: Game Design Fundamentals* (p. 79) by K. Salen and E. Zimmerman, 2004, Cambridge, MA: The MIT Press. Copyright 2004 by Massachusetts Institute of Technology.

Comparing the game dimensions identified by educational game researchers to those identified by game and play researchers, the following concepts overlap:

- Fantasy/Make believe/artificial context/safe

- Constricting rules

- Goal/outcome oriented with feedback

- Challenge/conflict/contest/complexity (optimized for players)

- Uncertainty of the outcome

- Active control/decision-making activity

- Inefficient processes for gathering information/mystery

In addition, because of the unique affordances of the computer technology used in digital games, a final dimension to add is sensory stimuli, which includes both visual display and sound. If a digital game successfully combines these elements, then the

player should become engrossed and absorbed in the activity. Additionally, if the digital game endogenously supports educational objectives, then these may be attained while providing a positive (affective) experience for the student.

Perhaps the best taxonomy of the elements of digital based learning games is provided by Malone and Lepper's (1987) heuristics for designing intrinsically motivating instructional environment (see Appendix A), which includes all of the dimensions previously identified, but also includes the important interpersonal motivations of competition, cooperation, and recognition.

These interpersonal and social dimensions of motivation are key features in the learning theory of social constructivism. An exemplar of a learning environment that captures the essential qualities of the theory of social constructivism (and cognitive constructivism) is problem-based learning (PBL) environments. Problem-based learning environments and how they motivate students and relate to digital games will be briefly explained, in the following section.

OVERVIEW OF DESIGNING MOTIVATING DIGITAL GAMES AND PROBLEM-BASED LEARNING ENVIRONMENTS

Given the somewhat ambiguous definition of digital games and the broad concepts that describe their characteristics, it is perhaps safe to assume that there are many different ways to design them. The first educational games can be classified under the rubric of computer-assisted or computer-aided instruction (CAI) applications, which consisted of drill-and-practice routines and tutorials. The underlying learning theory of these games was behaviorist in nature.

Learning in behaviorism is posited to occur when behavior changes due to experiencing external stimuli (Burton, Moore, & Migliaro, 1996). In CAI games, this would mean the development of a system based on predefined learning objectives and

centered on the subject matter with the technology as the agent in control of the learning. In these software programs, the student responds to some specific stimulus, such as a question. If the student responds appropriately according to the learning environment, then the student gets a reward, such as congratulating him or her. If the student does not respond appropriately, then the system typically goes back to the learning lesson so that the student may relearn the material to respond "correctly". The goal of drill and practice programs is for the student to respond without error to the questions.

Motivation in behaviorism is hypothesized to occur because an individual receives awards and punishments (i.e. extrinsic motivators) that affect the individual's tendency to respond a certain way (Greeno, Collins, & Resnick, 1996). Unfortunately, extrinsic motivators, which are often inauthentic in nature, can destroy the intrinsic motivation a person has to engage in an activity, and degrades the quality of certain kinds of task performance (Malone, 1981). Likewise, extrinsic motivators can destroy the continuing motivation of students to learn more about subjects outside of class (Maehr, 1976). Finally, CAI games often attempt to motivate by providing a strong dose of sensory stimuli, such sounds and animated graphics, to ameliorate the lack of other motivating elements. Unfortunately, by relying heavily on sensory curiosity to engage the player rather than other intrinsically motivating techniques, students quickly lose interest playing these games (Hogle, 1996). That is, students' interest in many CAI games are "caught" but does not "hold" or maintain for long (Hidi & Harackiewicz, 2000; Mitchell, 1993). For these reasons, behaviorist based CAI games have not been considered successful in the school environment for learning complex concepts (Hogle, 1996).

In contrast, the other two primary learning theories, cognitivism and constructivism, posit other motivational techniques. Cognitivists and cognitive

constructivists emphasize the natural inclination for students to be consciously engaged and to learn given certain learning environments (Greeno, Collins, & Resnick, 1996). Learning in cognitive constructivism is the inductive, non-linear cycle of appraising new experience, developing schemas, and reflection (Ginsburg & Opper, 1987). That is, new experience from the environment is compared to past experience and what was abstracted from past experience. If the new experience is not ignored, then the experience creates a level of disequilibrium or cognitive conflict in the mind. The new experience may be perceived to be so close to existing schema in the mind that it does not create very much disequilibrium and is assimilated in the mind using schemas based on past experience. However, if the person encounters something from the environment that is radically new, there is much more disequilibrium in the mind, and a new cognitive structure or schema will develop to accommodate this new experience. Through reflection, consciously or subconsciously, new experiences that are assimilated and accommodated are differentiated from and integrated with other schemas, and abstracted to higher levels of understanding (Ginsburg & Opper, 1987). The process of assimilation, accommodation, and reflection over successive cycles create robust and stable schemas that afford the individual the opportunity to understand how the world works and the possible permutations of objects in the world (Ginsburg & Opper, 1987).

Certain learning environments—ones that are more student centered than CAI programs—evoke the innate desire of individuals to learn. That is, the innate desire of people to resolve cognitive conflict (ie. disequilibrium) that occurs when encountering new experiences (von Glasersfeld, 1987) presented by certain learning environments is "intrinsic motivation." An activity is said to be intrinsically motivating if people engage in it 'for its own sake' and if they do not engage in it for extrinsic reasons (Malone, 1981). When a student is intrinsically motivated to learn something, they typically spend

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more time and effort learning, are self-directed, feel better about what they learn, and use it more in the future (Malone, 1981). Intrinsic motivation is something that researchers find over and over again when studying humans playing games (Rosas, Nussbaum, & Cumsille, 2003; Russell, 1994). The experience of playing digital games is often described as 'fun', which is another way of saying intrinsically motivating. Since there is a strong link between intrinsic motivation and continuing motivation (Maehr, 1976), it stands to reason that the higher the intrinsic motivation promoted by a learning environment, the greater the probability of students' having continuing motivation.

However, the need for intrinsic motivation notwithstanding, there is possibly one external motivator that is different from the others: social interaction. The importance of social interaction is part of the social constructivist view of motivation. Social constructivist theories of motivation are concerned with the individual's interaction with others in a context or social milieu in which the game is being played. Learning in the social constructivist perspective is being attuned to the affordances and constraints of artifacts and practices within a context or community (Greeno, Collins, & Resnick, 1996). Learning is the non-linear, cyclical process of valuing knowledge of the community, appropriating that knowledge, internalizing it, and using that knowledge to demonstrate practices and develop the individual's identity in the community (Wells, 2000). That is, learning is the process of understanding how to solve problems and interact with others that are socially acceptable to the community, be it an artifact, practice, or dialog. Thus, learning is a process of negotiation and the evaluation of an individual's understanding with others in a community (Lave & Wenger, 1991).

Social constructivists believe that motivation is the engagement to maintain interpersonal relationships and identity in a person's communities (Greeno, Collins, & Resnick, 1996). The existence of an appealing social group that plays digital games

provides motivation for players. This social group can be friends, relatives, or other game players. The super-motive is the reciprocal process of valuing the social group and the development of one's identity within that social group. That is, individuals have the need to belong to a social group or community where they can develop their self-esteem and attain esteem (via social recognition) from others through participation in that social group or community (Hickey, 2003; Maslow, 1955; Ryan & Deci, 2000). Thus, motivation is the process of negotiation of one's identity and participation in a community (Lave & Wenger, 1991).

There are many different types of learning environments that are based on cognitive and constructivist theories. According to Savery and Duffy (1995), one of the best exemplars of a constructivist (cognitive and social) learning theory based environments are ones called problem-based learning (PBL). They consider PBL environments to have the three primary underlying constructivist propositions: (1) understanding is in our interactions with the environment, as posited by cognitive constructivists, (2) cognitive conflict is the stimulus for learning and determines the organization and nature of what is learned, as posited by cognitive constructivists, and (3) knowledge evolves through social negotiation and by the evaluation of the viability of one's understanding, as posited by social constructivists, (Savery & Duffy, 1995, pp. 1-2).

Yet, there is no clear consensus on what is PBL, except that it is a learning process where students actively work together in teams to achieve a goal (Busari, 2000). Because of the lack of definition and because PBL represents a practical framework (praxis) based on constructivist theory, there are many ways to implement it in practice (Savery & Duffy, 1995). Barrows (1986), a main proponent of PBL, recognized that PBL "does not refer to a specific educational method" and "can address quite different

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educational objectives" (p. 481). However, Barrows (1996) does propose the following as the main characteristics of PBL:

- Learning is student-centered as students assume a major responsibility for their own learning;

- Learning occurs in small groups;

- Teachers are facilitators or guides;

- Problems form the organizing focus and stimulus for learning;

- Problems, similar to those one would face in future professions, are a vehicle for the development of problem-solving skills;

- New information is acquired through self-directed learning (pp. 5-6).

According to Mann, Eidelson, Fukuchi, Nissman, Robertson, and Jardines (2002), game-based learning can be considered a kind of PBL, because games and PBL share in the characteristics of an unknown outcome, multiple paths to a goal, construction of the problem context, and, when there are multiple players, collaboration. They found that students learned not only from the content of a PBL-based surgical management game, but also from the dialogue and sharing of knowledge while they participate in the activity. This type of learning through social interaction is consistent with the social constructivist perspective of learning that is exemplified by Lave and Wenger's (1991) theory of situated learning.

The benefits of PBL, according to Barrows, Barzak, Ball, and Ledger (2002), are that PBL promotes activation of prior learning, self-directed learning, and motivation. PBL environments promote intrinsic motivation and motivation from participation in a community that includes the teacher and fellow students. This intrinsic and situated motivation during engagement with PBL environments may lead to continuing motivation. Thus, a PBL approach to designing educational digital games may be

advantageous to learning, motivation while playing, and continuing motivation after playing the game has stopped. But what is continuing motivation and what are the advantages of promoting continuing motivation in students? The following section will describe the theoretical framework for continuing motivation.

CONTINUING MOTIVATION THEORY AND RESEARCH

For preschool children, learning is fun. There are no motivational problems for learning in these years (Cordova & Lepper, 1996). Their motivation is manifested by their choice of behavior, intensity of behavior, latency of behavior, and persistence of behavior, and is accompanied with cognitive (e.g. goal setting) and emotional reactions (Graham & Weiner, 1996). Motivation is often considered to be a necessary antecedent for learning (Gottfried, 1985; Lepper, Corpus, & Iyengar, 2005). Continuing motivation is the antecedent to learning more about a subject in the future, by the individual's own volition. In this section, the description and attributes of continuing motivation will be described in more detail.

Continuing Motivation

"One of the more important—but seldom studied—educational outcomes is, what might be termed, *continued motivation*" (Maehr, 1976, p. 443, italics original). Continuing motivation is defined as the tendency to return to and continue working on tasks in a non-instructional context that was initially confronted or learned at an instructional (classroom) context (Maehr, 1976), or the desire to reengage in the same or similar tasks in the future that are in instructional contexts. For example, a student may learn about the solar system in the classroom and then spontaneously choose a book in the library on astronomy outside of the requirements of the classroom, or he or she may desire to learn more about the solar system in the classroom in the future. Continuing

motivation has been assumed to be a continuing interest (Sorensen & Maehr, 1976), intrinsic in nature, and to exist without the need for extrinsic motivators. Continuing motivation differs from the motivational construct of persistence in that persistence is the motivation to perform on an immediate activity despite challenges, problems or obstacles, whereas continuing motivation goes beyond the immediate activity. That is, students with continuing motivation desire to persist in learning more about a subject sometime in the future, not just on the immediate activity. Continuing motivation also differs from the Zeigarnik effect—the need for closure on an activity—since the task at hand can be finished, while continuing motivation still exists (Maehr, 1976). Yet, like persistence, in the mind of the student, the task may be completed, but the desire to continue learning about the subject matter has not been brought to closure.

Continuing motivation is important for the following reasons. First, in our ever increasingly complex world, learning is continuous and not confined to school. Thus, it is not only important to learn academic subjects but also to have the willingness to engage in the subject matter again in the future. Second, summative assessment of students is "probably significantly affected by the degree to which the student chooses to reconfront the school task outside of the school context" (Maehr, 1976, p. 444). That is, classroom performance on assessments is probably influenced by the degree to which the student is willing to learn outside of the classroom. If higher continuing motivation contributes to higher academic performance, then this may influence the pattern of course selection. For instance, higher continuing motivation in science may lead to higher performance in the science classroom, which may further lead to learning more science and the selection of science courses in the future. Ultimately, continuous promotion of continuing motivation, along with higher performance and appropriate course selections, may lead students to choose much needed science and engineering careers. If this is true,

then the development of curricula and instruction that promotes continuing motivation is imperative in order to attract students to the science and engineering careers that the U.S. is currently lacking (National Science Board, 2006).

One type of curricula and instruction that may be able to promote continuing motivation to learn science are digital games. There is some evidence that playing digital games may promote students' continuing motivation. For instance, in a study by Rosas, Nussbaum, and Cumsille (2003), teachers reported that digital games were so motivating that students developed a greater interest in attending school (more punctually) and learning. Thus, the digital games were able to generalize the students' motivation to attend school and learn. As Lepper and Malone (1987) stated, "With a continuing use of such techniques [playing games], we may be able to build generalized positive attitudes toward school learning—attitudes that should carry over to other classroom activities" (p. 261). Though generalized motivation may not strictly be within the definition of continuing motivation, it does point to students becoming so highly motivated that this motivation transfers from the initial context to other contexts. That is, continuing motivation is the transfer of motivation to engage in the same task from one context to another context, whereas generalized motivation is the transfer of motivation to engage in a task in a context to a different task(s) in the same context. The commonality between these two types of motivation is that students become so highly motivated while engaged in a learning task, such as playing digital based learning games, that the students' motivation goes beyond the immediate task.

More direct evidence of continuing motivation is apparent in a study by Malouf (1987), which investigated the effects of playing instructional computers games on motivation to engage in a subsequent academic task. The subjects of the study were sixth, seventh, and eight-grade students in a suburban middle school that were identified

as learning disabled and having IQ scores with a mean of 93.0 (SD = 10.1). The students were administered the free-choice activity of completing a paper and pencil prefix matching task and four distracters tasks. The students were given 10 minutes to engage in any combinations of the tasks to any extent desired. The pretest was administered twice to determine the initial level of student motivation to engage in the prefix matching task. The students were then stratified by the number of prefix problems solved and randomly assigned to a computer game and computer non-game conditions, which emulated the game but without game features. Both conditions involved prefix matching. The experimental treatment was delivered within 2 weeks of the pretest and was comprised of two daily sessions of approximately 10-minute duration. Subsequently, a posttest using a free-choice activity was administered within one day after the experimental treatment. Significant differences were found between game and non-game students on the number of problems completed (t = 2.33, 21; p = 0.03) and the amount of time spent on task (t = 2.32, 21; p = 0.03) for the second free-choice activity. The study suggests that the instructional computer game produced significantly higher motivation on an academic task that continued beyond completion of task than the same program without game features. That is, the game promoted continuing motivation to engage in an academic activity. In conclusion, motivation to continue to perform an academic task was enhanced by playing a digital game that included a school-related task without any detrimental effect on performance.

Though there is some evidence of continuing motivation and its benefits, there has been very little research on the underlying dimensions of continuing motivation. That notwithstanding, the results of numerous studies have suggested that external evaluations and exogenous extrinsic rewards may inhibit continuing motivation (Malouf, 1987). Also, a study by Small, Bernard, and Xiqiang (1996) suggested that intrinsic

motivation in the form of perceived competence in a subject, control of the learning environment, and the feeling of connections to others (see self-determination theory by Ryan and Deci (2000)) while learning contribute to the continuing motivation of learners. They also found that feelings of arousal and pleasure contributed to generating and sustaining motivation to complete the task, but not continuing motivation.

In contrast, in a study by Shernoff and Hoogstra (2001), high involvement in high school math and science classrooms was found to be a significant predictor of continuing motivation. This study used data from a national longitudinal study of high school students lives in relationship to the future, entitled the Alfred P. Sloan Study of Youth and Social Development (SSYSD), to measure future aspirations and motivation in high school math and science classes. Participants in this study provided self-reports on the their moods and activities using the Experience Sampling Method (see Csikszentmihalyi (1987)) form. Seven Experience Sampling Method (ESM) variables were selected for analysis that pertained to students' motivation: (1) Interest, (2) Enjoyment, (3) Concentration, (4) Perceived Future Importance, (5) Perceived Skill, (6) Active Involvement, and (7) Mood. In addition, data about demographic characteristics, academic performance, and career aspirations were obtained. This data was compared to a follow-up study conducted on SSYSD participants to measure long-term performance and continuing motivation. Continuing motivation was measured as the selection of either science or math as the students' college major two years later. In addition, case studies were performed on the top or bottom 5 percent of engagement in high school math or science classes.

Results from the study showed that the students' selection of a science major in college was strongly predicted by students' interest (B = 0.836, p < 0.01) and enjoyment (B = 1.43, p < 0.01) in high school science classrooms two years earlier, after controlling

for gender, race, socioeconomic status, family type, and previous performance (N = 53). In addition, concentration in the classroom (B = 1.163, $p < 0.05$), perceived skill/competence (B = 0.916, $p < 0.05$), and mood (B = 2.024, $p < 0.05$) during high school science classroom instruction were also significantly correlated to students' selection of a science major. The case studies corroborated the quantitative results of intrinsic motivation (i.e. interest and enjoyment) being a strong influence on continuing motivation. In addition, highly engaged students reported interest and enjoyment in science, and students who experienced low engagement in science reported concern with performance, grades, and other external indicators of success. Interestingly, perceived future importance, career aspirations, and high school academic performance were not significant influences on continuing motivation to learn science. Thus, the learning environment must promote intrinsic motivation rather than focus on performance in order to support continuing motivation. Authentic engagement, including the intrinsically motivating factors of interest and enjoyment of science, appears to be the key to continuing motivation and lasting success of students in science (Shernoff & Hoogstra, 2001).

Thus, engagement has to be sufficient in quality and quantity to promote continuing motivation. The need for the learning environment to possess certain qualities to promote continuing motivation was suggested in a study by Pascarella, Walberg, Junker, and Haertel (1981). The sample of this study was 2,350 13-year-old students (17-year-old students were also sampled but for the purposes of this report, they will be ignored because this age group is outside of this study's middle school focus) who completed self-reports as part of a study conducted by the National Assessment of Educational Progress (NAEP). The two general categories of independent variables measured were student demographic and science achievement measures, and classroom

measures. Variables of student demographic and science achievement measures included: (1) achievement in science, (2) mother's and father's formal education, (3) home environment, (4) sex, and (5) ethnicity. Variables of classroom environment measures included: (1) class morale (i.e. intrinsic motivation), (2) utility of science content and science classes (i.e. the perceived usefulness of the task for a person's future), (3) teacher control, and (4) teacher encouragement. The dependent variable, continuing motivation, was determined from students' reports of an eight-item list of science activities that students' answered regarding how often they performed these activities when not required for science class.

Multiple-regression analysis with continuing motivation as the dependent variable was performed. They found that intrinsic motivation (t = 6.03, df = 1,164, p < 0.01), task utility of science content and science classes (t = 7.84, df = 1,164, p < 0.01), and teacher encouragement (t = 4.03, df = 1,164, p < 0.01) were significantly positively correlated to continuing motivation to learn science, with science achievement and student background held constant. Interestingly, extrinsic rewards in the form of encouragement from the teacher also had a significant positive relation to continuing motivation and science achievement. In addition, teacher control of the classroom was negatively associated (t = 6.09, df = 1,164, p < 0.01) with continuing motivation but positively associated with science achievement. This finding is consistent with Maehr's (1976) argument that focusing on controlling student behavior in order to "encourage attention to a task in the classroom can, simultaneously, discourage continuing interest in the task outside the classroom" (p. 445).
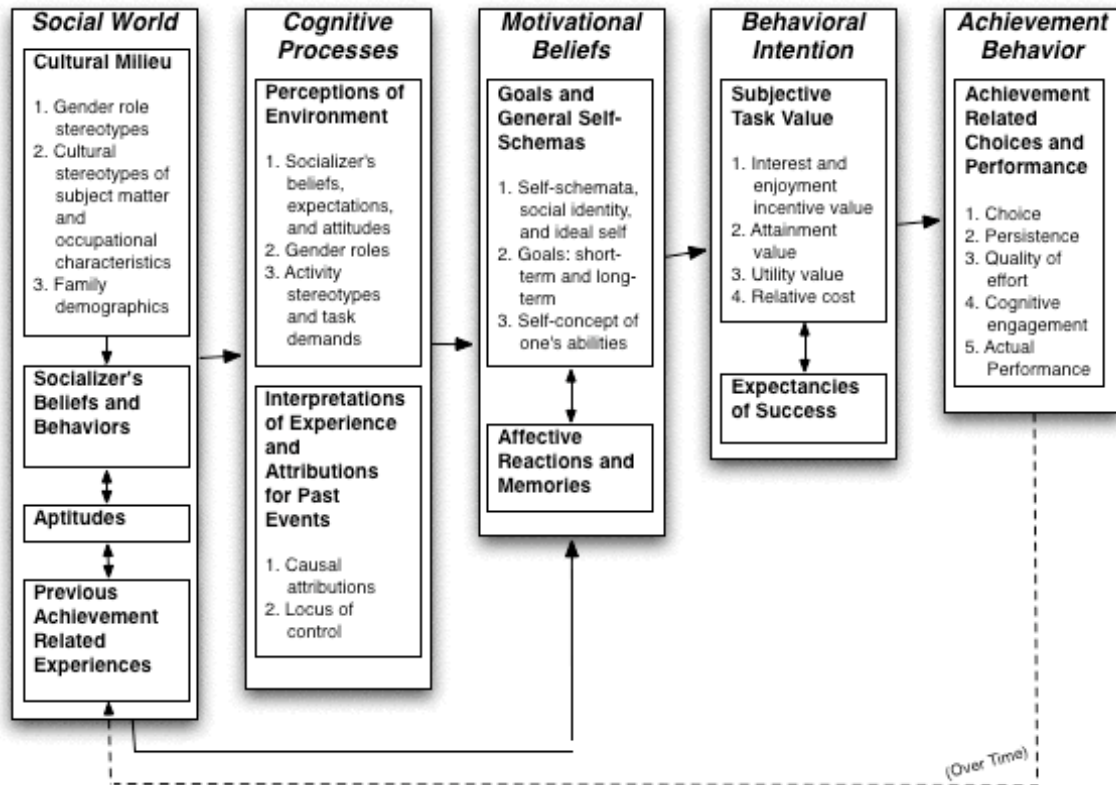
In summary, of the few studies that attempted to find the underlying dimensions of continuing motivation, there seems to be conflicting results. For example, one study pointed to the need for high engagement to promote continuing motivation (Shernoff &

Hoogstra, 2001), but another study found that high engagement was not necessary (Small, Bernard, & Xiqiang, 1996). Another example involves the perceived future importance to the student of the task in science, where one study (Shernoff & Hoogstra, 2001) found that it was not significant for promoting continuing motivation, but another study (Pascarella, Walberg, Junker, & Haertel, 1981) found that it was a significant contributor to continuing motivation. Thus, there is a need for a study that attempts to understand the underlying factors of continuing motivation. If the underlying dimensions can be determined, then specific curricular and instructional strategies can be developed to target these dimensions in order to maximize the promotion of continuing motivation. Ultimately, improving continuing motivation may help students continue to be interested in learning science, even beyond the classroom. With this in mind, the following section describes a proposed model for continuing motivation.

Eccles' Theory of Motivation Perspective as Model of Continuing Motivation

It is proposed here that Eccles' model of achievement motivation can provide the framework for understanding continuing motivation. This expectancy-value model developed by Eccles, Wigfield, and their colleagues has generated the most research on motivation for classroom academic achievement (Pintrich & Schunk, 2002). According to Wigfield and Eccles (2000), achievement motivation influences the choice, persistence, intensity, and performance of individuals. Figure 3 shows a simplified version of this complex and elaborate model.

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Figure 1: Simplified Version of Eccle's Expectancy-Value Model of Motivation

Social World

Cultural Milieu

1. Gender role stereotypes
2. Cultural stereotypes of subject matter and occupational characteristics
3. Family demographics

Socializer's Beliefs and Behaviors

Aptitudes

Previous Achievement Related Experiences

Cognitive Processes

Perceptions of Environment

1. Socializer's beliefs, expectations, and attitudes
2. Gender roles
3. Activity stereotypes and task demands

Interpretations of Experience and Attributions for Past Events

1. Causal attributions
2. Locus of control

Motivational Beliefs

Goals and General Self-Schemas

1. Self-schemata, social identity, and ideal self
2. Goals: short-term and long-term
3. Self-concept of one's abilities

Affective Reactions and Memories

Behavioral Intention

Subjective Task Value

1. Interest and enjoyment incentive value
2. Attainment value
3. Utility value
4. Relative cost

Expectancies of Success

Achievement Behavior

Achievement Related Choices and Performance

1. Choice
2. Persistence
3. Quality of effort
4. Cognitive engagement
5. Actual Performance

(Over Time)

Note: Adapted from (1) *Motivation in Education: Theory, Research, and Applications*, 2nd ed., (p. 61) by P. Pintrich and D. Schunk, 2002, Upper Saddle River, NJ. Copyright 2002, 1996 by Pearson Education, Inc. (2) Eccles, J. S., & Wigfield, A. (2002). "Motivational Beliefs, Values, and Goals," by J. S. Eccles and A. Wigfield, 2002, *Annual Review of Psychology*, 53(1), p. 119. Copyright 2002 by Annual Reviews. (3) "Expectancy--Value Theory of Achievement Motivation", by A. Wigfield and J, S, Eccles, 2000, *Contemporary Educational Psychology*, 25(1), (p. 69). Copyright 2000 by Academic Press.

In this model, achievement behavior is predicted by two components: expectancy and subjective task value, which, together, represent the intention to approach or avoid engaging a task, and, once engaged, the quality and quantity of effort. Though task value and ability self-concepts (i.e. expectancy) can be independently measured, they influence each other. Ability self-beliefs and task beliefs for a subject are often related reciprocally (Eccles & Wigfield, 2002).

Expectancy, according to Eccles and Wigfield (2002), is a person's self-evaluation of his or her ability and beliefs about the probability of success in upcoming

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tasks, whether in the immediate or longer-term future. These expectancy beliefs (i.e. ability self-concept) are analogous to Bandura's self-efficacy expectations. Bandura (1986) defines self-efficacy as the "People's judgments of their capabilities to organize and execute course of action required to attain designated types of performance" (p. 391). Bandura argues that his self-efficacy construct is not analogous to expectancy beliefs because self-efficacy is task-specific, whereas Eccles expectancy beliefs include a broader concept of competency belief in a given domain. For example, Bandura's argues the question 'how good are you at solving momentum problems?' is not the same 'how good are you at solving physics problems?' However, "empirical work has shown that children and adolescents do not distinguish between these two different levels of beliefs" (Eccles & Wigfield, 2002, p. 19). Thus, according to Eccles and Wigfield (2002), these two constructs may be theoretically different; however, they are highly related and indistinguishable in real-world achievement situations. In addition, though Bandura argues that self-efficacy represents a more task specific and situational view of Eccles' expectancy construct (Pintrich & Schunk, 2002), he and other researchers (Bandura, Barbaranelli, Caprara, & Pastorelli, 1996; Bong & Hocevar, 2002; Chen, Gully, & Eden, 2004) have measured general self-efficacy, such as social self-efficacy, that is not task specific, but instead domain specific.

Yet, there may be difference between these two constructs depending on the context. Expectancy is the evaluation of a person's probability of success and is comprised of both competency beliefs and outcome expectancy. Outcome expectancy is the individual's beliefs about the consequences of his or her actions (Pintrich & Schunk, 2002). That is, it is not only important that the person believes that s/he has the ability to perform but also that the outcome of the performance will result in achieving the goal. In many cases, the outcome expectancy does not affect the motivation to perform the

activity, since the person's actions is expected to have the appropriate consequence. In regards to playing a digital game, it is safe to assume that the student will believe that his or her actions will directly affect the outcome. In this case, the outcome expectancy is not important and the perceived competence is the salient aspect of expectancy. Therefore, for purposes of this dissertation, self-efficacy, expectancy, ability self-concept, perceived competence, and other competency-related beliefs will be considered the same construct.

Self-efficacy comes from four major sources: performance accomplishments (most influential source), vicarious experience, verbal persuasion, and physiological symptoms (Pintrich & Schunk, 2002). The possible sources of self-efficacy that digital games provide are (Lee, 2000):

- Performance accomplishments: successfully winning difficult digital games that provide, often public, rewards such as status or level;
- Vicarious experience: watching other players, who are similar to the observer, succeed at games;
- Verbal persuasion: others influencing the player's self-efficacy through verbal communication (i.e. encouragement);
- Emotional arousal: providing emotional arousal while playing games. This is corroborated by a study that found that while playing video games players' heart rates increased (Calvert & Tan, 1994).

Digital games often scaffold the development of self-efficacy by providing initial success and adaptive challenges. This is accomplished by either one of two methods: (1) evaluating the response to challenges and adjusting the difficulty of future challenges accordingly, and/or (2) providing pre-determined levels, where the initial level of difficulty for a series of challenges must be completed before progressing to a new level,

and, so forth, until the game is completed. Once a player starts mastering digital games, the player's self-efficacy, or judgment of their capabilities to attain their goal (i.e. playing and winning) will improve, which in turn will increase motivation to play.

Subjective task value—beliefs about value of doing the task—is the other reason why an individual wants to engage in an undertaking (Pintrich & Schunk, 2002). Subjective task value comprises of the sum of the components of attainment value, the utility value, and the intrinsic value, minus the cost value component (Eccles & Wigfield, 2002). The attainment value is the individual's determination about whether the task confirms or disconfirms the core aspects of the person's beliefs and self-concepts about his or her self. For example, a child who has the self-concept of being a "scientist" will likely determine that a science project has a high attainment value for him or herself to successfully achieve.   The utility value is the person's determination of whether completing the task successfully will be useful for achieving future goals, such as career goals. Utility value is about achieving " the ends of the means-ends of a task" (Pintrich & Schunk, 2002, p. 72). For instance, a student may not have much intrinsic interest in science, but a course in science may have a high utility value for her because she wants to become an engineer in order to earn a good wage. The utility value captures some of the extrinsic motivators that exists (Pintrich & Schunk, 2002; Ryan & Deci, 2000).   In general, extrinsic motivators are external rewards and punishments that affect the individual's tendency to respond a certain way (Greeno, Collins, & Resnick, 1996). For the previous example, the future reward of a good wage is the extrinsic motivator that is influencing the student's utility value belief.

The intrinsic interest or intrinsic value is the enjoyment of engaging in a task, or the "subjective interest in the content of a task" (Pintrich & Schunk, 2002, p. 72). Eccles and Wigfield (2002; Wigfield & Eccles, 2000) claim that intrinsic/interest value is a

similar construct to flow as defined by Csikszentmihalyi (1990), and intrinsic motivation as defined by Deci and Ryan (1992; Ryan & Deci, 2000) and by Harter (1992), and the construct of interest as defined by Hidi, Krapp, Renninger and Schiefele (Hidi & Renninger, 2006; Krapp, 2005; Schiefele, 1991). The intrinsic value in doing a science project can be because he or she finds it "fun" to do. According to Wigfield and Guthrie (1997), the student's intrinsic motivation and learning goals are critical predictors of long-term engagement in academic subjects, which is an indicator of long-term continuing motivation. Because the intrinsic value of motivation is likely the most important contributor to continuing motivation, a separate section is devoted to intrinsic motivation, flow, and interest theories.

Finally, there is the cost component of task value, which is the perceived negative side of engaging a task. Cost is relative because when people engage in a task, it means that they are not engaged on other tasks (Eccles & Wigfield, 2002), which can also be called the opportunity cost of doing an activity (Wikipedia, 2006e). Cost beliefs also include perceived amount of effort, pain, and anticipated emotional states. "For example, a college student might not choose to continue in science or math because he perceives that the costs in terms of effort required are too much for him to bear at this time" (Pintrich & Schunk, 2002, p. 73). However, cost has been studied very little and has not been explained in great detail by Eccles and colleagues (Anderson, 2000).

In terms of continuing motivation, both task value and expectancy may be important contributors. In general, Eccles and her colleagues have found that both intentions and decisions to take an academic subject—an outcome of long-term continuing motivation—is predicted by task values, whereas performance in the subject is better predicted by ability beliefs (Pintrich & Schunk, 2002). Specifically for math and science, it has also been found that task values predict course plans and enrollments,

whereas ability self-concepts are better predictors of performance in the subject (Eccles & Wigfield, 2002). Eccles and her colleagues (2002) have also shown that both expectancies and values predict career choices—another, if not the ultimate, outcome of continuing motivation.

Eccles and Wigfield (2002) argue that at some point self-efficacy and task values become positively related to each other because: (1) positive experiences when the child does well become attached to successful activities, and (2) lowering the subjective value of difficult activities may maintain self-esteem and global efficacy. That is, development of self-efficacy and subjective task value beliefs build upon each other reciprocally over time. Thus, due to the task value and ability self-concepts influencing each other, ability self-concept may also influence continuing motivation.

For instance, in a study to test the reciprocal relations between choices in courses and beliefs in sixth-grade math and science, Simpkins, Davis-Kean, and Eccles (2006) found that, contrary to previous studies, course selection was more strongly related to ability self-concepts than beliefs in the value of math and science. This longitudinal study measured the participation of 5th grade students after school activities—a strong indication of continuing motivation. Later, the same students' while in 6th and 10th grades reported their expectancies and subjective task value for science, along with their high school science course selections. In addition, the students' grades, parent education, and family annual income were collected. The study attempted to associate the gender, parent income, parent education, grades, after school activity participation, self-efficacy, and task value to the number of science courses selected. The researchers found that 5th grade students' continuing motivation, manifested as participation in out-of-school science activities not related to homework, predicted the students' self-efficacy and values in science in subsequent grades. In addition, those who had high self-efficacy or

interest in science were more likely to pursue science in high school than their peers. Their study also suggested that good grades in science reinforces ability self-concepts that in turn influences children to participate in after-school activities and continued coursework in these subjects. That is, good grades affect ability self-concept, which in turn affects continuing motivation. This is in contrast to previous studies that showed task value as more strongly related to course selection rather than self-efficacy. The researchers concluded that due to the reciprocal building of ability self-concepts and engagement with science content, they suggested that a "one-time intervention is not likely to have lasting effects on most youths" (p. 82).

In Eccles' model of achievement motivation, expectancies and subjective task values are influenced by the student's socio-cognitive motivational beliefs, which are his or her goals, self-evaluations of ability, and self-concepts of identity, as well as emotional reactions to past experiences and other memory schemata. Goals are cognitive representations of a future state, short-term or long-term, that the student is striving to attain. Self-concepts are the beliefs about the type of person an individual is now and what kind a person that the individual wants to become, which concerns the person's personality and identity. Another major influence are the emotions that people attach to past experiences and the content of what is remembered of past experiences.

These influencers, are in turn, are affected by cognitive processes related to motivation, which include the perceptions of his or her teachers', social group's and family's attitudes and expectations of them, and his or hers interpretations of and attributions for past experiences. Students are influenced by the expectations that they perceive that others have of them, i.e. social norms. Another influence are achievement related attributions for past experiences of which the most important are ability, effort, task difficulty, and luck (Eccles & Wigfield, 2002; Pintrich & Schunk, 2002). These

perceived causes for an event can be categorized into three casual dimensions, according to Weiner's model of attribution (Weiner, 2000): stability, locus, and control. Causal stability ranges from stable to unstable and refers to the attribution's permanence over time (Pintrich & Schunk, 2002). Some students perceive aptitude, such as science ability, to be constant over time, whereas effort is perceived to be unstable. Locus refers to whether the location of the cause is perceived to be within the student or outside of the student. "For example, ability and effort would be considered internal causes of success, whereas the ease of the task or help from others are external causes" (Weiner, 2000, p. 4). And finally, 'control' refers to the external versus internal locus of control. Luck, for example, is considered to be outside of the control of the individual.

Finally, in Eccles' model of motivation, the cognitive processes related to motivation are influenced by the social world in which the student resides. The influences include the student's beliefs about the cultural milieu, unique historical events, the student's social environment, including the interactions with others, actual capabilities, as well as past behavior and achievement (Eccles & Wigfield, 2002; Pintrich & Schunk, 2002) .

It is posited that the underlying dimensions of continuing motivation can be explained using Eccles' model of motivation. Nonetheless, intrinsic motivation was found in previous studies to be a significant contributor for the promotion of continuing motivation, though some extrinsic motivators may also contribute to the development of continuing motivation. Thus, continuing motivation appears to be closely related to intrinsic motivation, as originally suggested by Maehr and Sorensen (Maehr, 1976; Sorensen & Maehr, 1976). And as previously mentioned, Eccles' interest/intrinsic value is highly related, if not synonymous, to intrinsic motivation as posited by Deci and Ryan, flow theory as posited by Csikszentmihalyi, and interest theory as posited by Hidi, Krapp,

Renninger, and Schiefele. Because intrinsic value is considered a significant contributor to continuing motivation, in the following sections, these three highly related constructs—intrinsic motivation, interest and flow—will be described and compared.

Intrinsic Motivation as Contributor to Continuing Motivation

As suggested previously, continuing motivation appears to be closely related to intrinsic motivation. For instance, continuing motivation was found to decrease when certain extrinsic rewards were provided for performing a learning task (Sorensen & Maehr, 1976), which is the same result that has been found when investigating intrinsic motivation (Pintrich & Schunk, 2002). An activity is said to be intrinsically motivating if people engage in it 'for its own sake' and they do not engage in the activity in order to receive some external reward, such as money or status (Malone, 1981). For instance, people intrinsically value the feeling of having fun. And if it is expected to be attained, people are motivated to pursue it and engage in activities that provide it, for its own sake. Thus, the 'feeling of fun' is intrinsic in nature and is motivating. This intrinsic motivation is the one that researchers find over and over again when studying humans playing games (Dempsey, 1993; Tuzun, 2004; Westrom & Shaban, 1992).

Intrinsically motivating, interesting, captivating, enjoyable, and fun are more or less interchangeable concepts and terms, according to Malone and Lepper (1987). There are many different perspectives on the components of intrinsic motivation and this may be because intrinsic motivation is contextual in that it varies over time, circumstances, and how people view what they are doing (Pintrich & Schunk, 2002). One prominent perspective of intrinsic motivation is Deci and Ryan's (1992; Ryan & Deci, 2000) self determination theory. This theory posits that people are innately motivated to seek out optimal stimulation and challenges that meet the needs of autonomy, competence, and relatedness. Autonomy need is the need of humans to feel that they are in control of their

environment and is similar to control in flow theory that will be discussed later. That is, environments that provide choices and self-direction support the feeling of autonomy, which enhances intrinsic motivation. Competence need is the need to feel capable of acting appropriately in an environment and is similar to the matching of skills to challenge in flow theory. Relatedness is the need to feel secure and connected to others in the learning environment, particularly to the teachers and other authority figures. The need for security and connectedness is closely aligned with Maslow's (1955) theory of hierarchy of human needs of safety and belongingness. In Maslow's theory safety needs can be seen in individual's preference for familiar surroundings, and belongingness needs involve the need for affectionate relationships and the feeling of being part of a group (Petri, 1981). In support of the existence of the belongingness need, there have been numerous studies demonstrating that cooperative learning and group activities, such as those provided in problem-based learning environments, have a positive effect on students' interest, engagement, and motivation (Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2003). The desire of individuals to establish, strengthen, and maintain interpersonal relations—the sense of belonging to and participating in a social group or community—is aligned with the social constructivist view of motivation (Greeno, Collins, & Resnick, 1996), which is an underlying theory behind problem-based learning environments.

Besides Deci and Ryan, there are many other researchers of intrinsic motivation, with each one having a different emphasis as to the sources of intrinsic motivation. The researchers' diverse views of the elements that can promote intrinsic motivation are summarized below (Lepper & Malone, 1987, p. 258):

- Humans as problem solvers: challenge, competence, efficacy or mastery. (researchers—Bandura, Deci, Harter, Lepper, Weiner, and White),

- Humans as information processors: curiosity, incongruity, or discrepancy (researchers—Berlyne, Hunt, Kagan, and Piaget),

- Humans as voluntary actors: control and self-determination (researchers—Condry, deCharms, Deci, Nuttin, and Ryan)

- Humans as players: fantasy involvement using graphics, story, and sound (researchers—Lepper and Malone).

In summary, intrinsic motivation is enhanced by four sources in a learning environment: challenge, curiosity, control, and fantasy, as described in Table 3 (Pintrich & Schunk, 2002, p. 268).   In addition, as mentioned previously, the need to feel connected and belong in a group—the interpersonal motivation—is also a source of intrinsic motivation. Methods of promoting interpersonal motivation include organizing activities to have competition, cooperation, and recognition for achievement. Malone (1987) proposed a set of heuristics and principles for designing intrinsically motivating instructional environments that include all of the sources of intrinsic motivation (see Appendix A).

Table 3: Sources of Intrinsic Motivation

Source	Implications
Challenge	Present learners with task of intermediate difficulty that they feel efficacious about accomplishing
Curiosity	Present students with surprising or incongruous information that will motivate them to close a gap in their knowledge
Control	Provide learners with choices and a sense of control over their learning outcomes
Fantasy	Involve learners in fantasy and make-believe through simulations and games

Note: From *Motivation in Education: Theory, Research, and Applications*, 2nd ed., (p. 268) by P. Pintrich and D. Schunk, 2002, Upper Saddle River, NJ. Copyright 2002, 1996 by Pearson Education, Inc.

Although continuing motivation seems to be very similar to intrinsic motivation, continuing motivation may not be a case of intrinsic motivation because it is not clear if other sources of motivation are not involved (Miller & Hom Jr, 1990). During the time that Maehr posited continuing motivation, in the late 1970s and 1980s, intrinsic and extrinsic motivation were thought of as 'either/or' constructs. That is, either an individual was intrinsically motivated or extrinsically motivated, but not both. Since then, a number of studies, including those performed by Lepper and others, indicate that an individual can be both intrinsically and extrinsically motivated (Lepper, Corpus, & Iyengar, 2005; Pintrich & Schunk, 2002). Also, there may be levels in the process of going from fully extrinsically motivated to intrinsically motivated, where the extrinsic motivation continues to be internalized until the individual feels self-determined (Ryan & Deci, 2000). If this is true, then perhaps, there are some kinds of extrinsic motivators, as well as other motivational processes, that could influence continuing motivation. Maher argued that "there are reasons to assuming a separability and uniqueness" (Maehr, 1976, p. 445) of continuing motivation from intrinsic motivation. And for this study, intrinsic motivation and continuing motivation are considered separate constructs. That notwithstanding, intrinsic motivation is an important contributor to continuing motivation, and, thus, it is prudent to understand the other two major perspectives that are similar to intrinsic motivation, which are flow theory and interest theory.

Theory of Flow as Contributor to Continuing Motivation

Csikszentmihalyi (1990) provides a similar view of intrinsic motivation. His theory posits that humans are innately motivated to attain 'an optimal experience' or 'flow'. Csikszentmihalyi emphasizes the subjective experience of intrinsic motivation, whereas Ryan and Deci (2000) are concerned about the needs that underlie intrinsic motivation (Eccles & Wigfield, 2002). That is, Csikszentmihalyi focuses on the

immediate reasons for attaining the optimal experience, rather the ultimate reasons of the behavior, which is focused on by Ryan and Deci (Eccles & Wigfield, 2002). Ultimately, Eccles and Wigfield (2002) argue that this difference between flow and self-determination theory "reflects two sides of the same coin" (p. 113). However, this may not be entirely accurate since recent research has shown that for flow to become possible, both the challenges and skills must be relatively high (Eccles & Wigfield, 2002). Thus, it would seem that flow is a special case of intrinsic motivation and should be considered the feeling that an individual attains when highly motivated, intrinsically, while performing an activity.

Flow is an emotional and psychological state that occurs when an individual is fully engaged and immersed in an activity (Eccles & Wigfield, 2002). This emotional state is characterized by (1) the merging of action and awareness, (2) concentration and focus on a limited field of stimuli, (3) the loss of self-consciousness, and (4) the transformation of time (Eccles & Wigfield, 2002; Salen & Zimmerman, 2004).

Individuals attain flow from engaging in an activity through the following prerequisites: (1) task is optimally challenging, (2) task has clear goals, (3) task provides immediate feedback about performance, and (4) task promotes a feeling of control (Csikszentmihalyi, 1990, p. 49). First, challenges must be adaptable and just difficult enough so that the individual's skills and knowledge are continuously challenged as s/he masters (i.e. attains competence of) past challenges. As the individual masters challenges in an activity, s/he also attains a feeling of self-efficacy for accomplishing that activity. Second and third, the activity must provide clear goals and immediate feedback so that the individual knows whether s/he has come closer to reaching the goal and when the goal has been reached. This is particularly engaging when there are many minor goals leading to a major objective. When an activity is more open-ended, such as in PBL

environments, the person must learn to set intermediate goals and gauge progress or s/he may not enjoy the activity. Fourth, individuals must feel in control of the activity, though paradoxically in an uncertain situation (Csikszentmihalyi, 1990).

Csikszentmihalyi (1990) argues that often people, particularly children, need external incentives or extrinsic motivators to start an activity that is difficult and demands effort. However, regardless of the initial reasons of why an activity is undertaken, flow is attained when the activity is highly intrinsically motivating and rewarding. Again, the separation of extrinsic and intrinsic motivation is not clear-cut. There may be an almost immediate change from an activity that requires extrinsic motivation but then becomes intrinsically motivating, or perhaps both extrinsic motivation and intrinsic motivation are present at the same time. There may also be a continuous integration of extrinsic reasons for engaging in an activity until the activity becomes intrinsically motivating, as posited by Ryan and Deci (2000). For instance, Csikszentmihalyi (1990, p. 68) tells a story of a child who was required by his father to attend concerts, but the child hated listening to classical music. Then one day, after three years of painfully listening to classical music, he felt an overwhelming sense of the world of music—he experienced flow—as he discerned the melodic structure of a Mozart opera. Over time, he had built the skills of understanding music and integrated the external reasons for listening to classical music until he had reached the emotional state of flow.

Relationship of Theory of Interest to Continuing Motivation

In Eccles' model of motivation, the component of subjective task value of intrinsic value is interchangeably referred to as interest value. Indeed, the definition of this component is both the enjoyment of performing the activity (i.e. feeling of intrinsic motivation or flow) and the individual's interest in the activity (Eccles & Wigfield,

2002). Thus, it may be productive to understand the theory of interest, as it relates to intrinsic motivation.

Unfortunately, different definitions and theoretical perspectives on the construct have plagued research into what is interest (Pintrich & Schunk, 2002). However, there are three general approaches on interest: individual interest (disposition of the person), interestingness (characteristics of the context and situation), and the resulting psychological state of the individual due to the interaction of the person with the context and situation (Pintrich & Schunk, 2002). The psychological state of experiencing an interesting activity is considered to be either actualized individual interest or situational interest.

The characteristics of a situation or context that students think are interesting leads to the generation of situational interest. That is, different features of a context and content can generate immediate interest in the student for learning a subject or performing the activity to learn the subject. A few common features include novelty, surprise, complexity, ambiguity, and certain types of themes, such as death and sex (Pintrich & Schunk, 2002). Some of these features appear to very similar to those posited by flow theory and intrinsic motivation. However, one difference is that interest researchers posit that situational interest is tied to specific content that generate interest in students, and may last longer than simply arousal, which they often characterize as intrinsic motivation.

It has been suggested that situational interest may have two phases: one where interest is triggered and another where interest is further maintained (Hidi & Harackiewicz, 2000; Mitchell, 1993). "If the situational experience is accompanied by enjoyment, delight, and learning, the opportunity for developing long-term motivation may occur" (Guthrie, Hoa, Wigfield, Tonks, & Perencevich, 2006, p. 93) That is, if a

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situation succeeds to "catch" or trigger the student's interests then there is an opportunity for that interest to "hold" or maintain (Hidi & Harackiewicz, 2000; Mitchell, 1993). These concepts are analogous to Dewey's (1913) concept of interest that included the constructs of identification (trigger) and absorption (holding). Holding interest for longer than the situational experience requires learning conditions that are meaningful for and valued by the students (Mitchell, 1993). Krapp (2002) considers this holding of interest to be a stabilized situational interest that may lead to individual interest. This stabilized situational interest may develop into a personal or individual interest (Pintrich & Schunk, 2002).

In addition to situational interest, interacting with the appropriately interesting context and content may actualize the student's personal or individual interest. As Pintrich and Schunk (2002, p. 292) elaborate:

> For example, a student may have a fairly high level of personal interest in science-related topics and, in her reading class, she occasionally gets to read expository texts about science topics. On these occasions, she experiences a heightened psychological state of interest in contrast to other occasions during reading class when she reads about other topics. In this case, however, her personal interest in science is activated in the science class and she experiences actualized individual interest.

What is remarkable about this example is that the student's interest in science continued from the context of the science class to the context of the reading class. This is akin to continuing motivation to learn science in that motivation to engage in science continued from the science classroom to contexts outside of the classroom. Perhaps, the ultimate state of continuing motivation is the development of an individual interest in a subject.

Individual or personal interest is considered to be a relatively stable, enduring disposition toward a content or object (Pintrich & Schunk, 2002). Individual interest can be defined in specific domains and academic subjects or it can be defined as a general orientation toward the desire to learn new information (Ainley, Hidi, & Berndorff, 2002; Schiefele, 1991). This general interest orientation is similar to mastery goal orientation (see pages 213-229 in Pintrich and Schunk (2002)) that represents the approach behavior to novel, uncertain, or puzzling phenomena with the goal of understanding (Ainley, Hidi, & Berndorff, 2002).

More than fifty studies have shown that interest in learning and achievement are positively correlated (Krapp, 2002). Specifically for science, others have found that interest in science was also a contributor to performance by students (Shernoff & Hoogstra, 2001). Also, research has found that interest in a subject affects whether or not a student enrolls in future courses in that content domain (Harackiewicz, Barron, Tauer, Carter, & Elliot, 2000; Shernoff & Hoogstra, 2001), which is congruent with the results that link task value to course selection.

The characteristics of individual interest are that it has feeling-related and value-related components, and it is intrinsic in nature (Krapp, 2002; Schiefele, 1991). That is, individual interest is intrinsic in character and not attained for external reasons (Schiefele, 1991). The feeling-related component refers to the positive feeling associated with an object and/or activity, especially enjoyment and engagement. This feeling-related valence under certain conditions may be experienced as flow (Krapp, 2002; Schiefele, 1991). The value-related component is the personal significance attributed to the object and/or activity. That is, the value-related valence is a cognitive construct that represents personal values and goals toward the object of interest (Krapp, 2002; Schiefele, 1991). These values can be influenced by the social milieu that the student is situated, as

described by Eccles' model and social constructivist theory. The two valence measures, feeling and value, are highly correlated (Ainley, Hidi, & Berndorff, 2002).

In addition to these two psychological constructs, Renninger (2000) posited that there is a stored-knowledge component that represented the individual's knowledge and understanding of subject content, and its relationship to individual interest has been confirmed empirically (Ainley, Hidi, & Berndorff, 2002). That is, there must be enough organized knowledge possessed by the person in order for individual interest to emerge. This knowledge not only leads the individual to seek challenges and answers to his or her piqued curiosity, but also "informs his or hers developing sense of possible selves" (Renninger, 2000, p. 379). That is, a deepening knowledge that is valued shapes a person's identity.

Individual interest has been closely linked to the intrinsic motivational concepts of flow, intrinsic interest, intrinsic motivation, and situational interest (Krapp, 2005; Renninger, 2000). Krapp (2002) posits that actions based on interest have the "quality of being intrinsic motivation" (p389). However, the intrinsic motivational concepts are often characterized as arousal and engagement in the short term, whereas individual interest represents a more ongoing and deepening engagement with particular subject content and an individual interest is always directed toward that content (Renninger, 2000). Perhaps the distinction is that intrinsic motivation is more related to situational interest, whereas individual interest is more related to a high level of continuing motivation.

The process of interest development is not fully understood but there have been some recent attempts to describe it. The early development of interest seems to be influenced by affect toward the subject, but further interest development involves the interaction of knowledge with the affect (Ainley, Corrigan, & Richardson, 2005). Krapp

(2002) postulated that individual interest develops from the occurrence of a situational interest through a stage that he termed "stabilized situational interest." He suggested that this stabilized situational interest comprises of feeling-related and value-related components, as does individual interest, and is driven by the needs identified in self-determination theory (Ryan & Deci, 2000) of autonomy, competence, and relatedness. Several empirical studies support the premise that the amount and quality of experiences that fulfill these three needs have a direct influence on the emergence and stabilization of interests (Krapp, 2005).

In contrast, Hidi and Renninger (2006) proposed their own four-phase model of interest development. In this model, the development of individual interest from situational interest progresses through two stages: (1) maintained situational interest and, then subsequently, (2) emerging individual interest, as shown in Table 4 below (Hidi & Renninger, 2006, pp. 114-115).

Table 4: Developmental Phases Between Situational and Individual Interest

Phase 2: Maintained Situational Interest	Phase 3: Emerging Individual Interest
Maintained situational interest refers to a psychological state of interest that is subsequent to a triggered state, involves focused attention and persistence over an extended episode in time, and/or reoccurs and again persists:	Emerging individual interest refers to a psychological state of interest as well as to the beginning phases of a relatively enduring predisposition to seek repeated reengagement with particular classes of content over time:
1. Situational interest is held and sustained through meaningfulness of tasks and/or personal involvement	1. Emerging individual interest is characterized by positive feelings, stored knowledge, and stored value
2. A maintained situational interest is typically, but not exclusively, externally supported	2. An emerging individual interest is typically but not exclusively self-generated
3. Instructional conditions or learning environments provide meaningful and personally involving activities, such as project-based learning, cooperative group work, and one-on-one tutoring, can contribute to the maintenance of situational interest	3. Instructional conditions or the learning environment can enable the development of an emerging individual interest

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| 4. | A maintained situational interest may or may not be a precursor to the development of a predisposition to reengage particular content over time as in more developed forms of interest | 4. | An emerging individual interest may or may not lead to well-developed individual interest |

In Hidi's and Renninger's model, perceived self-confidence, autonomy, and social-relatedness also support the development and deepening interest in a reciprocal relationship. Unfortunately, the distinctions between the maintained situational interest stage and the emerging individual interest stage are not obvious, and may be difficult to measure. In addition, there does not seem to be any studies that have reported measuring the difference between these two stages, possibly due to the recent emergence of the proposed model or due to the difficulty of measurement.

When comparing Eccles' model of motivation to interest theory, there seems to be several highly related, if not directly overlapping, constructs. The intrinsic part of the intrinsic/interest value component of the subjective task value in Eccles' model has the same attributes as the feeling-related valence of interest theory. Both constructs are defined as the positive feelings of fun and enjoyment that an individual experiences while engaged in an activity and/or content. And, the interest part of the intrinsic/interest value includes the person's interest in the activity, which may reflect a situational interest or actualized individual interest. Eccles' attainment value has the same attributes as the value-related valence of individual interest since both are defined as cognitive components related to personal value and goals toward an object. The only construct that may differ is stored-knowledge in interest theory. Eccles' theory of motivation does not directly address this construct.

In summary, the interestingness of a task initially trigger the student's engagement, which may lead the student to maintain engagement on the task until

completion, and when this occurs, the task is defined as having situational interest for the student. Over time, if the student's motivation continues beyond the immediate task to learn more, the student may develop an individual interest for a subject matter. Unfortunately, the process of development between situational interest and individual interest is not well understood at this time, with no agreed upon models. What does seem plausible is that some types of interesting learning contexts promote situational interest that leads to continuing motivation to learn a subject, which over time and repeated exposure, turns into an individual interest for that subject. And, once an individual already has an identity structured around goals and actions related to a subject, changing the pattern of a person's interests is difficult and seldom happens (Krapp, 2002). Thus, it is imperative to start at an early age the process of promoting long-term engagement, i.e. continuing motivation, with academic subjects by providing students with interesting tasks involving the subject matter.

Summary of Model of Continuing Motivation

It has been proposed that the model of the underlying dimensions of continuing motivation can be Eccles' expectancy-value model. In this model, behavioral intention or motivation to achieve a goal is supported by both the expectation of accomplishing this goal and the value of the goal. In the case of learning science, this can be described as the student's perceived sense of competency in accomplishing the learning task in science and the subjective value of that learning task for the student. The student's perceived sense of competency has been termed by various researchers as self-efficacy, ability self-concept, and other terms referring to competency-based beliefs. The subjective task value of the activity has four components: attainment value, utility value, intrinsic/interest value, and cost. Attainment value is the personal importance of doing well in the activity and is synonymous with the value-related component of an individual

interest in interest theory. Utility value is value that students determines how well a task relates to current and future externally rewarding goals, such as career goals. Thus, this component captures some of the extrinsic reasons for task engagement. Intrinsic/interest value is the feeling of enjoyment that an individual gets from performing an activity, and is synonymous with intrinsic motivation, flow theory, the feeling-component of individual interest, situational interest and, perhaps individual interest, itself. The sources for the promotion of intrinsic value or intrinsic motivation are challenges, curiosity, competency, fantasy, and interpersonal motivators. Finally, cost is an understudied component that captures the negative aspects of engaging in a task.

This model has several advantages for describing the underlying dimensions of continuing motivation. One, this model includes self-efficacy, which has been suggested to contribute to continuing motivation. Two, students may be extrinsically motivated from the utility value of the task, as well as the intrinsically motivated from the intrinsic task value. This is in congruence with the view that some extrinsic motivators may contribute to continuing motivation. Three, this model includes perhaps the most important contributor to continuing motivation—intrinsic value, which is synonymous with intrinsic motivation, flow, situational interest, and the feeling-valence of individual interest, and interest value, which is highly related to individual interest. Four, this model includes attainment value, which is an important component in the development of individual interest. Individual interest—the ongoing long-term engagement in a subject—is perhaps the ultimate goal and level of continuing motivation. It should be noted that Eccles model does not include the value of stored knowledge, which has also been suggested as a component of individual interest.

Attitude Toward Science as Continuing Motivation

In science education, there is a related view of continuing motivation called attitude toward science. Unfortunately, although there has been decades of research on attitude toward science, there is no consensus among researchers as to what science-related attitudes are and how to measure it (Francis & Greer, 1999). Moreover, researchers have not even agreed on the differences between attitudes, beliefs, and values (Moore & Foy, 1997). Thus, the definition of science attitudes continues to be vague and ambiguous, because both the terms "science" and "attitudes" take on inconsistent meanings for different people and contexts (Germann, 1988). For instance, for middle school students, does science mean science in the classroom or science in general? Are their attitudes different if they think of science as biology versus science as physics, or task specific, such as laboratory work versus theoretical problem-solving? Is attitude solely affective in nature or does it have a cognitive component? For instance, many surveys have shown that students' attitude toward science education are negative, whereas their attitude toward science in general are positive. This has led, to speculate that "school science might do more harm than good!" (Osborne, Simon, & Collins, 2003, p. 1060).

Klopfer (1971) was one of the first investigators who attempted to categorize the affective domain in science education as:

- the manifestation of favorable attitudes towards science and scientists;
- the acceptance of scientific enquiry as a way of thought;
- the adoption of 'scientific attitudes';
- the enjoyment of science learning experiences;
- the development of interests in science and science-related activities; and

- the development of an interest in pursuing a career in science or science related work.

In general, researchers divide attitude as it relates to science into scientific attitude and attitude toward science (Germann, 1988). Scientific attitude is the person's approach to solving problems, assessing information, and decision-making that models those of scientists. Attitude toward science may include scientific attitudes, as well as beliefs about scientists, scientific careers, scientific interests, and science in the classroom (Germann, 1988), depending on the researcher's definition. One school conceptualizes attitudes as a multi-dimensional construct with three distinct components: cognitive, affective, and behavioral, while another school of thought, represented by Ajzen and Fishbein (1972), conceptualizes attitude solely as affective in nature, and as a general and enduring feeling about science (Spellman & Oliver, 2001).

Studies have suggested that students' positive attitudes toward science are prerequisites for them to consider science courses and a science career (Smist & Owen, 1994; Spellman & Oliver, 2001). This is similar to the findings that subjective task value in Eccles' model is a better predictor of course and career selection. Also, research has suggested that previous achievement is a stronger predictor of science achievement and that success leads to positive feelings (Sorge, Newsom, & Hagerty, 2000). This may be due to the building of self-efficacy through students' evaluating past achievement. For instance, in a study by George (2000), science self-efficacy was found to be the strongest predictor of attitude toward science throughout middle school years. Thus, it is not clear whether the predominant casual sequence is that changes in achievement and self-efficacy in science causes changes in interest in science or vice-versa (Freedman, 1997). This is similar to the view that self-efficacy and subjective task value build upon each other reciprocally.

Overall, research provides strong evidence that feelings of enjoyment combined with success in early secondary science courses are "likely to lead to a positive commitment toward science that is enduring" (Osborne, Simon, & Collins, 2003, p. 1060). Currently, the popular model is that making science instruction exciting and encouraging promotes a positive attitude in science that may improve science achievement (Freedman, 1997). Finally, some research suggests that the perceived difficulty in science is the "*major* factor inhibiting" (Osborne, Simon, & Collins, 2003, p. 1070, italics original) the selection of science classes. In Eccles' and continuing motivation terms, evoking intrinsic/interest motivation in science activities may promote continuing motivation to learn science, which may improve achievement in science. In contrast, the perceived difficulty cost of engaging in science detracts from continuing motivation to learn science.

Similar to the results from studies of student intrinsic motivation in science, researchers have found that attitude toward science generally decline over the middle and high school years (George, 2000). In addition, simple generalizations about how and why there are changes in attitude toward science have not been found (Osborne, Simon, & Collins, 2003). Moreover, a number of studies conducted in science classrooms have shown only a minor shift in attitude using a particular treatment (Osborne, Simon, & Collins, 2003). As Seigel and Rainey (2003) state "it is rare to find dramatic changes in beliefs or attitudes in a short time" (p. 759). For instance, Jarvis' and Pell's (2005) study of children's attitudes toward science after a visit to a national space center found no evidence of a long-term effect, after five months, on "enthusiasm for science" (p. 77). These findings are congruent with Simpkins, Davis-Kean, and Eccles' (2006) argument that "one-time intervention is not likely to have lasting effects on most youths" (p. 82), and Krapp's (2002) view that changing the pattern of a person's individual interests is

difficult and seldom happens. Yet, encouragingly, Jarvis and Pell (2005) did find a significant increase in space science interest immediately after the visit. Perhaps attitude toward science or continuing motivation to learn science dissipates as the student is reengaged in less interesting science activities.

Unfortunately, there seems to be a lack of appropriate, reliable, and effective instruments to measure attitude toward science, because of the lack of agreement on its definition. In particular, there are questions of construct validity when attempting to measure attitudes (Sorge, Newsom, & Hagerty, 2000). Despite this lack of clarity, or perhaps because of it, there were more than 50 different instruments used in studies to assess attitude toward science, by 1983 (Helgeson, 1992; Munby, 1997).

All of these instruments were self-reports of students' attitude toward science were used to quantitatively determine its attributes. However, attitude self-report measures may not measure all the student's views on science (Osborne, Simon, & Collins, 2003). Thus, qualitative methods may provide a better understanding of attitude toward science in context. That is, qualitative measures may be productive in exploring issues of attitude toward science in the school context, and how that may relate to the student's immediate and future behaviors. Unfortunately, there have been only a few qualitative studies that have explored students' attitude toward science (Osborne, Simon, & Collins, 2003) or continuing motivation.

The various measures of attitude toward science illustrate the conundrum that this line of research has encountered. On the one hand, there is consensus that a positive attitude toward science is critical for students to become scientifically literate. On the other hand, there is no consensus on the definition of attitude and how to measure it. Worse yet, most measurements of this attitude are for "science". Unfortunately, researchers' conception of science and the students' may differ widely, and be context sensitive (Munby,

1982). As Munby (1982) argues "After all, the contexts for comprehending the terms are legion: science teaching per se, this year's science class, today's class or subject matter, the science I can't learn in school, the science I get from television, or the science my Dad does at the textile plant" (p. 618). Munby points to the need for specificity and the inclusion of context when asking questions regarding attitude toward science or continuing motivation to learn science,. Finally, the measurement of attitude toward science would be greatly simplified if researchers would agree to focus on measuring the positive or negative feeling about science, such as "I like science" and "I hate science" (Koballa & Crawley, 1985, p. 223).

In summary, research suggests that positive attitude toward science strongly influence students choices of science related courses. That is, students' enduring feelings toward science heavily influences their choice to continue taking science courses and their selection of science courses. This is congruent with research regarding how subjective task value influence course selection. Further, it is proposed that some of the elements of Klopfer's (1971) taxonomy of attitude toward science overlap with Eccles' model of motivation. In particular the following elements of Klopfer's taxonomy appear to be highly related to Eccles' intrinsic/interest value component: (1) the enjoyment of science learning experiences and (2) the development of interests in science and science-related activities. These two elements could lead to the third element of Klopfer's taxonomy: the development of an interest in pursuing a career in science or science related work. Perhaps these dimensions are built over time in that respective order. That is, the enjoyment of science learning experiences builds the development of interests in science and science-related activities, and, with success in science, leads to the development of an interest in pursuing a career in science or science related work. Perhaps continuing motivation can be conceptualized as the bridge between the

enjoyment of science learning experiences and the development of individual interests in science and science-related activities, and a career in science or science related work.

In conclusion, it appears that attitude toward science is highly related to the concept of Eccles' subjective task value, and, in particular, Eccles' interest and intrinsic value component, which is posited to influence continuing motivation to learn science. For the purposes of this study, attitude toward science will be defined as an enduring like or dislike of science, as suggested by Koballa and Crawley (1985). From this definition, attitude toward science may be able to be measured by determining the changes in students' intrinsic/interest value of science over time.

Summary on Continuing Motivation and its Underlying Dimensions

In this section, it was argued that Eccles' theory of motivation can be used as the underlying theory of continuing motivation and attitude toward science, and subsumes the previous work on intrinsic motivation theory, flow theory, and interest theory. The need to link these disparate theories is not a new idea. Osborne, Simon, and Collins (2003) have called on science educators to use the body of literature on motivation to help remediate the problem of negative attitude toward science in school, implying the need to use motivational theory to understand attitudes. Other researchers have pointed out the evidence that "motivational variables can be a significant predictor of continuing motivation in the field of science" (Shernoff & Hoogstra, 2001, p. 85). If Eccles' expectancy-value theory of achievement motivation can be used to understand the underlying dimensions of continuing motivation to learn science, then ultimately, this understanding may lead to better curriculum and instruction to promote continuing motivation to learn science, which may lead to an individual interest, and science and science-related careers.

DESIGN-BASED RESEARCH

The traditional method of research in motivation is to investigate the hypothesized phenomenon in a laboratory setting where there is more control over the variables. This experimentation produced rigor, validity, and the possibility of replicability under the same laboratory conditions (Hoadley, 2004). Unfortunately, the trade-offs for laboratory experimentation is the lack of context that is representative of school classrooms. In addition, the desire to be objective and detached can result in disconnects between theory and practice. These tradeoffs and approach have often resulted in the predominant educational research models in not contributing to educational innovation (Bell, 2004). Thus, though laboratory experimentation ensured measurement validity, or the ability to ensure that the measurement reflected what was attempted to be measured, there has been a lack of validity that the results accurately reflect the truth of the hypothesis under real-world context (Hoadley, 2004). The need for real-world validity includes accurate alignment of the treatment with the theory, or treatment validity, and research that informs the research questions that are being studied in real-world contexts and practice, or systemic validity (Hoadley, 2004). Finally, consequential validity is needed where the results of the experiment is applied to the development of theory for future prediction and implementation (Hoadley, 2004).

Guerro (1998) argues that "Within the academic community, there is probably no issue more intractable than finding ways to overcome the historical split between theory and practice" (p. 154). The split between theory and practice is an ancient one, recorded from the time of the ancient Greeks, more than 2,000 years ago. Plato believed in the abstract, theoretical approach to philosophy (Wikipedia, 2006f). In contrast, Aristotle believed in the grounded techne (i.e. art and craft of everyday practice) approach to philosophy (Wikipedia, 2006a). Guerra (1998) writes, "the schism that remains between

theory and practice also represents a division of labor that fails to fulfill the needs of the students that we serve" (p. 159). But before we address how to overcome this split, we must change how we conceptualize these two concepts.

Dewey (1938a) postulated that "Mankind likes to think in terms of extreme opposites…its beliefs in terms of Either-Ors, between which it recognizes no intermediate possibilities" (p. 17). The dichotomization of theory and techne is, yet, another example of this kind of thinking. The internationally renowned scholar, Bourdieu (Guerro, 1998), believed that his peers must overcome this dichotomization that have prevented academicians from understanding techne. Without theory, there are no generalizations that allow for the transfer of techne from one context to another. Without techne, there can be no purpose for theory, or even the affordance of theory to construct.

How do we break out of this dichotomization? Theory and techne, as with many other concepts that are dichotomized, should be viewed instead as dialectical in nature. In Hegelian (Wikipedia, 2006b) terms of the dialectical relationship, techne is the thesis and theory the antithesis. The two conflicting concepts are resolved into a synthesis, called praxis. Guerra (1998) wrote, "Friere developed a practice-based approach…that blends his theoretical interpretations with those very practices in what he refers to as praxis" (p. 154), which is the "in-between space where theory and practice become one, where the two inform each other in dialogical terms to the point where they become indivisible" (p. 154). Another view of this dialectical relationship is to view theory developed in the laboratory, which is almost exclusively quantitative in nature, as objectivist and techne in the field as subjectivist, which is often described in qualitative research methods. Thus, the dialectical relationship between theory and practice correlates to the dialectical relationship between objectivity/positivism and

subjectivity/constructivism/interpretivism, which are predominately associated with quantitative and qualitative methodologies, respectively.

In philosophical terms, the Helegian synthesis of theoretical stances of positivism (thesis) and interpretivism (antithesis) is pragmatism. Pragmatists reject the either-or choice between positivism and interpretivism and the suggested incompatibility between methods, logic, and epistemology (Tashakkori & Teddlie, 1998). Pragmatists stress practicality, change, growth, uncertainty, incompleteness, contingency, and consequences of knowledge and action, in the human experience, as we explore its wide-open field of possibilities (Greene, 1988; Pulliam & Van Patten, 2003). Pragmatists use many diverse ideas and approaches that value both objective and subjective knowledge to determine 'what works' (Creswell & Clark, 2007). So, what research approach should a pragmatist in education use? Design-based research (DBR) is a research paradigm that intertwines research with practice and fits well with the purposes of education (Bell, 2004).

Design-based research (DBR) is the research praxis aligned with pragmatic philosophy, where the validity of a theory is its ability to explain phenomena and produce change in the world (Barab & Squire, 2004; Dewey, 1938b), which corresponds to treatment, systemic, and consequential validity. DBR inquiry does not claim Truth as is argued by objectivists, nor does it claim no truths as advocated by some subjectivists, but instead claims that truths are theories that 'fit', in the Darwinian sense (Davis, 2004), in our current context of the world and can produce work in the current generation of the world. In this way, DBR can be considered trustworthy, credible, and useful, which goes beyond the positivistic view of generalizability (Barab & Squire, 2004; Schoenfeld, 1992).

One goal of DBR is usefulness. DBR's goal is to design something that not only develops theory, but also is valuable to others. This criterion not only requires the deep

understanding of one particular context, but DBR must also show relevance to other contexts. This type of generalization has been referred to as a *petite generalization* (Stake, 1995), and it is the kind that Clifford Geertz (Barab & Squire, 2004; Geertz, 1973), a well-regarded anthropologist, refers to as the importance of having both experience-near significance and experience-distant relevance.

DBR moves beyond evaluation to systematically engineering the learning context to improve and understand the systemic and consequential validity of theoretical claims generated in the laboratory (Barab & Squire, 2004). That is, DBR is concerned about improving a particular designed artifact and developing models of how humans act and think. Knowledge is produced through recursive questioning, aiming, implementing, and analyzing results (Barab & Squire, 2004). By engineering and sustaining educational innovations in everyday settings, DBR attempts to understand important things about the complex nature of pedagogy (Bell, 2004).

Because pedagogy is just too complex a phenomenon for any one theoretical perspective or research method (Bell, 2004), DBR uses a pluralistic theoretical approach to developing a rich, composite understanding of human pedagogy. As Charmaz (2004) argues, "Gaining multiple views of the phenomenon strengthens the power of our claims to understand it" (p. 983). Thus, one of the strengths of DBR is that it is a high-level methodological orientation that crosses various theoretical perspectives (Bell, 2004). Another benefit of performing DBR research is that it addresses the social context, and provides better potential for influencing pedagogical practices by producing tangible programs and products with consequential evidence and validity. And the research methodology to perform DBR that is most aligned with the philosophy of pragmatism and the praxis of DBR is mixed methods.

Studies using mixed methods combine quantitative and qualitative approaches during different phases of the research process to create a product that is aligned with the pragmatic paradigm (Tashakkori & Teddlie, 1998).

As Creswell and Clark explain (2007, p. 5):

Mixed methods research is a research design with philosophical assumptions as well as methods of inquiry. As a methodology, it involves philosophical assumptions that guide the direction of the collection and analysis of data and the mixture of qualitative and quantitative approaches in many phases in the research process. As a method, it focuses on collecting, analyzing, and mixing both qualitative and quantitative data in a single study or series of studies. Its central premise is that the use of quantitative and qualitative approaches in combination provides a better understanding of research problems than either approach alone.

Furthermore, many researchers in motivation recognize the benefit of using mixed methods approaches to provide a more full and in depth explanation of student motivation (Walker, Pressick-Kilborn, Arnold, & Sainsbury, 2004).

There are four major types of research designs used in the mix methods methodology: Triangulation Design, the Embedded Design, the Explanatory Design, and the Exploratory Design (Creswell & Clark, 2007). Triangulation Design studies attempt to obtain complementary qualitative and quantitative data on a research topic for purposes of converging the data to best understand the research problem. In this design, both qualitative and quantitative data are considered on equal footing. In Embedded Designs, a qualitative or quantitative data set provides support to the other primary data set. In Explanatory Designs, qualitative data is gathered after obtaining quantitative results to explain or build upon the results. Finally, Exploratory Design studies use results from qualitative methods to develop or inform the quantitative methods. Within

each of these designs there are different variants, such as the simple model, the convergence model, the data transformation model, and the validating quantitative data models of Triangulation Design, that are used depending on how the researcher attempts to gather and merge the data (Creswell & Clark, 2007). The selection of the mixed methods research design and variants depend on "factors such as timing, weighting, and mixing" (Creswell & Clark, 2007, p. 59).

Finally, one of the benefits of DBR is that it affords the ability to combine etic (i.e. behavior description familiar to the observer) and emic (i.e. behavior description meaningful to the actor) data using mixed-methods that cross traditional boundary lines and theoretical lenses to enhance our understanding of pedagogy (Bell, 2004). This affordance often drives DBR studies to collect, align, coordinate, and analyze large quantities of qualitative and quantitative datasets of various types, which can be challenging. Dede (2004) warns that "this combination of challenges may seem less a promising new approach to scholarship than a type of study conceived in hell as Sisyphus-like torture for investigators" (p. 108). In addition, this massive collection of mix-methods data potentially introduces Hawthorne effects (Brown, 1992), where merely studying and observing people can change their behavior. Dede (2004) also believes that collecting and shifting through huge amounts of data to compensate for a design with high noise-to-signal ratio is counterproductive or a massive overkill. Similarly, a concern raised about DBR is the tendency to be "selectively attentive to data that conform to the researcher's expectations" (O'Donnell, 2004), which has been termed the *Bartlett effect* (Brown, 1992). Finally, DBR risks being a venue for endlessly tweaking suboptimal educational artifacts in hopes of an unlikely breakthrough (Dede, 2004).

It is hoped that digital based learning games can provide a learning environment that will enhance the development of continuing motivation. Digital games have been found to be highly motivational to play, based on numerous research findings (Randel & Morris, 1992; Rosas, Nussbaum, & Cumsille, 2003; Russell, 1994), which may promote continuing motivation. A few previous studies have suggested that motivation from playing digital games may have enough power to continue the students' motivation to learn an academic task after the playing the game has finished (Malouf, 1987; Rosas, Nussbaum, & Cumsille, 2003). However, research is needed to determine whether a lengthy engagement with a digital game that requires solving a science related problem can promote continuing motivation to learn science.

The digital game must be designed to highly engage the student in a science related activity, which hopefully will promote continuing motivation to learn science. Considering this, there is an advantage of using problem-based learning (PBL) principles in the design of the digital game. The underlying theories of PBL principles are cognitive and social constructivism. Cognitive constructivism posits that there is an innate desire of people to resolve cognitive conflict (i.e. disequilibrium) that occurs when encountering new experiences presented by certain learning environments. The process of resolution of this cognitive conflict is 'intrinsically motivating' for the person and the resolution is intrinsically rewarding. An activity is said to be intrinsically motivating if people engage in it 'for its own sake' and if they do not engage in it for extrinsic reasons (Malone, 1981). Using a problem-based learning game has the advantages of promoting intrinsic motivation both by the game elements and by the intrinsic rewards for solving challenges and problems. Since there is a strong link between intrinsic motivation and continuing motivation (Maehr, 1976), it stands to reason that the higher the intrinsic motivation

promoted by a learning environment, the greater the probability of students' having continuing motivation.

The other theory underlying PBL environments is social constructivism. Social constructivists believe that motivation is the engagement to maintain interpersonal relationships and identity in a person's communities (Greeno, Collins, & Resnick, 1996). The need to feel connected to others is also considered intrinsically motivating (Ryan & Deci, 2000). Again, a PBL based digital games, if designed and developed properly, should promote interpersonal and intrinsic motivation that may lead to continuing motivation to learn.

In order to research the efficacy of a PBL based digital game to promote continuing motivation to learn science, ways of measuring and understanding continuing motivation must be selected. Measurement should align with the underlying dimensions of continuing motivation. Unfortunately, the underlying contributors to continuing motivation is not very well understand. It is proposed that Eccles' expectancy-value theory of motivation may be a good model to use to study these dimensions because (1) it is a well researched and successfully proven theory for explaining achievement motivation, (2) the theory subsumes other motivational theories, including intrinsic motivation, flow theory, and interest theory, that are probably major contributors to continuing motivation, (3) Eccles' theory is comprehensive in that it provides the opportunity of researching the possible other contributors to continuing motivation, such as self-efficacy.

Another requirement of researching continuing motivation is the decision of the research context and methodology to use. The selection of the methods to be used is based on how they work under certain circumstances. This pragmatic approach also extends to the research context. The context of the intervention to study continuing

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motivation must work both to inform research and to improve pedagogy in the classroom. This type of research is called design-based research (DBR) and the methodology that works best with DBR is mixed methods—using both quantitative and qualitative methods to better understand the studied phenomenon in the classroom setting.

The next chapter will describe in detail the intervention and the research design of this study.

Chapter 3: Methodology

The development of lifelong learners is an oft-touted, rarely achieved goal of almost every educational enterprise. (p. 232)

- Koschmann, Myers, Feltovich, & Barrows (1993)

This chapter explains the methodology and methods that will be used in the study of continuing motivation to learn science using a problem-based digital game called *Alien Rescue*. In this study, the overarching philosophical stance of the researcher will be pragmatism using mixed methods in a naturalistic setting. The remainder of this chapter will examine both the design rationale of the new version of Alien Rescue and the design of the research study to answer the research questions.

RESEARCH QUESTIONS

The purpose of this study is to investigate whether digital games can motivate students to continue learning academic subjects, after instruction has ended. In particular, motivating students to continue to learn science after playing a science based PBL digital game called *Alien Rescue III*. The following are the research questions for this dissertation:

1 Can playing a problem-based learning game in science, *Alien Rescue III,* promote continuing motivation to learn science? Does continuing motivation to learn science change over time after completion of instruction?

2 Is continuing motivation subject, domain, or task specific?

3 What are the psychological dimensions of continuing motivation? Is there a relationship between the knowledge gained during instruction and continuing motivation?

4   Does continuing motivation to learn in future classroom instruction differ from continuing motivation to learn outside of the classroom?

It is anticipated that students' continuing motivation to learn science will be discernible when students finish using *Alien Rescue III* at the end of their learning unit and that the continuing motivation will dissipate as students are reengaged in regular classroom activities in science.

DESIGN RATIONALE OF ALIEN RESCUE

Design based research (DBR) is an intervention in an educational setting with the intention of improving education and informing theory. This intervention is both intentionally designed before enactment and the actual implementation of the intentional design (Collins, Joseph, & Bielaczyc, 2004). Thus, for others to understand the intervention, the intentional design and the actual implementation must both be documented (Hoadley, 2004). In addition, since the DBR approach involves the progressive refinement in design, previous versions of the design must be presented to the world (Collins, Joseph, & Bielaczyc, 2004). With these guidelines in mind, the remainder of this section is focused on the current design of *Alien Rescue*, version 2, and the rationale for the design changes implemented for version 3.

Alien Rescue II is a stand-alone problem-based learning (PBL) software program that is pedagogically the same as *Alien Rescue I*, but technically enhanced. *Alien Rescue* is a multimodal hypermedia learning environment based on the science curriculum for 6th grade in Texas and is designed in accordance with the National Science Education Standards and the Texas Essential Knowledge and Skills (TEKS) guidelines (Liu, Williams, & Pedersen, 2002). *Alien Rescue* typically takes three weeks (twelve to fifteen 45-minute class periods) to complete. *Alien Rescue* presents a complex problem for scientific investigation and decision-making by children (University of Texas at Austin, 2002). The story of *Alien Rescue II* has a

science fiction premise that allows students to take on the role of a scientist in charge of finding habitats, i.e. planets or moons, in our solar system for six endangered aliens. In order to find habitats for the aliens, students must learn, using a rich set of cognitive tools, about the planets and moons in our solar system. The learning objectives include increasing knowledge of our solar system and improving problem-solving skills. The following is a description of *Alien Rescue II* by Liu, Williams, and Pederson (2002, pp. 259-260):

> The science fiction premise of *Alien Rescue* takes students to a newly operational international space station where they become a part of a worldwide effort to rescue alien life forms. Students are informed that a group of six species of aliens, fleeing their own planetary system, have arrived in Earth orbit….Students, acting as scientists, are asked to participate in this rescue operation, and their task is to determine the most suitable relocation site for each alien species. To solve this problem, students must engage in a variety of activities. They must learn about the aliens and identify the basic needs of each species. They must then investigate the planets and moons of our solar system, searching them for possible matches with the needs of the aliens. Students gather this information by performing searches in the databases and launching probes that they have constructed to gather the additional information not available through the existing databases. They must also engage in collaborative planning and decision-making as they determine how to use the resources of the solar system effectively. In the course of developing a solution plan, students learn about both our solar system and the tools and procedures scientists use to gather that information. The hypermedia program allows students to have access to all the tools and information needed to develop a solution plan, but the program is structured in such a way as to not suggest what that solution should be. Students are

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encouraged to explore the virtual space station as they determine for themselves the information they need and the process they will use to develop a solution plan.

Studies on *Alien Rescue II* have shown it to be an effective learning environment for science knowledge and problem-solving (Bera & Liu, 2006; Liu, 2004, 2006), and evoke intrinsic motivation (Liu, 2004; Liu, Hsieh, Cho, & Schallert, 2006; Pedersen, 2003; Toprac, 2006). However, students, on average, did not significantly ($p = 0.0517$) improve their attitude toward science by using *Alien Rescue II* (Liu, 2004). As argued in Chapter 2, the difficulty of finding changes in attitude toward science are probably due to the ambiguity of the term "science" for students and the context of where the student learns about science. Another possibility is that *Alien Rescue II* does not quite evoke enough intrinsic motivation to transfer positive feelings to learning about science.

In addition, as would be expected, not all students have been successful using *Alien Rescue II*. In a study by Bera and Liu (2006), they found that low achieving students, as measured by factual and applied knowledge tests, exerted less mental effort and experienced difficulty in seeking information and self-monitoring. Liu (2004) found that on average students did not find homes for all of six aliens, with TAG (talented and gifted) student finding homes for five aliens, RegEd (regular education) students finding homes for four aliens, and ESL/LD (English as a second language/learning disability) students finding homes for three aliens. In addition, she found that the ESL/LD students felt that *Alien Rescue II* was considerably less educationally valuable compared to TAG and RegEd students. Liu attributed her findings to the "large quantity of information to be sifted through and large amount of reading involved, which makes it more challenging for the ESL/LD students" (Liu, 2004, p. 373). These results are not unexpected. For instance, in a study by Palincsar, Magnusson, Collins, and Cutter (2001), they found that students with language and learning disabilities face conceptual and literacy challenges. Likewise, another study by

Toprac (2006) on *Alien Rescue II* found that students were demotivated and/or negatively affected by: (1) lack of feedback, (2) not enough time, and (3) too much challenge. One student's comment on *Alien Rescue's* lack of feedback was, "But I kind of agree with Mara, I think they should tell you if you got it right and show how if they like where they live." That is, the student wanted feedback from the program about decisions that s/he made. Another student who thought that there should have been more time said, "I'm not [confident of answer] because I was in a hurry because I couldn't find it [habitat for alien]." Regarding too much challenge, another student said, "It's hard because it hard to find homes for them [aliens]. It's hard for me." This difficulty that some students have in using *Alien Rescue II* to learn science could be attributed to both cognitive and motivational factors. Cognitively, these students may need additional scaffolding to better prepare them to seek information. This is the same recommendation that teachers implementing *Alien Rescue II* have voiced (Liu, 2004). Motivationally, RegEd and ESL students may need additional intrinsic motivational and self-efficacy affordances in order to enhance persistence. In addition, this higher level of motivation may promote continuing motivation to learn science.

In order to determine what features of *Alien Rescue* that should be included, removed, or improved, the current design was evaluated using Malone and Lepper's (1987) set of heuristics and principles for designing intrinsically motivating instructional environments (see Appendix B for a detailed analysis and Table 5 for a summary).

Table 5: Evaluation of the Intrinsically Motivating Sources of *Alien Rescue II* and Design
Implications for *Alien Rescue III*

Sources of IM	Features	Sub-Features	Evaluation	AR3 Design & Comments
Challenge	Goals	Clear & fixed	Sufficient	-
		Short-term goals	Lacking	Level design provides short-term goals. Not typically part of PBL.
		Long-term Goals	Sufficient	-
	Uncertain Outcomes	Variable Difficulty Levels	Lacking	Groups of students are assumed to have similar competency within the classroom. Not typically considers in PBL designs.
		Multiple Goals	Lacking	Level design with increasing difficulty scaffolds player. Not typically part of PBL designs.
		Hidden Information	Needs Improvement	Information regarding the antagonist is revealed over time.
		Randomness	Lacking	No randomness is included.
	Performance Feedback		Lacking	Feedback by showing the consequences of decisions.
	Self-Esteem		Lacking	Easy problem is presented to student after observing expert.
Curiosity	Sensory		Needs Improvement	More up-to-date look and feel.
	Cognitive		Needs Improvement	Surprise when antagonist initially attacks and intrigue about conflict between aliens.
Control	Contingency		Sufficient	-
	Choice		Sufficient	Addition of instructionally irrelevant personalization.
	Power		Lacking	Powerful effect of battle at the end due to student's decisions.
Fantasy	Emotional		Sufficient	-
	Cognitive		Sufficient	-
	Endogeneity		Sufficient	-
Cooperation			Sufficient	-
Competition			Lacking	Not typically part of PBL.
Recognition			Lacking	Not typically part of PBL.

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From this analysis, it was determined that the following motivational features would be included in the next version of *Alien Rescue*.

1. Three levels that the student must complete to solve the whole problem. Each level is progressively more difficult to scaffold the student cognitively and to enhance self-efficacy and self-esteem. There is clear indication of success between levels.

2. A guided activity, also called a game tutorial, is included, where a computer-animated expert solves a simple problem to show the student the process and then the student solves another simple problem, on his or her own. This is accomplished at the beginning of the game in order to enhance the student's self-efficacy before being presented with a more complex problem.

3. Information about a malicious alien character in the narrative is revealed over time in order to provide a mystery element to *Alien Rescue*.

4. The inclusion of surprising outcomes based on student's actions, including some very powerful effects, and intrigue in the narrative.

5. Formative feedback and summative feedback on performance by showing the consequences of the student's decisions on habitats, along with brief descriptions on the quality of the decisions.

6. The inclusion of instructionally irrelevant personalization—students' name is used in *Alien Rescue*—which has been found to be intrinsically motivating (Cordova & Lepper, 1996).

7. Upgrade of visual content to update the look and feel of the program to enhance sensory curiosity.

Using these motivational elements, a new story of *Alien Rescue* was developed that was grounded in pedagogical theory and game-play elements (see Appendix C). In addition,

a storyboard was created to guide development (see Appendix C). The design of the new version of the software program, *Alien Rescue III*, can be compared to what is considered to be a digital game (see Overview of Digital Games in Chapter 2). That is, the following characteristics of an educational digital game can be identified in the design of *Alien Rescue III*:

- Fantasy/Make believe/artificial context/safe: science fiction narrative where students play the role of a scientist to rescue aliens with no negative endogenous consequences

- Constricting rules: yes

- Goal/outcome oriented with feedback: goal of finding homes for endangered aliens with feedback on decisions

- Challenge/conflict/contest/complexity: challenge is progressively more complex (with levels) and endogenous conflict with a malicious alien

- Uncertainty of the outcome: outcome with malicious alien is unknown and is based on quality of decision-making by students

- Active control/decision-making activity: student makes choices of what information to gather and analyze to make a decision

- Inefficient processes for gathering information/mystery: information is spread amongst databases and must be consolidated in a notebook for analysis and information regarding the malicious aliens is progressively revealed in order to provide mystery

From this comparison, it is clear that *Alien Rescue III* can be considered a digital game.

Another feature of the design of *Alien Rescue III* is not requiring teacher involvement in order to play and finish the game. This was done so that *Alien Rescue III* would be a more

scalable solution for schools. That is, some teachers have problems implementing constructivist curriculum, such as PBL environments, in the classroom, because the challenges can be formidable (Airasian, 1997). Successful learning with most PBL environments assumes a conducive classroom environment with a capable teacher. Teachers using PBL environments need to support and guide student learning through scaffolding and modeling, encourage and help students manage learning and metacognitive processes. If a teacher is capable of doing this, then *Alien Rescue III* continues to be a learning environment to support the teacher's efforts, as did *Alien Rescue II*. Unfortunately, even when the teacher is capable, they often have too many students in the classroom to perform this style of teaching adequately. If a teacher is not capable of performing the role of a facilitator, for whatever reason, or if the teacher is not present, then *Alien Rescue III* provides adequate affordances for learning science by scaffolding the student through the levels of difficulty and by providing feedback on the students' actions.

PARTICIPANTS AND CONTEXT

This study will be held in three classrooms in a suburban public middle school in central Texas, which was chosen based on convenience. Each science class has on average 28 students. At an 80% acceptance rate the average number of participants in a class will be approximately 22, with a total of 66 participating students in the study. Sixty-six participating students represent approximately 20% of the sixth grade.

There are a total of approximately 1000 students at the middle school with the sixth grade constituting approximately 33% of the student body. The ethnic makeup of the school is: 69% White, 22% Asian/Pacific Islander, 6% Hispanic, and 3% African American (State of Texas, 2005). The school is, overall, almost evenly split between females and males.

MATERIALS AND DATA SOURCES

Treatment

The problem-based learning (PBL) software environment, *Alien Rescue III*, will be used as the intervention. *Alien Rescue III* is a digital game based on the science curriculum for 6th grade in Texas and designed in accordance with the National Science Education Standards and the Texas Essential Knowledge and Skills (TEKS) guidelines (Liu, Williams, & Pedersen, 2002). *Alien Rescue III* is predicted to require three weeks (fifteen 45-minute class sessions) to complete. *Alien Rescue III* presents a complex and meaningful problem for scientific investigation and decision-making by children. Previous studies on *Alien Rescue II* have shown it to be engaging (Pedersen, 2003) and provide an effective learning environment for science knowledge and problem-solving (Liu, 2004). All previous studies have been done in the classroom.

DATA SOURCES

Both quantitative and qualitative methodologies will be used to gather data in order to address the research questions. Most of the data will be obtained through self-reports and interviews. This is considered as a standard method since most studies on the effects of motivation are based on indirect measures, such as student's self-ratings for quantitative data and interviews for qualitative data.

Quantitative Measurements

Continuing Motivation to Learn Science

In a study by Pascarella, Walberg, Junker, and Haertel (1981), continuing motivation was measured using a self-report questionnaire of eight items (see Appendix D) measuring the frequency of student participation in non-school science activities that are not required for science class (alpha internal consistency of 0.77 for early adolescents). In this

questionnaire students are asked, about how often have they have done science activities when not required for science classes.

This questionnaire was modified in the following three ways: (1) redundancy was eliminated in order to shorten it, (2) items were updated to be more current, such as the addition of the internet in some of the activities, (3) an item was included regarding playing science games and simulations to capture this current popular activity, (4) two additional subscales were added to address domain specific science, i.e. space science and astronomy, and task-specific science, such as gravity. The task-specific items aggregated the actions, such as reading, talking, and listening, into a single item instead of separately as in the other two scales. This was done to reduce the number of items to something reasonable for students to stay engaged throughout the process of answering questions. Table 6 shows the changes made to the questionnaire and why. The resulting self-report questionnaire to measure continuing motivation has 15 questions and is called the Continuing Motivation To Learn Science Survey (CMTLSS), as shown in Appendix F.

The need for specificity of science in the measurement of continuing motivation is argued by Mundy (1982) in his statement "After all, the contexts for comprehending the terms are legion: science teaching per se, this year's science class, today's class or subject matter, the science I can't learn in school, the science I get from television, or the science my Dad does at the textile plant" (p. 618). For example, a similar approach to the CMTLSS was taken by Hickey, Petrosino, Pellegrino, and The Cognition & Technology Group at Vanderbilt (1994) when they asked students how much they engaged in various science, space travel and space science, and topic-specific activities that were explicitly presented in a learning environment over a two week period. What is notable is the large overlap between the items in the science category of their Science/Space Science Activities Checklist (SSSAC) and the items asked in the study by Pascarella, Walberg, Junker, and Haertel (1981). For instance, in SSSAC the

question "Talked about science topics with friends" is closely related to the continuing motivation item asked in Pacarella et al's questionnaire, "Talk about science outside of science class?" Yet, the SSSAC also includes items that are more specific than "science", such as space science, and task-specific, such as "Talk about or read about radiation?" Unfortunately, since the purpose of SSSAC was not to measure continuing motivation, this questionnaire included items that were not relevant, such as "Draw anything about space or space travel at home?" Furthermore, reliability and validity information were not reported. For these reasons, the SSSAC will not be used in this study.

Table 6: Modification of Continuing Motivation Questionnaire by Pascarella et al (1981)

Original	Modification	Rationale
1. Read science articles in newspapers.	1. + 4. Read science articles in newspapers or magazine or internet outside of science class?	Reduce redundancy since articles can be read in multiple places, including on the internet.
2. Worked with science-related hobbies.	2. + 8. Work with science-related hobbies or on science projects outside of class?	Reduce redundancy since science projects and science-related hobbies are highly related.
3. Gone to hear people give talks on science.	5. Watch science shows on TV or internet outside of class?	It is now common to watch short videos on the internet.
4. Read science articles in magazines.	6. Read books about science or scientists outside of science class?	The "outside of science class" is to remind the students of the context.
5. Watched science shows on TV.	3. + 7. Talk or listen about science outside of science class?	It is rare to hear public speeches on science outside of academia. The addition of "listen" includes public speeches and related opportunities, e.g. radio. The "with friends" was deleted because talking to relatives and others is also valid.
6. Read books about science or scientists.	Played with any about science games or simulations outside of science class?	This item was added because many adolescents play computer and video games—some of which could be about science.
7. Talked about science topics with friends.		
8. Done science projects.		

Students will be instructed to think about "How often have you done the following activities during the last two weeks, when not required for science class?" before completing the survey. Note the addition of the words "last two weeks" to both align with the time period of this study and to focus the students on reporting on the activities from the immediate past. The highest possible composite score for this survey is 60 and the lowest is 15. The highest possible score for the subscales of 'Science Subject' and 'Science Domain' are both 24 and the lowest is 6. For the Science Task subscale, the highest possible score is 18 and the lowest is 3.

Students' Science Knowledge

In order to measure the students' knowledge and understanding of scientific concepts in *Alien Rescue*, a shortened version of the standard Science Knowledge Test (Liu, 2004) will be administered pre- and post-test. The standard Science Knowledge Test (SKT) instrument comprises of twenty-five multiple-choice questions that measures factual (n=15) and applied (n=10) knowledge of astronomy concepts introduced by *Alien Rescue* (Liu, 2004). The standard Science Knowledge Test has been used in previous studies (Liu, 2004) of *Alien Rescue* and has an internal consistency reliability of 0.73 (KR-20). The shortened version, the Short Science Knowledge Test (SSKT) has 5 fewer science application questions and though the number of possible choices is the same, one answer is always "Not Sure" so that student guessing is reduced. Content validity of SKT has been assured by pilot-testing the instrument numerous times with classroom teachers and university faculty in astronomy education (Liu, 2004). The highest possible score of the SSKT is 20 and the lowest is zero, with incorrect answers scored as zero for the question. In addition, 'not sure' answers will be tracked separately with the highest possible score of 20 (i.e. all questions are answered 'not sure') and the lowest is zero. Examples of the questions comparing the SKT to the SSKT follow (Liu, 2004).

Factual: Which of these worlds is a planet (not a moon)?

Science Knowledge Test	*Short Science Knowledge Test*
1. Charon	1. Io
2. Io	2. Phobos
3. Phobos	3. Uranus
4. Uranus	4. Not Sure

Application: You need to design a probe to go to Titan to find out if it has a magnetic field or earthquakes. Which of the following would you choose to include on your probe?

Science Knowledge Test	*Short Science Knowledge Test*
1. A battery and a solar panel	1. A battery and a solar panel
2. An infrared camera and a magnetometer	2. A barometer and a seismograph
3. A barometer and a seismograph	3. A magnetometer and a seismograph
4. A magnetometer and a seismograph	4. Not Sure

Dimensions of Continuing Motivation

The Dimensions of Continuing Motivation Survey (DCMS), as shown in Appendix F, contains items to assess student's perceived ability and subjective task value as posited by Eccles and colleagues (Eccles & Wigfield, 1995). Subjective task value has the following subscales: perceptions of importance, interest, and attainment value. In addition, the DCMS includes two items related to the cost of engaging in space science or astronomy. The purpose of this questionnaire is to determine the contributors and detractors of continuing motivation to learn space science or astronomy after playing *Alien Rescue III*. The DCMS was developed by using previously published questionnaires and substituting the words "science" or "math" or "chemistry" with the words "space science and astronomy." The words space science and astronomy were chosen to adhere to Munby's (1982) suggestion to

enhance the specificity of the meaning of science. Yet, getting any more specific would have dramatically increased the number of items that would have probably been detrimental in terms of accuracy of response from students. Overall, these scales have been found to have strong face, convergent, discriminant validity and psychometric properties when used for Grades 5 through 12 (Eccles & Wigfield, 1995).

The perceived ability items will ask the students how good they were at space science and astronomy (Likert scaling of 1 = *not at all*, 7 = *very good*), how good they were at space science and astronomy relative to other subjects (1 = *not at all*, 7 = *very good*), and how good they were at space science and astronomy relative to their fellow students (1 = *one of the worst*, 7 = *one of the best*). The highest possible score on this scale is 21 and the lowest is 3. Simpkins, David-Kean, and Eccles (2006) found acceptable reliability for the "science" version of this scale for 6th grade with Cronbach's alpha = 0.86. Items will be changed to the future tense for the pre-test. For example, "How good do you think you would be at space science or astronomy are you?" is the question for the pre-test version of the DCMS and "How good are you at space science or astronomy are you?" will be the post-test version of the DCMS. This approach is consistent with that used in the study by Simpkins, David-Kean, and Eccles (2006).

The subjective task value inventory consists of three major subscales: perceptions of importance, interest, and attainment value. Importance in space science or astronomy asked students how useful is learning space science and astronomy (1 = *not at all useful*, 7 = *very useful*), and how useful is learning space science and astronomy relative to other subjects (1 = *not at all useful*, 7 = *very useful*). The reliability in 6th grade for a three-item version using "science/physics" of this subscale was alpha = 0.92 and the 10th grade two-item version, as shown above, using "chemistry" was alpha = 0.84. The two-item version will be used in order to reduce the total number of items in the DCMS to a reasonable number. Because this

study will use the two-item version for 6th graders, it is anticipated that the reliability of importance subscale for this study will be between 0.84 and 0.92. Interest in space science or astronomy will ask students how interesting is working on space science or astronomy assignments (1 = *very boring*, 7 = *very interesting*) and how much they like space science or astronomy (1 = *not at all*, 7 = *very much*). The interest related question attempts to measure the interest aspect of intrinsic motivation, which would indicate an individual interest in science before the treatment and both situational interest and actualized individual interest after the treatment. The feeling related question measures the feeling-valence of individual interest in science, and attitude toward science, according to Koballa and Crawley's (1985) definition. Reliability in 6th grade for the "science" version of this scale is 0.92. This particular subscale also has a pre-test version that uses the future tense, such as "how much do you think you would like space science or astronomy?"

Because interest may be measuring the student's individual interest and feeling related question may be measuring situational interest and/or attitude toward science, this subscale will be divided into two minor subscales: the interest subscale and the affective subscale. Students will high pre-test scores in the interest subscale will be considered to have an individual interest in science, whereas as students with low pre-test scores will be considered to not have an individual interest in science. Scores that rise between pre-test and post-test will be attributed to students' interest increasing due to the treatment promoting situational interest (for those with initially low interest score) or actualized interest (for those with initially high interest score). Likewise, students who score high on the affective scale on the pre-test will be considered to have a positive attitude toward science and students who scored low will be considered to not have a negative attitude toward science. The measurement of attitude of science consisting of the students reporting their like or dislike in learning science is congruent with the recommendations of Koballa and Crawley (1985), as

discussed in Continuing Motivation in Science as Attitude Toward Science section in Chapter 2. Scores that increase between pre-test and post-test in the affective subscale will be attributed to students' attitude toward science improving due to the treatment. Intrinsic motivation will be measured by the summation of the interest and the affective subscales. Increases in students' scores of the composite of the interest and affective subscales will be considered to have had an increase in intrinsic motivation.

Attainment value in space science or astronomy will ask students to rate how important it was to them to be good at space science or astronomy and how important it was to them to be good at space science or astronomy relative to other subjects. Reliability for the subscale for math has been alpha = 0.67 for students from 5th through 12th grade (Meece & et al., 1990) and alpha = 0.61 to 0.88 across math, reading, and sports domains for 2nd and 4th grade (Wigfield & Harold, 1997).

Cost perception is separately measured from subjective task value and perceived ability, because it is a relatively understudied concept in Eccles' expectancy-value theory (Anderson, 2000). In the original development of the perceived cost items for math in high school, two subscales were developed: task difficulty with 3 items (alpha = 0.80) and required effort (alpha = 0.78) with four items (Eccles & Wigfield, 1995). For this study, students will be asked two task difficulty question about how difficult space science or astronomy is (1 = *very easy*, 7 = *very hard*) and how difficult is it relative to other subjects (1 = *my easiest*, 7 = *my hardest*. It was decided to use only two items per scale in order to keep the total number of items in DCMS manageable. The measurement of students' reports of their perceived difficulty in engaging science is congruent with Osborne, Simon, & Collins' (2003) argument that perceived difficulty in science is the major reason why students do not select science courses. In addition, for the required effort subscale, students will be asked about how hard they have to work to do well in space science or astronomy (1 = *not very*

hard, 7 = *very hard*) and how hard they have to work relative to other subjects (1 = *much harder in other subject than in space science or astronomy*, 7 = *much harder in space science or astronomy than other subjects*). As in some of the other scales, the future tense is will be used for the pre-test, such as "How hard do you think would have to try to do well in space science or astronomy?" The composite score for the perceived cost scale is the addition of these two subscales.

However, cost perception has also been conceptualized as relative cost of doing a task compared to doing other more valued tasks (Eccles & Wigfield, 2002), which can also be called the opportunity cost of doing an activity (Wikipedia, 2006e). The perceived task difficulty items of the DCMS appear to more closely relate to the perceived difficulty in absolute terms for the student and also relative to other subjects. These items do not seem to capture the opportunity cost of freely doing space science or astronomy activities when other activities are available. This cost may be very important outside of the school environment where continuing motivation may or may not manifest itself. Measuring opportunity cost of doing space science or astronomy will be further explored using qualitative measures.

Qualitative Data Gathering

The researcher, a middle-class, middle-aged Caucasian male, will gather qualitative data as a participant-observer using a realist ethnographic approach (Creswell, 2005). The researcher will be in the role of a participant-observer in order to assist the teacher in facilitating the class on playing *Alien Rescue III*. A realist ethnography approach to data collection will be the researcher's attempt to capture an objective account of the situation that avoids personal bias, political goals, and judgment (Creswell, 2005). However, as in all social science, and particularly with qualitative research, the researcher's subjectivity will undoubtedly influence the researcher's attention to events, perception, unconscious appraisal (Cornelius, 1995), and prejudgment (Gadamer, 1977; Warnke, 1987). Any process of

ethnography involves the selection and interpretation of the setting, which ultimately excludes some information, because observations are guided by a person's conceptual framework (Tabak, 2004).

Interviewing

The sampling method for interviews will be a combination of theory sampling and maximal variation sampling. Theory sampling is the purposeful sampling within a group in order to discover or generate a theory (Creswell, 2005). Maximal variation sampling is a purposeful sampling method to discover individuals who differ on some characteristics (Creswell, 2005). Since group means, found through quantitative analysis, of the participants will already describe the average characteristics of the participants, the maximal variation sampling qualitative methods will focus on participants outside of the norm to understand their views of science and their own motivations. The theory sampling method will be used to gather data from the students who are near the norm of the classes in order to triangulate the qualitative results with the quantitative results. In this way, using the combination of sampling methods will produce qualitative data from multiple perspectives in order to best represent the complexity of the intervention and a holistic view of the resulting concepts.

From the results of the Continuing Motivation To Learn Science Survey (CMTLSS), three students will be initially identified for interviews: one with a low score (low continuing motivation to learn science), one with a score near the average, and one with a high score. These three students will be interviewed one week before playing *Alien Rescue III* and then within one week after finishing the *Alien Rescue III* treatment. In the second meeting, the student will be asked to check the transcribed answers and interviewer's interpretation of the answers for accuracy to enhance validity of the data and results. Moreover, the student will be asked if s/he have changed his or her opinion on any of the answers.

In addition, two students will be identified after the *Alien Rescue III* treatment whose scores on the CMTLSS changed over the course of the treatment: one whose score went higher and one whose score went lower. In the second meeting, two weeks later, the student will be asked to check the transcribed answers and interviewer's interpretation of the answers for accuracy. Moreover, the student will be asked if s/he have changed his or her opinion on any of the answers.

Finally, three more students will be identified for interviewing from the results of the CMTLSS administered two weeks after the treatment: one with a low score, one with a score near the average, and one with a high score. As with the other interviews, a second meeting will be held later to determine the accuracy of the answers and interpretation and whether anything has changed. In total, eight students will be interviewed with three with low continuing motivation, two with near average continuing motivation and three with high continuing motivation. All interviews using the Continuing Motivation Interview Guide (see below for details) are estimated to take 15-25 minutes each and will be performed during the student's free time in school or after school.

The interview guide that will be used for the semi-structured interviews was developed by modifying and extending an interview guide developed by Stuart (2003), as shown in Appendix H. The interview questions of the Intrinsic Value Interview Guide (IVIG) were designed to explore the influences for intrinsic/interest value. The IVIG was designed to strictly align with the meanings of the interest/intrinsic value component of Eccles subjective task value to enhance face validity. The content validity was validated using two theorists in the area of subjective task value research. A pilot test by Stuart (2003) of the interview guide was also performed in order to assess whether the questions accurately conveyed the appropriate intended meanings for the interviewees.

The interview guide for this study, the Continuing Motivation Interview Guide (CMIG), is shown in Appendix I. To create the Continuing Motivation Interview Guide the IVIG was modified by substituting the words "science" for "sport", and "continuing interest" for "interest" in order to align the study's focus on continuing motivation, which is interchangeable with the term continuing interest. Continuing interest is used instead of continuing motivation because this term is easier for the age group in this study to understand. In addition, the sex-role and significant others questions were refocused to social norm and relatedness questions. Moreover, the interview guide was extended to explore students' indications of continuing motivation, behavioral intention to continue learning science, and students' view of how their self-efficacy, intrinsic motivation, attainment value, knowledge, and utility value influences their continuing interest in science. In total, there are three warm-up questions, including the permission to audiotape the interview, and 21 core questions regarding continuing motivation.

The interview questions will be the same for all interviewees. Before proceeding to the core interview questions, the researcher will provide some introductory comments and warm-up questions, including the permission to audiotape the interview, the student's self-report on science grades, and interest in science fiction. In addition, the student will be informed that the interviewer would like to know more about the student's thought on continuing interest, which is described as "how enjoyable science is or how much you like science, even outside of the classroom." Then, the student will confirm the interest answer that s/he provided on the CMTLSS (e.g. "you have rated space science or astronomy as very boring to you...is that correct?). Following confirmation, the next two questions will qualitatively gauge whether the student' has ever experienced continuing motivation by asking him or her about whether any science topic has interested them beyond the classroom and whether s/he performed any science related activities, such as reading a science article,

outside of class any time in the past. The next two questions attempt to gauge the perceived continuing motivation (i.e. behavioral intention) to learn more science in the near future by asking if s/he is interested in learning more about the current science topic of study in either class or outside of class.

The next series of questions explore the student's view of the components of subjective task value. The components of self-efficacy, intrinsic motivation, attainment value, and utility value have one question each. Each question is similarly constructed as "Do you think that how *component attribute* has influenced your continuing interest in science and how so?" The *component attribute* is the defining characteristic of the subjective task value component. For instance, for intrinsic motivation the question is "Do you think that how *fun it is to learn or do science* has influenced your continuing interest in science and how so?" The cost component questions have two questions in the same format: (1) for effort needed to be good at science, and (2) the amount of time it takes to be good at science. In addition, there is one question that asks about preferred activities at home instead of engaging in science activities to explore the opportunity cost aspect of this component.

The final series of questions attempt to explore the influences to continuing interest in science. These questions are very similar, if not almost identical, to the questions in Stuart's IVIG (2003), as previously described. Other than substitution of "space science or interest" for "sport", the major differences are: (1) the addition of an attitude toward science/feeling related valence question, (2) the addition of a knowledge valence question, and (3) the focus on social norms and relatedness questions instead of sex-roles. The attitude toward science question is based on Koballa and Crawley's (1985) argument that attitude toward science is simply the like or dislike of science. Thus, the question is "Do you have positive or negative feelings, such as like or dislike, toward science?" The knowledge related question is the attempt to explore whether there is a relationship between stored-knowledge and interest as

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suggested by Renninger (2000). The question is "Do you believe that the amount of knowledge you have about science has influenced your continuing interest in science?" Finally, there are questions related to social influences that is part of Deci and Ryan's (1992; Ryan & Deci, 2000) self-determination theory, and belongingness that is part of Maslow's (1955) theory of hierarchy of human needs. These questions ask about classmate, friends, family, teachers, and others who may have influenced the student's continuing interest in science. For example, "Do you think that your classmates have influenced your continuing interest in science?" The last question of this interview guide is probe question to find out if the student can think of anything else that may have influenced his or her interest in science.

In addition to the interviews conducted using the Continuing Motivation Interview Guide, semi-structured interviews will be conducted in the classroom while students are playing *Alien Rescue*. Students will be interviewed in groups while they are engaged with *Alien Rescue*. Questions will be focused on student's perceptions of this affective outcome from playing Alien Rescue, possible influences on their desire to learn science, continuing motivation to learn science, and behavioral intention to continue learning science after finishing *Alien Rescue*. The following five core questions will be asked:

1. Do you like *Alien Rescue*? How much (1-5 scale)? Would you like learning science using similar computer games?

2. Do you think that you learned a lot of science by using *Alien Rescue*?

3. Does your experience learning science by playing *Alien Rescue* change your liking or interest in science? Why?

4. Do you talk with your peers about science concepts or problems in *Alien Rescue* outside of class? If so, when and what do you talk about?

5. After finishing the game, do you think you will like to learn more about space science or astronomy? In class? Outside of class?

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These semi-structured interviews will be performed at least twice to the same groups in order to determine any changes. If changes do occur then the interviewer will probe to find out the reasons why. All interviews will be recorded using audiotape if all the members of a group have agreed to participate in this study and have provided permission to be audio taped. Otherwise, the members of a group who have agreed to participate in the study, but did not agree to be tape-recorded, will have his or her answers recorded by pencil and paper.

All interviews will be transcribed. Reflective/analytic memos of interviews and observations will capture etic data, which will represent the researcher's interpretation of the qualitative data (Creswell, 2005).

Classroom Observations

The three students who participated in the initial interviews using the Continuing Motivation Interview Guide will be observed in class while playing *Alien Rescue*. Emic data from observations will be gathered using field notes. Emic data is information provided by the participants in the study and will be gathered through observing the students in the classroom. The focus of the emic data is to observe the engagement of these students with *Alien Rescue* and their interactions with fellow students to see if this may have any relationship with their continuing motivation to learn science. In addition, there will be a focus on observing if there are any gender differences between the interactions of students with each other and *Alien Rescue*. Elaboration of field notes and reflective/analytic memos of observations will capture etic data.

Classroom observations will also attempt to collect information on the implementation of *Alien Rescue* to enhance the understanding of the context of this study and to further refine design and future integration of *Alien Rescue* into science classrooms.

PROCEDURES AND ANALYSIS

This study will be undertaken using the triangulation mixed methods design (Creswell, 2005) that will integrate quantitative and qualitative data so that each dataset carries equal weight, priority, and consideration. Collection of data from quantitative and qualitative methods will occur simultaneously and will be used to triangulate to provide a better understanding of the results (Creswell, 2005) in order to attempt to address the research questions.

Approval Process

The first step will be to obtain approval of the research site, the parent's of the participants, the participants, and the University of Texas at Austin's Institutional Review Board. The approval of the research site will require approvals at the district level, the principal level, and the teacher levels. The initial permission to perform research in the classrooms will be verbally approved by the teachers and principal. The permission at the school district level will require a written approval process yet to be determined but probably closely aligned with the process at the University of Texas at Austin, and will probably require the written approval of the principal. Once approved, the school district will issue a site permission letter, see Appendix J, that is required by the University of Texas at Austin to approve the conduct of the study.

An application for approval will be submitted to the University of Texas at Austin's Institutional Review Board. The forms for the approval process are the following (see Appendix J): a research proposal, consent letter, assent letters, site approval, and the various questionnaires used in this study, as previously described. As indicated, there are two assent approvals for students. One assent approval letter is provided to all the students who have permission from their parents for their approval. Another assent approval letter is provided for the eight students who have already agreed to participate in the study and is willing to be

interviewed using the Continuing Interest Interview Guide. Once all the approvals have been obtained then the study will proceed.

Research Procedure

The purpose of this study is to investigate whether digital games can motivate students to continue learning academic subjects, after instruction has ended. In particular, motivating students to continue learning science from playing a science based digital game, called *Alien Rescue*, is of interest. That is, the focus is on how this digital game may be able to promote continuing motivation to learn science. The expected time to complete playing *Alien Rescue III* is three weeks with each week having five sessions of approximately 45 minutes each. The independent variable is *Alien Rescue III*. The following are the research questions and procedures that will attempt to address these questions.

Quantitative Procedures

Can playing a problem-based learning game in science, Alien Rescue III, promote continuing motivation to learn science? Does continuing motivation to learn science change over time after completion of instruction?

The Continuing Motivation To Learn Science Survey (CMTLSS) will be administered before and after the treatment of playing *Alien Rescue*. The pre-test administration will take place within a week of treatment, and one post-test administration will take place within a week after treatment and another post-test two weeks later. There are four dependent variables; overall science continuing motivation, science-only continuing motivation, space science domain continuing motivation, and space science tasks continuing motivation. To determine the overall science continuing motivation a repeated measures ANOVA will be used to find any significant changes before and after treatment on the composite scores of all the items in the CMTLSS. Scoring the science items in the CMTLSS science subscale and comparing the average for the class before and after treatment using the

repeated measures ANOVA will determine the science-only continuing motivation. Likewise, the space science domain and space science tasks continuing motivation will be determined using those subscales' class averages and the repeated measures ANOVA. Any significant differences (alpha equal to or less than 0.05) between students' average scores of CMTLSS will be determined by the repeated measures ANOVA. If there are any significant differences, the effect sizes will be determined to estimate the strength of the differences between the means. In addition, the internal consistency reliabilities for this scale and subscales will be determined.

Is continuing motivation subject, domain, or task specific?

As a result of addressing the two previous questions, this question will automatically be addressed using quantitative measures. That is, the average changes in the scores of the subscales of Science Subject, Science Domain, and Science Task will be determined and reported. The subscale with the largest positive change in score will be assumed to have the largest change in positive continuing motivation. The averages over time will be compared to determine if one level of specificity changes more than another level.

What are the psychological dimensions of continuing motivation? Is there a relationship between the knowledge gained during instruction and continuing motivation?

In order to attempt to understand the psychological dimensions of continuing motivation an explanatory research design correlational study will be used. The variables of the Dimensions of Continuing Motivation Survey (DCMS) will be correlated to the outcome variable of continuing motivation, as measured by the Continuing Motivation To Learn Science Survey (CMTLSS). The variables of the DCMS are: competency beliefs (self-efficacy), utility value, attainment value, intrinsic value (divided into interest value and affective value), and cost (divided into difficulty value and effort cost). The correlational analysis will determine the amount that each variable in DCMS contributes to the variance in

continuing motivation to learn science as measured by the CMTLSS science domain subscale. That is, the increase in the CMTLSS science domain subscale score will be correlated to the increase in each of the subscale scores in the DCMS. The CMTLSS science domain subscale was selected because it closely matched the wording of the DCMS. In addition, the gain in science knowledge as measured by the Short Science Knowledge Test (SSKT) will be correlated to the increase in CMTLSS science domain subscale scores in order to determine if it contributes to the variance in continuing motivation to learn science. In this case, the CMTLSS science domain subscale was selected to maintain consistency in results. Significant correlations ($p < 0.05$) will be used to develop a predictive model of continuing motivation. Finally, the internal consistency reliabilities for the DCMS scale and subscales will be determined, as well as for the SSKT.

Qualitative Procedures

The grounded theory constructivist approach (Creswell, 2005) will be used to analyze the qualitative data gathered to address all the research questions. The constructivist perspective of grounded theory recognizes that knowledge generated from grounded theory is a mutual creation by the viewer and the viewed (Charmaz, 2006). The constructivist approach to grounded theory focuses on the "views, values, beliefs, feelings, assumptions, and ideologies of individuals than in gathering facts and describing acts" (Creswell, 2005, p. 402). The data will be coded using the constructivist approach and the emerging design process in which data will be analyzed as collected, instead of waiting until all the data is collected (Creswell, 2005). The constant comparison method will be used to inductively generate and connect raw data to codes, codes to categories, and categories to themes (Creswell, 2005). Theories from the themes will emerge from this process that will be compared to the quantitative results. Theories and themes will be member checked to improve validity (Creswell, 2005).

Case studies of students with low, near average, and high continuing motivation to learn science will be developed. In addition, a case study of two individuals whose continuing motivation changed during the course of playing *Alien Rescue* will be developed. The interviews will also address all the research questions.

Can playing a problem-based learning game in science, Alien Rescue III, promote continuing motivation to learn science? Does continuing motivation to learn science change over time after completion of instruction?

Questions (1) and (2) from the Continuing Interest Interview Guide (CMIG) will be used to gauge their level of continuing motivation to learn science and individual interest for science before treatment. During treatment, the following questions in the classroom will address their current level of continuing motivation: "Do you talk with your peers about science concepts or problems in *Alien Rescue* outside of class? If so, when and what do you talk about?" and "After finishing the game, do you think you will like to learn more about space science or astronomy? In class? Outside of class?" In addition, interview questions (3) and (4) from the CMIG will be used both before and after treatment to address this research question. The difference between the answers may indicate a difference in continuing motivation.

The researcher will also attempt to gauge any changes in continuing motivation between the initial interview and the follow up interview to determine any changes over time. In particular, what is of interest is the change in answers (1) – (4) from after the finish of playing *Alien Rescue* and two weeks later.

Is continuing motivation subject, domain, or task specific?

There are no specific questions from the CMIG addressing this research question. However, students may provide information about what specifically that they believe that interests them while answering the other questions.

What are the psychological dimensions of continuing motivation? Is there a relationship between the knowledge gained during instruction and continuing motivation?

The dimensions of continuing motivation will directly be addressed by questions (5) – (11), where each question is regarding each specific component of self-efficacy and subjective task value in Eccles' model. In addition, questions (12) – (21) attempt to find the influences for self-efficacy and subjective task value. Of particular interest are the changes for the questions over time. Finally, the classroom interview questions (2) – (5) will attempt to explore this issue on a more instantaneous basis. That is, answers to these questions provide a snapshot view of dimensions of continuing motivation. However, the researcher will attempt to find any changes over time to the students' answers, as well.

Does continuing motivation to learn in future classroom instruction differ from continuing motivation to learn outside of the classroom?

The differences between the answers to questions (3) and (4) of the CMIG address this research question.

Triangulation

The results of the quantitative and qualitative analysis will be compared and to the extent possible, integrated. The resulting triangulated results could show convergence, inconsistency, or be complementary (Creswell, 2005). Both quantitative and qualitative results will be shown. The quantitative results will provide the opportunity for generalizability, while the qualitative result will provide a better understanding of the context and meaning (Creswell, 2005). All theory postulated from the results will be suggestive and tentative in nature—a petite generalization (Stake, 1995)—with the hope that others in a similar context can use the results to better create and/or implement computer learning environments, particularly using digital games, to promote continuing motivation while achieving learning objectives.

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Appendices

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Appendix A: Heuristics and principles for designing intrinsically motivating instructional environments

In the article "The making learning fun: A taxonomy of intrinsic motivations for learning and intrinsic motivation and instructional effectiveness", by Malone and Lepper (1987, p. 248), they provide a set of heuristics and principles for designing intrinsically motivating instructional environments.

I. INDIVIDUAL MOTIVATIONS

The activity should provide a continuously optimal (intermediate) level of difficulty for the learner.

    a) Challenge: the activity should provide a continuously optimal (intermediate) level of difficulty for the learner

        i Goals: The activity should provide short-term, as well as long-term, goals.

            1) Present Clear and Fixed, or

            2) Easy For Students to Generate Goals Themselves

        ii Uncertain Outcomes

            1) Variable Difficulty Levels: Level of difficulty should be graded in terms of the skills to be acquired by the learner and the current level of skill of the learner. Level of difficulty should increase with the acquisition of increased skill by the learner. Response criteria beyond accuracy (e.g. response

speed or competition) should not be used until the skill has

been consolidated.

2) Multiple Levels of Goals: Multiple goals with increasing

level of difficulty as the acquisition of increased skill by the

learner, which should not encourage the learner to experience

success without the accomplishment of instructional goals

3) Hidden Information, Selectively Revealed

4) Randomness: Randomness should not interfere with the

effective presentation of material for instructional purposes,

including the organized sequencing (when appropriate) of

problems for the learner and the informational value of

response feedback.

iii) Performance Feedback: Performance feedback should be frequent,

clear, constructive, and encouraging, and provide evidence of competence,

and improvement by the learner. Normative feedback should be very

effective for highly competent learners; ipsative feedback may be more

effective for less competent learners. Promotions should be made salient

and demotions deemphasized.

iv) Self-Esteem: The activity should employ graded difficulty levels and

positive feedback techniques to promote feelings of competence. The

activity should employ personally meaningful goals that have

instrumental, fantasy, or social relevance for the learner

b) Curiosity: The activity should provide an optimal (moderate) level of informational complexity or discrepancy from the learner's current state of knowledge and information.

    i) Sensory Curiosity: Sensory curiosity may be enhanced by variability in audio and visual effects. The activity should promote interactive exchange with the learner. "Technical events" should not distract from the central learning task.

    ii) Cognitive Curiosity: Curiosity may be promoted by instructional techniques that cause learners to be surprised and intrigues by paradoxes, incompleteness, or potential simplifications. Cognitive curiosity will be enhanced when activities deal with topics in which the learner is already interested. Techniques for highlighting incompleteness, inconsistency, or a lack of parsimony in the learner's understanding should focus the learner on skills to be acquired.

c) Control: The activity should promote feeling of self-determination and control on the part of the learner.

    i) Contingency: The activity should provide a responsive learning environment. "Endogenous" feedback is preferred to "exogenous" feedback (e.g. audiovisual effects, fantasies).

    ii) Choice: The activity should provide and emphasize moderately high levels of choice over various aspects of the learning environment.

Personalization of the activity may enhance perceptions of choice. For instance, choice should be provided concerning instructionally irrelevant aspects of the activity (e.g. characters, names, fantasies, icons). Also, limited choice may be provided concerning the use of help routines or the timing of promotions. Finally, choice should not be permitted to interfere with an effective sequencing of problems or the provision of appropriate feedback for instructional purposes.

iii) Power: The activity should permit the learner to produce powerful effects.

d) Fantasy: The activity may promote intrinsic motivation through the use of fantasy involvement.

i) Emotional Aspects: Fantasies should be designed to appeal to the emotional needs of learners. Fantasies should encourage identifications with imagined characters or contexts. Personalization of fantasies maybe beneficial and fantasy elements should be geared to the prior interests of the learner.

ii) Cognitive Aspects: Fantasies should provide appropriate metaphors or analogies for the material presented for learning. Fantasy activities should contain goals that reinforce, rather than compete with, instructional goals. For instance, feedback for failure should not be more interesting than feedback for success. Also, fantasy should not permit the learner to

experience subjective success without the achievement of instructional

goals.

iii) Endogeneity: Fantasies should have an integral, endogenous,

relationship to the material to be learned and preferred to exogenous

fantasies.

2) INTERPERSONAL MOTIVATIONS

a) Cooperation: The appeal of the activity may be enhance by enlisting the

motivation to cooperate with others. Endogenous cooperative motivation may be

produced by segmenting the activity into inherently interdependent parts.

b) Competition: The appeal of the activity may be enhanced by enlisting the

motivation to compete with others. Endogenous competitive motivation may be

produced by creating an activity in which competitors' actions affect each other.

c) Recognition: The appeal of the activity may be increased if the learner's

efforts receive social recognition. Endogenous recognition motivation may be

produced by activities that provide natural channels for students' efforts to be

appreciated by others.

Appendix B: Evaluation of *Alien Rescue II* and Design Implications

1) INDIVIDUAL MOTIVATIONS

The activity should provide a continuously optimal level of difficulty for the learner.

    a) Challenge
        i) Goals: Activity should provide short-term, as well as long-term, goals.

Long-term goals are clear and fixed. However, there is a lack of short-term goals. The addition of short-term goals must be balanced with the pedagogical goal of students becoming self-directed. The inclusion of short-term goals is typically not part of PBL designs. This trade-off is acceptable because the short-term goals require the same learning activities as the long-term goal and scaffolds learning and motivation.

        ii) Uncertain Outcomes

            1. Variable Difficulty Levels: Level of difficulty adjusted to the skill of the particular learner.

Currently, level of difficulty is not variable depending on the initial skill of the learner. Instead, in a PBL design, groups of learners are assumed to possess the skills to meet the challenge.

2. Multiple Levels of Goals: Multiple goals with increasing level of difficulty as the acquisition of increased skill by the learner, which should not encourage the learner to experience success without the accomplishment of instructional goals.

   Currently, there is one goal. Level design with increasing difficulty to scaffold learner is designed for AR3. Not typically part of PBL designs. Rather there is typically only one complex problem.

3. Hidden Information, Selectively Revealed

   Currently, information is not hidden but rather it is nested and complex. In design of AR3, information about the antagonist is revealed over time.

4. Randomness: Randomness should not interfere with the effective presentation of material for instructional purposes.

   Currently, there are no surprising/random feedback or outcomes. None are planned for AR3.

iii) Performance Feedback: Performance feedback should be frequent, clear, constructive, and encouraging, and provide evidence of competence.

   Currently, there is no performance feedback.   In AR3, feedback is provided by showing the consequences of the student's

decisions, along with short explanations of the quality of the decisions.

iv) Self-Esteem: The activity should employ graded difficulty levels and positive feedback techniques to promote feelings of competence.

Currently, there does not exist any graded difficulty levels. A guided activity, also called a game tutorial, is included, where a computer-animated expert solves a simple problem to show the student the process and then the student solves another simple problem, on his or her own. This is accomplished at the beginning of the game in order to enhance the student's self-efficacy before being presented with a more complex problem.

b) Curiosity: The activity should provide an optimal level of informational complexity or discrepancy from the learner's current state of knowledge.

i) Sensory Curiosity: Audio and visual effects.

Currently, the visual effects are sufficient but appear outdated. More up-to-date visual effects would improve the look and feel.

ii) Cognitive Curiosity: Curiosity may be promoted by techniques that cause learners to be surprised and intrigued.

Currently, there are no surprises in *Alien Rescue II*. The design of AR3 includes surprise when antagonist initially attacks and intrigue about the conflict between aliens.

c) Control: The activity should promote feeling of self-determination and control on the part of the learner.

i) Contingency: The activity should provide a responsive learning environment.

Currently, *Alien Rescue II* is very responsive.

ii) Choice: The activity should provide and emphasize moderately high levels of choice over various aspects of the learning environment.

Currently, *Alien Rescue II* affords a lot of choice to the students. The addition of instructionally irrelevant personalization would be additive (Cordova & Lepper, 1996).

iii) Power: The activity should permit the learner to produce powerful effects.

Currently, *Alien Rescue II* does not provide powerful effects. Powerful effects of battle at the end due to student's decisions are included in the design of AR3.

d) Fantasy: The activity may promote intrinsic motivation through the use of fantasy involvement.

i) Emotional Aspects: Fantasies should be designed to appeal to the emotional needs of learners.

Currently, *Alien Rescue II* has a high level of fantasy.

ii) Cognitive Aspects: Fantasies should provide appropriate metaphors or analogies for the material presented for learning. Fantasy activities should contain goals that reinforce, rather than compete with, instructional goals.

Currently, *Alien Rescue II* provides fantasy activities that do not compete with instructional goals.

iii) Endogeneity: Fantasies should have an integral, endogenous, relationship to the material to be learned and preferred to exogenous.

Currently, fantasy in *Alien Rescue II* is endogenous.

2) INTERPERSONAL MOTIVATIONS

a) Cooperation: The appeal of the activity may be enhance by enlisting the motivation to cooperate with others.

Currently, the problem presented in *Alien Rescue II* is complex; requiring students to cooperate in order to solve it.

b) Competition: The appeal of the activity may be enhanced by enlisting the motivation to compete with others.

Alien Rescue **is inherently a non-competitive learning environment, as as most PBL environments. Teachers may provide competition outside of** **Alien Rescue** **but this is not encouraged.**

c) Recognition: The appeal of the activity may be increased if the learner's efforts receive social recognition.

Alien Rescue **does not inherently provide social recognition. Teachers may provide that outside of** **Alien Rescue** **but this is not encouraged.**

Appendix C: Design of *Alien Rescue III*

The Story of Alien Rescue

[GP1] You have been inducted into the Academy of Research and Exploration in Space (ARES). ARES' mission was to seek out new life forms and develop new knowledge regarding life and our universe. ARES was a secret organization known only to a few people.

While you were on the orientation tour of the secret lab conducted by the robot, Whiz, an alarm sounded! An alien spacecraft, about the size of breadbox, was found at the outer reaches of our atmosphere. Whiz attempted communication with the aliens with little success. Suddenly, while you were in the lab, the aliens started communicating to you (and only you) telepathically.

"We are the Xenoi", an alien said. "We need your help. Thousands of your light years ago, our planet was destroyed when the closest star went super nova under very strange conditions. Even as advanced a civilization as we were, the explosion caught us by surprise, as our models and predictions had calculated that at least a million years had still to pass before this would happen. All we could do in our desperate effort to survive was to launch a few ships in which we placed the most important genetic samples— representative of life in our planet—into hibernation and send them in trajectories that would one day reach those systems we had deemed as having a high probability of sustaining life. And this is how we came to your planet. We beg you! Unless you can assist us, all of our wonder, all of our technological advancement and all of our wisdom will cease to exist. We have the ability to read people's hearts and minds, and we have seen you are good people. Based on our scan of your computer systems, we will trust your judgment in finding a suitable place in your solar system where we could start rebuilding our world. All we can offer in return for this is our friendship and wisdom and gratitude. If you decide to help us, please hurry! For our life support systems will not hold us much longer. These are the things we need to live." [GP2] A brief list of requirements suddenly appeared on the largest computer monitor. While looking at the list of requirements, the Xenoi provided a picture of their species — a hideous looking race.

Immediately, you ask Whiz to help the Xenoi. Whiz used the lab's computer and knowledge of the solar system to find a home. Whiz determined that Earth was the best place for the Xenoi to live, but only in a special place on Earth that was hospitable to them. [PF2] [PF3] [GP3] The Xenoi agreed and go there.

The Xenoi were grateful and said, "Since we have mind-melded, don't be surprised if we find out when you are in distress. We will then provide you with our advice telepathically." [PF5] The Xenoi flew their spaceship to their special place on Earth.

Whiz tells you that it was time to learn the computer system and that Whiz must get recharged and will be back when it is fully operational. While you were learning the system, a crackly voice started to communicate with you. You quickly adjusted the electromagnetic frequency of the receptor to obtain clearer audio and visual. Suddenly, a beautiful-looking alien commander appeared on the screen. The alien spoke with a gentle voice, "We are the Aurora and we need your help. We have traveled a long distance in search of a group of fugitives. These scoundrels are sought back in our solar system for causing the destruction of several planets. They travel disguised as benign creatures. A great reward has been offered for them. However, our ship is low on fuel and we need a place in your solar system where we can stay while refueling is performed. We will download our requirements so that you can tell us where we should stay. Our power systems are low but we can scan the habitat you selected to ensure that it is appropriate for us. We are ready to download now." The data from the Aurora started appearing on the computer screen.

While you watched the screen, a message from the Xenoi came into your mind. The Xenoi told you not to help the Aurora, though they did not explain why. [PF6]

You re-focused your attention on the data from the Aurora and their living requirements. You decided to help them, as Whiz had helped the Xenoi. You started searching the solar system for the appropriate habitat for the Aurora. When you made your decision, you informed the Aurora. The Aurora then scanned the habitat to ensure that it was appropriate. [GP4] [PF8] Once they were satisfied, they flew to their new habitat.

A few days later, the world found out about yet another alien spaceship with six new alien species aboard: the Akona, Eolani, Jakala-Tay, Kaylid, Sylcari, and the Wroft. [GP5] You were shuttled up to the alien spaceship with Whiz and you explore the alien spaceship. [PF4]

Suddenly, the Xenoi tell you that the Aurora will attack the spaceship soon. [PF9] You grab the alien computer and 7 orbs that the Xenoi tell you about. You get back into your rocket to go to Paloma. The Aurora attack but their photons are deflected. The Xenoi explained that the orbs are a shielding system that could be used to prevent the Aurora from attacking the spaceship again but it consumed a lot of energy, and thus could not be used forever.

A picture of the Aurora appeared on the aliens' spaceship computer screen. The Aurora said, "We did not mean any harm to you. We thought you were trying to help the scum onboard. Please allow us to come aboard your ship and take you away their computer and orbs." The Xenoi advised you not to do that. [PF17] The Aurora told you that these new aliens destroyed the Aurora's world and that they were following and attacking the Aurora wherever they went. They told you that if you attempted to help their enemies then they would consider humans to be their enemies, too. The Xenoi told you not to believe the Aurora and to help the aliens on the spaceship. [PF7] [PF6]

You decided to help the six new aliens. You learned more about them and their characteristics from their computer. The computer system told you that two aliens out of the six species were low in life-support, and a gauge of the life-support system verified this. [GP6] [GP7] [GP8] [GP9] You helped these two aliens find new habitats in our solar system. After their departure, there were four aliens left aboard the ship. In appreciation, the two aliens provided Earth with antimatter technology to allow the probes to travel faster.

Then, the Aurora contacted you again. This time, they called you their enemy. You found out that they were building a great machine on the planet where they had landed and that they would use this machine to harvest hydrogen from the sun to create a great cannon that could destroy Earth. You also found out from the new aliens that the Aurora was the enemy of everyone and the Aurora wanted to destroy all of them. It was the Aurora that attacked the other aliens' ship when they were in flight and damaged it.

You now determined that another two alien species are low in life-support. [GP6] You helped those two aliens find new home, leaving you in the company of the last two aliens. [GP7] [GP10] [GP11] In appreciation, these aliens give earth force-field shielding capabilities. Suddenly, the Aurora attacked Earth and Earth was protected from being destroyed by the new shields. [GP12] The Aurora was not successful.

After the Aurora attack, you turned your attention to selecting the appropriate habitats for the remaining two aliens before their life support systems failed. [GP14] [PF10] In appreciation, the aliens give earth long-range phaser technology. The Aurora attacked Earth again and Earth protected itself from being destroyed. The aliens that you helped were instrumental in protecting Earth. [GP15] Earth was saved.

Alien Rescue Game Play/Mechanics

1. Before the game begins, the student has entered his/her name in AR and is referred by AR using that name. [PF1]
2. Screen of Xenoi requirements are shown. It requires matching two needs to solve.
3. Through video cut-scenes the student is shown how to determine that Earth is the best place for the planets. They are then placed on a particular spot on Earth. [PF2]
4. Introductory problem solving exercise to select a planet for the Aurora, requiring two needs to be fulfilled. There could be up to three choices of habitats. [PF8]
   a. First attempt by student
      i. If the habitat the student selects is appropriate, then the commander comes on and says "Thank you for your help. We noticed that you are lacking in technology for space travel. To

reward you for your help we are sending down fusion propulsion technology that will enable you to send probes at very high speeds." (Fusion technology [PF7] becomes a permanent choice of Probe Power Systems, but is very expensive and time-consuming to make because it requires the rare element Einsteinium, which is named after Einstein. Thus, only one per alien-placement can be launched.) Then, the Aurora fly to their new habitat.

        ii. If it is not an appropriate habitat, the commander says, "What? Is this some kind of trick? Are you our enemy? I want a place for us and I want it soon! No more tricks!" [PF10]

   b. Second attempt

        i. If you then provide an appropriate choice, the Aurora commander says, "So you are not our enemy but I am still not pleased. However, I will send you one fusion propulsion booster that can make a single rockets travel faster in space as a show of peace between us." (Only one fusion booster probe launch is allowed.)

        ii. If the choice is not appropriate, then the commander says, "You are showing us that you are our enemy. We destroy all life forms that are against us. You have one more chance and that is all!"

   c. Third attempt

        i. If your next choice is appropriate then the Aurora commander says, "We do not trust you! We will continue to monitor you from our new home!" And they fly away.

        ii. If the choice is not appropriate then Whiz takes over and completes the mission, and the Aurora call Earth their enemy. [PF11] [PF12] [PF13]

5. Existing Alien Rescue news story of alien spaceship appearance and UN involvement inserted here.

6. One alien species is dropping faster than another in life support systems.

7. One of the two aliens' optimal habitats could be Earth. [PF2]

8. The player may decide to launch probes to gather information about the solar system. If a fusion probe is launched then data comes back after XXX. If a "conventional" power system probe is launched then data comes back after YYY. [PF20]

9. Exercise (Level 1) to determine the habitats for two aliens with 3 fulfillment needs. Upon determination, the player must submit a report to the UN of why he/she chose those habitats. The player ensures the space-pod automated travel through the solar system does not get pulled into planets' gravitation [PF15]. The alien scans the habitat for appropriateness.

   a. Attempts to select habitat

        i. If the habitat is unacceptable then the alien rejects the habitat, tells you why [PF5], and asks for another home. This is repeated until the third time, in which case the Whiz takes over and places the aliens on a barely adequate habitat. [PF11] [PF12]

        ii. Habitat is acceptable, then the alien tells you why it is acceptable. Alien ship lands on the habitat. Suddenly, the Aurora attacks. [PF21]
    b. Consequences of student selection [PF18]
        i. Habitat is optimal, then the Aurora is defeated (100% of the time).
        ii. Habitat is sub-optimal, then the Aurora is defeated (50%) or there is a stalemate (50%) with the Aurora ship orbiting the planet.
        iii. Habitat is barely adequate, then the Aurora is defeated (33%) or there is a stalemate (67%) with the Aurora ship orbiting the planet.
        iv. After the aliens are on their habitats they gift Earth one antimatter [PF19] propulsion power system, which returns back to Earth and can be reused. If an antimatter probe is launched then data is provided in ZZZ. The antimatter power system can be used only once per alien.

10. One of the two aliens' sub-optimal habitats is Earth. [PF2]
11. Player determines the habitats for two aliens with 4 fulfillment needs (Level 2). The player then must submit a report to the UN of why it chose those habitats. The player then must fly the space-pod through the solar system toward the habitat avoiding the gravitation pull of planets and the habitat. The alien ship then scans the habitat while in orbit.
    a. Attempts to select habitat
        i. If habitat is unacceptable then the alien rejects the habitat, tells you why, and asks for another home. This is repeated until one more time, in which case the Whiz takes over and places the aliens on a barely adequate habitat.
        ii. Habitat is acceptable, then alien ship lands on the habitat. Suddenly, the Aurora attacks.
    b. Consequence of student selection
        i. If habitat is optimal, then the Aurora is defeated (100% of the time).
        ii. Habitat is sub-optimal, then the Aurora is defeated (p=50%) or there is a stalemate (50%) with a Aurora ship orbiting the planet.
        iii. Habitat is barely adequate, then the Aurora is defeated (20%) or there is a stalemate (80%) with a Aurora ship orbiting the planet.
        iv. After the aliens are on their habitats they give Earth force-field technology, which can be used to help protect Earth from attacks from space. [PF18]

12. Ending Scenarios of Level 2
    The Aurora attacks the humans on Earth with their cannon (not at full power as the machine is not complete). Earth's force-field technology [PF19] deflected the attack, but the Aurora remained in the solar system.
13. One of the two aliens' barely adequate habitats is Earth. [PF2]
14. Player determines the habitats for two aliens with 5 fulfillment needs (Level 3). The player then must submit a report to the UN of why it chose those habitats. The player then must fly the space-pod through the solar system using maps and

avoiding the gravitation pull of planets and any Aurora inhabitations and ships. For each habitat, the alien ship flies to habitat and scans while in orbit.

    a. Attempts to select habitat
        i. If habitat is unacceptable then the Whiz takes over and places the aliens on a barely adequate habitat.
        ii. Habitat is acceptable, then alien ships lands on the habitat. The Aurora attacks.
    b. Consequences to student habitat selections
        i. If habitat is optimal, then the Aurora is defeated (100% of the time).
        ii. Habitat is sub-optimal, then the Aurora is defeated (50%) or there is a stalemate (50%) with a Aurora ship orbiting the planet.
        iii. Habitat is barely adequate, then the Aurora is defeated (20%) or there is a stalemate (60%) with a Aurora ship orbiting the planet or the new aliens are driven off the habitat and must be placed elsewhere (20%).
        iv. The aliens give Earth laser attack technology, which can be used to attack things in space.

15. Ending Scenarios of Level 3
    a. (If all aliens are placed on optimal habitats.) The Aurora attacked the humans on Earth again but with greater force this time. The force-fields were destroyed by the Aurora cannon. The only way to defeat the Aurora is by counterattacking with the newly acquired lasers, which require all of the alien races to help with power generators that can harvest solar energy just like the Aurora do. The Aurora was totally defeated and their last spaceship was flushed down a blackhole.
    b. (If all aliens are placed on optimal or sub-optimal habitats.) The Aurora attacked Earth again but with greater force this time. The force-fields were destroyed. Earth's laser destroyed the Aurora's cannon, habitat, and attacking spaceships (with the help of the good aliens). The Aurora was defeated but escaped in their last spaceship and left the Solar System.
    c. (If any aliens are placed on barely adequate habitats.) The Aurora attacked Earth again but with greater force this time. The force-fields were destroyed. Earth's laser destroyed the Aurora's cannon and habitat. However, the Aurora spaceships are not destroyed. The Aurora attacked Earth on the ground. The Aurora's attack destroyed Earth's laser but by using conventional and nuclear weapons, they were repulsed. The Aurora spaceships remain in the Solar System.

Alien Rescue's Pedagogical Foundation [PF]

1. Student identifies a name that is used by AR. Motivation enhancement according to theory. Cordova, D. I., & Lepper, M. R. (1996). Development of an online identity (Gee, 2003)

2. Possible TEKS include: causation of seasons, water cycles, and history of science. 112.22. Science, Grade 6. (a) (2)
3. Whiz find home for Xenoi. Mentoring/scaffolding/cognitive apprenticeship. Vygotsky and others
4. ~~Increasing cognitive curiosity. Malone and Lepper.~~
5. Coaching/mentoring/scaffolding/cognitive apprenticeship. Vygotsky and others
6. Ethics and the practice of science. Evidence based decisions. No TEKS identifies this topic.
7. 112.22. Science, Grade 6. (b) (8) (9) AND 112.24. Science, Grade 8. (b) (8) Science concepts. The student knows that matter is composed of atoms.
8. Introductory problem solving exercise (2 needs to be fulfilled) and progressive increases in challenge in three levels: 3, 4, and 5 needs. Scaffolding & Csikszentmihalyi's flow & Malone/Lepper Vygotsky ZPD
9. ~~Parents kidnapped. Disequilibrium in Maslow's safety need.~~
10. Rewards for successfully completing tasks and feedback for unsuccessfully doing so. Feedback, Bandura's Social Learning Theory, Cognitive Dissonance Theory (Festinger, 1962), Bayes's Theorem and Problem Solving Theory.
11. Chance for failure that is influenced by student. Csikszentmihalyi's flow on control, Locus of Control, Self-Determination Theory (Deci and Ryan)
12. Performance feedback on actions. Csikszentmihalyi's flow & Malone/Lepper.
13. Ipsative feedback is more effective for less competent learners. Malone/Lepper
14. Goals: short-term (place 2 x aliens) and long-term (place all aliens). Malone/Lepper
15. Map of solar system with gravitation pull of planets. 112.22. Science, Grade 6 (a) (2) AND 112.23. Science, Grade 7 (a) (2)
16. Uncertain/variable outcomes depending on which planet aliens are placed. Malone & Lepper
17. Information on Aurora and actions of the Aurora are selectively revealed. Increasing cognitive curiosity. Malone & Lepper. Evidence Based Learning
18. Endogenic consequences when placing the aliens or launching probes. Malone & Lepper
19. ~~The use of powerful technology beyond our current abilities. Malone & Lepper~~
20. ~~Feedback from probes is timed based on propulsion technology. Cognitive Dissonance Theory (Festinger, 1962)~~
21. Conflict with Aurora. Malone/Lepper's competition

Alien Rescue's Storyboard

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Level 1: Screen 6

Level 1: Screen 7

The orbs provide deflector shields....

Level 1: Screen 8

PASSWORD

Level 1: Screen 9

Level 1: Screen 10

We did not want you here ...

Did not believe in me!

Level 1: Screen 11

Location
Alien
Spacestation

Location
Planet Claire

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Level 1: Screen 15.3

Level 1: Screen 15.4

Level 1: Screen 16

Level 1: Screen 16.1

Level 1: Screen 16.2

Level 1: Screen 17

Level 1: Screen 18

Level 1: Screen 19 (optional)

Level 2: Screen 1

Level 2: Screen 2

Level 2: Screen 3

Level 2: Screen 4

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Level 3: Screen 1

Level 3: Screen 2

Level 3: Screen 3

Level 3: Screen 4

Level 3 Screen 5-5.5

Level 3: Screen 6-6.2

Level 3: Screen 7

Level 3: Screen 8

Level 3: Screen 9

Level 3: Screen 10

Level 3: Screen 11

Level 3: Screen 12

Level 3: Screen 13

Level 3: Screen 14

Level 3: Screen 15

Level 3: Screen 16

Level 3: Screen 17

Level 3: Screen 18

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Appendix D: Continuing Motivation Self-Report Questionnaire

Continuing motivation self-report questionnaire developed by Pascarella, Walberg, Junker, and Haertel (1981), Students are asked, "How often have you done each of the following activities when not required for science classes?"

	Never	Seldom	Sometimes	Often
Read science articles in newspapers.				
Worked with science-related hobbies.				
Gone to hear people give talks on science.				
Read science articles in magazines.				
Watched science shows on TV.				
Read books about science or scientists.				
Talked about science topics with friends.				
Done science projects.				

Scoring: 1 = never, 2 = seldom, 3 = sometimes, 4 = often.

Appendix E: Continuing Motivation To Learn Science Survey

In the last two weeks, how often have you done each of the following activities when **not required** (you wanted to do it on your own) for science classes?

		Never	Seldom	Sometimes	Often
Science Subject	Read science articles in newspapers or magazine or internet outside of science class?				
	Work with science-related hobbies or on science projects outside of science class?				
	Watch science shows on TV or internet outside of science class?				
	Read books about science or scientists outside of science class?				
	Talk or listen about science outside of science class?				
	Played with any science games or simulations outside of science class?				
Science Domain (space)	Read space science or astronomy articles in newspapers or magazine or internet outside of science class?				
	Work with space science or astronomy related hobbies or projects outside of science class?				
	Watch space science or astronomy shows on TV or internet outside of science class?				
	Read books about space scientists or astronomists outside of science class?				
	Talk or listen about space science or astronomy outside of science class?				
	Play with any space science or astronomy games or simulations outside of science class?				
Science Domain (genes)	Read science articles in newspapers or magazine or internet about genetics outside of science class?				
	Work with genetics related science hobbies or projects outside of science class?				
	Watch shows on TV or internet on genetics outside of science class?				
	Read books about geneticists outside of science class?				

	Talk or listen about genetics outside of science class?				
	Play with any genetics related games or simulations outside of science class?				
Space Science Task Related	Talk or read or listen or play a game or watch TV about probes or space missions outside of science class?				
	Talk or read or listen or play a game or watch TV about space aliens outside of science class?				
	Talk or read or listen or play a game or watch TV about one of the following science concepts outside of science class: Atmosphere, craters, gravity, magnetic fields, radio waves, super novas, temperature?				
Genetics Task Related	Talk or read or listen or play a game or watch TV about one of the following science concepts outside of science class: genes, chromosomes, selective breeding, and inherited traits?				

Scoring: 1 = never, 2 = seldom, 3 = sometimes, 4 = often.

Appendix F: Short Science Knowledge Test

Use the answer sheet provided to put down your answers to these questions.

1.   Which of these worlds is a planet (not a moon)?

   A. Io
   B. Phobos
   C. Uranus
   D. Not Sure

2.   Which of these worlds is a gas giant?

   A. Saturn
   B. Earth
   C. Pluto
   D. Not Sure

3.   Which of the following worlds is a moon of Jupiter?

   A. Europa
   B. Mars
   C. Charon
   D. Not Sure

4.   Which of these worlds is farther from the sun than Saturn?

   A. Earth's moon
   B. Mercury
   C. Charon
   D. Not Sure

5. Venus

   A. is a gas giant
   B. has an atmosphere denser than Earth's
   C. is very cold because of a greenhouse effect
   D. Not Sure

6. Io

     A. is the closest planet to the sun
     B. has active volcanoes
     C. is as cold as Pluto
     D. Not Sure

7.   Which of these worlds has the lowest surface gravity?

     A. Earth
     B. Triton
     C. Jupiter
     D. Not Sure

8.   What is the difference between a moon and a planet?

     A. moons are closer to the sun than planets
     B. planets have plant life and moons do not
     C. moons orbit planets but planets do not orbit moons
     D. Not Sure

9.   Which of the following does an atmosphere do for a world?

     A. causes volcanoes to erupt
     B. pushes heat out into space so the world doesn't get too hot
     C. protects it from meteors
     D. Not Sure

10. Which of the following does a magnetic field do for a world?

     A. protects it from the solar wind
     B. lowers its temperature
     C. gives it seasons
     D. Not Sure

11. Craters are caused by

     A. earthquakes
     B. magnetic fields
     C. meteor impacts
     D. Not Sure

12. You are standing on the surface of a world and see the sun in the sky. The rest of the sky is black and you can see stars. What do you know about that world?

    A. It is a gas giant.
    B. It has no atmosphere.
    C. It has no magnetic field.
    D. Not Sure

13. Which of the following is **NOT** the name of a temperature scale?

    A. Fahrenheit
    B. Titan
    C. Celsius
    D. Not Sure

14. Ice

    A. can be made of many substances, not just water
    B. covers most of the surface of Io
    C. is an element
    D. Not Sure

15. Which of these instruments can be used to learn about temperature on a world?

    A. seismograph
    B. infrared camera
    C. mass spectrometer
    D. Not Sure

16. Imagine that you need to determine whether or not a moon's surface has carbon. What instrument would you use?

    A. wide angle camera
    B. mass spectrometer
    C. seismograph
    D. Not Sure

17. Scientists want to measure the pressure of Mars' atmosphere. What instrument would they use?

    A. barometer
    B. thermometer
    C. magnetometer
    D. Not Sure

18. Suppose that you want to take closeup pictures of features on the surface of Callisto, but you can only afford to send an orbiter. What instrument would you include?

      A. infrared camera
      B. narrow angle camera
      C. barometer
      D. Not Sure

19. You need to design a probe to go to Titan to find out if it has a magnetic field or earthquakes. Which of the following would you choose to include on your probe?

      A. a battery and a solar panel
      B. a barometer and a seismograph
      C. a magnetometer and a seismograph
      D. Not Sure

20. Will a mass spectrometer work on a flyby probe?

      A. Yes, but only if you include solar panels
      B. No, because mass spectrometers must come into contact with the substance they analyze
      C. No, because mass spectrometers only work on orbiters and landers
      D. Not Sure

Appendix G: Dimensions of Continuing Motivation Survey

Please circle the degree to which each statement is characteristic or true of you.

Space Science/Astronomy Competence/Expectancy Beliefs Subscale
1. How good (do you think you would be) at space science/astronomy are you?
       1   2   3   4   5   6   7

not at all   very good

2. Compared to most of your other school subjects, how good are you (do you think you would be) at space science/astronomy?
       1   2   3   4   5   6   7

not at all   very good

3. If you were to list all the students in your class from the worst to the best in space space science/astronomy, where would you put yourself?
       1   2   3   4   5   6   7

one of the worst   one of the best

Space Science/Astronomy Utility Value Subscale
1. Some things are you learn in school help you do things better outside of class, that is, they are useful. For example, learning about plants might help you grow a garden. In general, how useful is what you learn in space science/astronomy?
       1   2   3   4   5   6   7

not at all useful   very useful

2. Compared to most of your other activities, how useful is what you learn in space space science/astronomy? (not at all…very useful)
       1   2   3   4   5   6   7

not at all useful   very useful

Space Science/Astronomy Attainment Value Subscale
1. For me, being good in space science/astronomy is
       1   2   3   4   5   6   7

not at all important   very important

2. Compared to most of your other activities, how important is it for you to be good at space science/astronomy?
       1   2   3   4   5   6   7

not at all important   very important

Space Science/Astronomy Intrinsic Value Subscale

1. (Interest subscale) In general, I find (think I would find) working on space science/astronomy assignments

      1   2   3   4   5   6   7

very boring   very interesting

2. (Affective subscale) How much do you (do you think you would) like doing space space science/astronomy?

      1   2   3   4   5   6   7

not at all   very much

Space Science/Astronomy Cost Beliefs Subscale

1. In general, how hard (do you think) is space science/astronomy for you (would be)?

      1   2   3   4   5   6   7

very easy   very hard

2. Compared to most other school subjects that you take, how hard is (do you think it would be) space science/astronomy?

      1   2   3   4   5   6   7

my easiest   my hardest

3. How hard do you (think would) have to try to do well in space science/astronomy?

      1   2   3   4   5   6   7

not very hard   very hard

4. To do well in space science/astronomy I have (think I would have) to work

      1   2   3   4   5   6   7

much harder in   much harder in
other subjects   space science or
than in space science   astronomy than in
or astronomy   other subjects

Appendix H: Intrinsic Value Interview Guide of Self-identified Sources

I am going to start asking you some questions about how your **interest** in sport developed. By interest I mean how enjoyable sport is or how much like sport. On this sheet you have rated sport as _____ (e.g. very boring…very interesting) to you. First, is that correct? Ok, then I would like to now ask you some questions about things that influenced your interest in sport.

1. Can you tell me about any situations, people, or experiences that influenced your developing an in sport?
2. What other things to do you think lead to your interest in sport
3. Are there any other situations, people, or other experiences that you can recall which influenced your interest in sport
4. Probe: any other things that come to mind that you would like to add before we finish?

You have talked about some of the things that have affected your interest in sport. I'd like to get your ideas about whether these additional things also influenced your interest in sport.

Cost Questions
5. Do you think that the effort needed to be good at sport has affected your interest in sport? If yes, why? If no, why not?
6. Do you think that the amount of time it takes to be good at sport has affected your interest in sport? If yes, why? If no, why not?

Affective Questions
People have both positive and negative feelings about activities in which they participate.
7. Have positive feelings you have experienced in sport influenced your interest in sport? If yes, why? If no, why not? What are your positive feelings?
8. Have negative feelings you have experienced in sport influenced your interest in sport? If yes, why? If no, why not? What are your negative feelings?

Sex-role Stereotypes
9. Has anyone ever told you that sport was inappropriate for you?
10. Do you think that others opinions on the appropriateness of sport for you have influenced your interest in sport? How so?

Significant Others
We all have people in our lives that we spend time with, such as in school, at home, and in the various activities in which we participate.
11. Do you think that the people in your life have influenced your interest in sport? If yes, who has? If not, why do you think that is?

Appendix I: Continuing Interest Interview Guide

<u>Introductory Comments and Questions</u>

1. Thank you for agreeing to participate in this interview.

2. This interview is part of my school work at the University of Texas at Austin

3. Some people do or do not like to learn science. I am going to ask you some questions about this and why.

4. There are no right or wrong answers to the questions. So, please answer them as honestly as possible. Also, for each question, please provide me with as many examples as you can remember.

5. Your name will not be associated with your answers. So, please feel free to answer honestly.

6. I would like to use a tape recorder to help me record your answers instead of me writing everything down. Is that ok with you?

7. First, I would like to ask you some background questions.
    a. How good are your grades in science?
    b. Do you like science fiction? Examples?

<u>Main Questions</u>

I am going to start asking you some questions about how your continuing interest developed. By continuing interest I mean how enjoyable science is or how much like science, even outside of the classroom. On this sheet you have rated space science or astronomy as _____ (e.g. very boring…very interesting) to you. First, is that correct? Ok, then I would like to now ask you some questions about things that influenced your continued interest in science.

<u>Indication of Behavioral Intention to Continue Learning Science Questions</u>
   1. What science topic would you like to learn more of outside of class or in class?

<u>Self-Efficacy Question</u>
   2. How has how good you are at science influenced your continuing interest in science?

<u>Intrinsic Motivation Question</u>
   3. How has how fun it is to learn or do science influenced your continuing interest in science?

Attainment Value/Value-Related Valence Question
   4. How has the important science is for you influenced your continuing interest in science?

Utility Value
   5. How has how useful science is influenced your continuing interest in science?

Cost Questions
   6. How has the amount of time or effort needed to be good at science affected your continuing interest in science?

   7. When not at school what are some other activities that you would rather do than continue learning about science at home?

General Influences on Continuing Interest Questions
   8. What situations, people, or experiences have influenced your developing a continuing interest or disinterest in science?

Attitude Toward Science/Feeling Valence/Affective Questions
   9. What are your feelings toward science?

Stored-Knowledge Valence Question
   10. Do you have that the amount of knowledge you have about science has influenced your continuing interest in science? Why?

Social Influences Questions
   11. How have the people in your life, such as friends, classmates, family, teachers, and so forth influenced your continuing interest in science?

   12. Probe: any other things that come to mind that you would like to add about what has influenced your interest in science before we finish?

Appendix J: Forms for the UT-Austin IRB Approval Process

<u>Research Proposal</u>

I.   **Title:** Continuing Interest Development by Playing Alien Rescue

II.   **Investigators (co-investigators):** Paul Toprac

III.   **Hypothesis, Research Questions, or Goals of the Project:** The goal of this study is to determine if students will develop continuing motivation to learn science, and why, by playing a computer game called Alien Rescue.

IV.   **Background and Significance**: In its report ("Preparing Our Children: Math and Science Education in the National Interest," 1999), the National Science Board (NSB), the governing body for the National Science Foundation, pointed out an alarming fact: U.S. students lag far behind other high-performing countries in math and science, especially at the middle school level. At the heart of this problem is students' lack of interest in mathematics and science at the pre-college level. Several prominent educators suggest that this is a result of weak instructional materials that fail to provide a supporting context and real-world applications. The NSB recognized this as a problem of national importance and recommended that it be addressed through the development of quality instructional materials at all levels.

Alien Rescue, is an innovative English-only language software game, which is designed to be part of a sixth -grade science curriculum. The content of Alien Rescue is focused on learning about our solar system and Earth. The game, on CD-ROM, uses educational technologies to offer the type of rich context for learning that is often missing from K-12 classrooms. It addresses the pressing need for technology-enhanced, high quality science materials at the middle school level. The intention is for Alien Rescue to increase the number of U.S. students interested in science. For more information on Alien Rescue, go to http://www.edb.utexas.edu/alienrescue/.

The need for the U.S. is for more students to develop an interest in science. This study attempts to find out if students can develop interest in science by playing Alien Rescue and why.

Research Method, Design, and Proposed Statistical Analysis: Children at the XXXX school will be asked to answer questions in the Science Knowledge Test, the Dimensions of Continuing Motivation, and the

Continuing Motivation to Learn Science Survey before the intervention. After the intervention and two weeks later, the same three tests will be administered again. Observations and semi-structured interviews will be conducted according to Grounded Theory in the classroom for those who agreed to participate. In addition, there will be select group of students will be interviewed outside of class.

V.   Human Subject Interactions

A. Sources of potential participants: XXXX School

B. Procedures for the recruitment of the participants: Parents at the XXXX School will be asked if their children would like to participate in the study. In addition, for the children who parents have agreed for their participation, these students will be asked to give their permission, as well. The available population between 11-14 for this study is approximately YY.

C. Procedure for obtaining informed consent: A Consent form will be sent to the parents for their signature and an assent form will be provided for the children.

D. Research Protocol: Children will be asked to complete the Science Knowledge Test, the Continuing Motivation to Learn Science Survey, and the Dimensions of Continuing Motivation before beginning the study. Then, for up to three weeks, children will play Alien Rescue. This program and forms are only in English. During this time the children will be interviewed and observed. Eight students will be interviewed outside of science class using the Continuing Interest Interview Guide. In addition, short interviews will be conducted during science class, along with classroom observations. After completing Alien Rescue, the children will be administered the Science Knowledge Test, the Continuing Motivation to Learn Science Survey, and the Dimensions of Continuing Motivation, and again two weeks later.

E. Privacy and confidentiality of participants: If the results of this research are published or presented at scientific meetings, the identity of the participants will not be disclosed. Any reports derived from the research will not reveal anyone's true names, but pseudonyms will be used instead or the data will be aggregated without the use of names.

F. Confidentiality of the research data: The data will be in the form of papers and computer files that will be kept at the PI's house under lock and key (and alarm system). I will store them in a locked file cabinet and when working with them, I will make sure that is not easily viewed or accessible to

the members of my household. Files on my computer system will be encrypted and/or allowed access only by password.

G. Describe your research resources: Children will have access to the computers at the school. The data will be analyzed at home.

VII.   **Risks:** No other physical or mental discomforts are foreseeable.

VIII.   **Benefits:** All students may benefit motivationally by playing Alien Rescue.

IX.   **Sites or agencies involved in the research project:** The XXXX school will be the site where the research will be performed. Approval from this site is still processing.

<u>Site Approval Letter</u>

- Address line 1
- Address line 2
- City, State/Postal Code
- Email address.com

Date

Dr. Lisa Leiden, Ph.D.
Director, Office of Research Support and Compliance
P.O. Box 7426   Campus Mail
Austin, TX 78713
Lisa.leiden@mail.utexas.edu

Dear Dr. Leiden:

The purpose of this letter is to grant Paul Toprac, a graduate student at the University of Texas at Austin permission to conduct research at [name of organization]. The project, "Continuing Interest Development by Playing Alien Rescue" entails students being of Continuing Motivation, and the Continuing Motivation to Learn Science Survey questionnaires before playing Alien Rescue. After playing Alien Rescue and two weeks later, the same three tests will be administered again. Observations and semi-structured interviews will be conducted in the classroom for those who agreed to participate. In addition, there will be select group of children will be interviewed outside of class, if those students agree. [name of organization] was selected because of its proximity to the researcher. I, [insert directors name] do hereby grant permission for Paul Toprac to conduct research at [insert organizations name].

Sincerely,

<u>Consent Approval Form</u>

Informed Consent to Participate in Research

The University of Texas at Austin

You are being asked to participate in a research study. This form provides you with information about the study. The Principal Investigator (Paul Toprac) or his/her representative will provide you with a copy of this form to keep for your reference, and will also describe this study to you and answer all of your questions. Please read the information below and ask questions about anything you don't understand before deciding whether or not to take part. Your participation is entirely voluntary and you can refuse to participate without penalty or loss of benefits to which you are otherwise entitled.

Title of Research Study: Continuing Interest Development By Playing Alien Rescue

Principal Investigator(s) (include faculty sponsor), UT affiliation, and Telephone Number(s): Paul Toprac, Ph.D. student, 512/663-1488

Funding source: Not applicable

What is the purpose of this study? The goal of this study is to determine if students will develop continuing motivation to learn science, and why, by playing a computer game called Alien Rescue.

What will be done if your child takes part in this research study? Your child will be asked to answer questions in the Science Knowledge Test, the Dimensions of Continuing Motivation, and the Continuing Motivation to Learn Science Survey questionnaires before playing Alien Rescue. After playing Alien Rescue and two weeks later, the same three tests will be administered again. Observations and semi-structured interviews will be conducted in the classroom for those who agreed to participate. In addition, there will be select group of children will be interviewed outside of class, if those students agree.

What are the possible discomforts and risks? No physical or mental discomforts are foreseeable.

What are the possible benefits to you or to others? None, except perhaps your child will become more motivated to learn science.

If you choose to take part in this study, will it cost you anything? There is n cost.

Will you receive compensation for your participation in this study? None.

What if you are injured because of the study? If injuries occur as a result of study activity, eligible University students may be treated at the usual level of care with the usual cost for services at the Student Health Center, but the University has no policy to provide payment in the event of a medical problem.

If you do not want to take part in this study, what other options are available to you? The participation of your child in this study is entirely voluntary. You are free to refuse to be in the study, and your refusal will not influence current or future relationships with The University of Texas at Austin or with the school that your child is attending.

How can you withdraw from this research study and who should you call if you have questions?

If you wish to stop your participation in this research study for any reason, you should contact the principle investigator: Paul Toprac **at (512)** 663-1488**. You should also call the principle investigator for any questions, concerns, or complaints about the research. You are free to withdraw your consent and stop participation in this research study at any time without penalty or loss of benefits for which you may be entitled. Throughout the study, the researchers will notify you of new information that may become available and that might affect your decision to remain in the study.**

In addition, if you have questions about your rights as a research participant, or if you have complaints, concerns, or questions about the research, please contact Lisa Leiden, Ph.D., Chair, The University of Texas at Austin Institutional Review Board for the Protection of Human Subjects, (512) 471-8871. You may also contact the Office of Research Compliance and Support at <u>orsc@uts.cc.utexas.edu</u>.

How will your privacy and the confidentiality of your research records be protected?
If the results of this research are published or presented at scientific meetings, your identity will not be disclosed. Any reports derived from the research will not reveal anyone's true names, but pseudonyms will be used instead or the data will be aggregated without the use of names.

If in the unlikely event it becomes necessary for the Institutional Review Board to review your research records, then the University of Texas at Austin will protect the confidentiality of those records to the extent permitted by law. Your research

records will not be released without your consent unless required by law or a court order. The data resulting from your participation may be made available to other researchers in the future for research purposes not detailed within this consent form. In these cases, the data will contain no identifying information that could associate you with it, or with your participation in any study.

Will the researchers benefit from your child's participation in this study? No benefits for the researcher other than the completion of his school work at the University of Texas at Austin.

Signatures:

As a representative of this study, I have explained the purpose, the procedures, the benefits, and the risks that are involved in this research study:

_____

Signature and printed name of person obtaining consent   Date

You have been informed about this study's purpose, procedures, possible benefits and risks, and you have received a copy of this form. You have been given the opportunity to ask questions before you sign, and you have been told that you can ask other questions at any time. You voluntarily agree to participate in this study. By signing this form, you are not waiving any of your legal rights.

_____

Printed Name of Subject   Date

_____

Signature of Subject   Date

_____

Signature of Principal Investigator   Date

<u>Assent Approval Form</u>

Letter Of Assent
Title   Continuing Interest Development By Playing Alien Rescue

University of Texas at Austin

You are being asked to be part of a study. This form provides you with information about the study. The person in charge, Paul, will describe this study to you and answer all of your

questions. Please listen to the following information, which is stated below, and ask any questions you might have before deciding whether or not to take part. Your participation is entirely voluntary. You can refuse to participate without any consequences. You can stop being in the study at any time. To do so simply tell Paul you wish to stop.

The purpose of this study is to learn about using a computer game in science class to help kids want to learn more science.

If you agree to be in this study, we will ask you to do the following things:
- Answer questions on paper in three separate times during science class
- Be willing to be interviewed during science class
- Be willing to be observed by someone while working on the computer program

Total estimated time to participate is a maximum of in study is 3 hours over the next several weeks

Risks and Benefits of being in the study:
- This study will not hurt you.

Compensation:
- There is no compensation

Confidentiality and Privacy Protections:
- Your name and anything about you will be kept confidential and no one outside of the study will know these things.

Contacts and Questions:
     If you have any questions about the study please ask now. If you have questions later or want additional information, talk to Paul. If you feel like something is wrong please contact Lisa at (512) 471-8871 or email: orsc@uts.cc.utexas.edu.

Statement of Assent:

I understand about participating in this study. I would like to participate in the study.

Signature:_____ Date: _____

Signature of Investigator:_____ Date: _____

Letter of Assent For Interviewees of the Continuing Interest Interview Guide

Letter Of Assent
Title   Continuing Interest Development By Playing Alien Rescue

University of Texas at Austin

You are being asked to be part of a study. This form provides you with information about the study. The person in charge, Paul, will describe this study to you and answer all of your questions. Please listen to the following information, which is stated below, and ask any questions you might have before deciding whether or not to take part. Your participation is entirely voluntary. You can refuse to participate without any consequences. You can stop being in the study at any time. To do so simply tell Paul you wish to stop.

The purpose of this study is to learn about using a computer game in science class to help kids want to learn more science.

If you agree to be in this study, we will ask you to do the following things:
• Be willing to be interviewed outside of science class

Total estimated time to participate is a maximum of in study is 1.5 hours over the next several weeks
Risks and Benefits of being in the study:
• This study will not hurt you.

Compensation:
• There is no compensation

Confidentiality and Privacy Protections:
• Your name and anything about you will be kept confidential and no one outside of the study will know these things.

Contacts and Questions:
        If you have any questions about the study please ask now. If you have questions later or want additional information, talk to Paul. If you feel like something is wrong please contact Lisa at (512) 471-8871 or email: orsc@uts.cc.utexas.edu.

Statement of Assent:

I understand about participating in this study. I would like to participate in the study.

Signature:_____ Date: _____

Signature of Investigator:_____ Date: _____

Vita

Paul Toprac is currently a PhD candidate in the Instructional Technology Program in the Department of Curriculum and Instruction at the College of Education in the University of Texas at Austin. Prior to graduate school, Toprac was in the information technology industry. Over the course of twenty years in the Information Technology industry, his roles ranged from CEO to executive director to product manager to consultant. In these roles, he has lectured, moderated, facilitated, and presented in both formal educational settings, such as the University of Texas at Austin and the Austin Community College, and informal educational settings, such as SXSW and the Austin Technology Council. He also has created and/or produced more than 100 educational seminars and conferences. He was born in Austin, Texas on May 10, 1960. His parents were Anastasios Antoniou (A. A.) "Tony" Toprac. Ph.D. P.E. and Despina "Dena" Comninos Toprac.

Toprac holds a Bachelor's of Science in Chemical Engineering and a Master's of Business Administration from The University of Texas at Austin.

Permanent address: 5008 Westview Dr., Austin, TX 78731

This dissertation was typed by Paul K. Toprac.