The Effect of Navigation Maps on Problem Solving Tasks

Instantiated in a Computer-Based Video Game

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ABSTRACT

Cognitive load theory defines a limited capacity working memory with associated auditory and visual/spatial channels. Navigation in computer-based hypermedia and video game environments is believed to place a heavy cognitive load on working memory. Current 3-dimensional computer-based video games (3-D, computer-based video games) often include complex occluded environments (conditions where vision is blocked by objects in the environment, such as internal walls, trees, hills, or buildings) preventing players from plotting a direct visual course from the start to finish locations. Navigation maps may provide the support needed to effectively navigate in these environments. Navigation maps are a type of graphical scaffolding, and scaffolding, including graphical scaffolding, helps learners by reducing the amount of cognitive load placed on working memory. Navigation maps have been shown to be effective in 3-D, occluded, video game environments requiring complex navigation and simple problem solving tasks. Navigation maps have also been shown to be effective in 2-dimensional environments involving complex problem solving tasks. This study will extend the research by combining these two topics—navigation maps for navigation in 3-D, occluded, computer-based video games and navigation maps in 2-dimensional environments with complex problem solving tasks—by examining the effect of a navigation map on a 3-D, occluded, computer-based video game problem solving task. In addition, the effect of a navigation map on motivation will be examined.
CHAPTER I: INTRODUCTION

With the current power of computers and the current state-of-the-art of video games, it is likely that future versions of educational video games will include immersive environments in the form of 3-D, computer-based video games requiring navigation through occluded paths in order to perform complex problem solving tasks. According to Cutmore, Hine, Maberly, Langford, and Hawgood (2000), occlusion refers to conditions where vision is blocked by objects in the environment, such as internal walls or large environmental features like trees, hills, or buildings. Under these conditions, one cannot simply plot a direct visual course from the start to finish locations (Cutmore et al., 2000). This study examines the use of navigation maps to support navigation through a 3-D, occluded, computer-based video game involving a complex problem-solving task.

Chapter one begins with an examination of the background of the problem. Next the purpose of the study is discussed, followed by why the study is significant—how it will inform the literature—and the hypotheses that will be addressed. The next sections in chapter one include an overview of the methodology that will be utilized, assumptions that inform this topic, study limitations and delimitations, and a brief explanation of the organization of this proposal.

Background of the Problem

Educators and trainers began to take notice of the power and potential of computer games for education and training back in the 1970s and 1980s (Donchin, 1989; Malone, 1981; Malone & Lepper, 1987; Ramsberger, Hopwood, Hargan, & Underfull, 1983; Ruben, 1999; Thomas & Macredie, 1994). Computer games were hypothesized to be potentially useful for instructional purposes and were also hypothesized to provide multiple benefits: (a) complex and diverse approaches to learning processes and outcomes; (b) interactivity; (c) ability to address cognitive
as well as affective learning issues; and perhaps most importantly, (d) motivation for learning (O’Neil, Baker, & Fisher, 2002).

Research into the effectiveness of games and simulations as educational media has been met with mixed reviews (de Jong & van Joolingen, 1998; Garris, Ahlers, & Driskell, 2002). It has been suggested that the lack of consensus can be attributed to weaknesses in instructional strategies embedded in the media and issues related to cognitive load (Chalmers, 2003; Cutmore, Hine, Maberly, Langford, & Hawgood, 2000; Lee, 1999; Thiagarajan, 1998; Wolfe, 1997). Cognitive load theory suggests that learning involves the development of schemas (Atkinson, Derry, Renkl, & Wortham, 2000), a process constrained by a limited working memory with separate channels for auditory and visual/spatial stimuli (Brunken, Plass, & Leutner, 2003). Further, cognitive load theory describes an unlimited capacity, long-term memory that can store vast numbers of schemas (Mousavi, Low, & Sweller, 1995).

The inclusion of scaffolding, which provides support during schema development by reducing the load in working memory, is a form of instructional design; more specifically, it is an instructional strategy (Allen, 1997; Clark, 2001). For example, graphical scaffolding, which involves the use of imagery-based aids, has been shown to be an effective support for graphically-based learning environments, including video games (Benbasat & Todd, 1993; Farrell & Moore, 2000-2001; Mayer, Mautone, & Prothero, 2002). Navigation maps, a particular form of graphical scaffolding, have been shown to be an effective scaffold for navigation of a 3-dimensional (3-D) virtual environment (Cutmore et al., 2000). Navigation maps have also been shown to be an effective support for navigating and problem-solving in a 2-dimension (2-D) hypermedia environment (Baylor, 2001; Chou, Lin, & Sun, 2000), which is made up of nodes of information and links between the various nodes (Bowdish, & Lawless, 1997). What has not
been examined, and is the purpose of this study, is the effect of navigation maps, utilized for navigation in a 3-D, occluded, computer-based video game, on outcomes in a complex problem-solving task.

Statement of the Problem

A major instructional issue in learning by doing within simulated environments concerns the proper type of guidance, that is, how best to create cognitive apprenticeship (Mayer, Mautone, & Prothero, 2002). A virtual environment creates a number of issues with regards to learning. Problem-solving within a virtual environment involves not only the cognitive load associated with the to-be-learned material (referred to as intrinsic cognitive load: Paas, Tuovinen, Tabbers, Van Gerven, 2003), it also includes cognitive load related to the visual nature of the environment (referred to as extraneous cognitive load: Brunken, Plass, & Leutner; Harp & Mayer, 1998), as well as navigating within the environment—either germane cognitive load or extraneous cognitive load, depending on the relationship of the navigation to the learning task (Renkl, & Atkinson, 2003). An important goal of instructional design within these immersive environments involves determining methods for reducing the extraneous cognitive load and/or germane cognitive load, thereby providing more working memory capacity for intrinsic cognitive load (Brunken et al., 2003). This study will examine the reduction of cognitive load, by providing graphical scaffolding in the form of a navigation map, to determine if this can result in better performance outcomes as reflected in retention and transfer (Paas et al., 2003) in a game environment.

Purpose of the Study

The purpose of this study is to examine the effect of a navigation map on a complex problem solving task in a 3-D, occluded, computer-based video game. The environment for this
study is the interior of a mansion as instantiated in the game SafeCracker® (Daydream Interactive, 1995). The navigation map is a printed version of the floor plan of the first floor, with relevant room information, such as the name of the room. The problem solving task involves navigating through the environment to locate specific rooms, to find and acquire items and information necessary to open safes located within the prescribed rooms, and ultimately, to open the safes. With one group playing the game while using the navigation map and the other group playing the game without aid of a navigation map, this study will exam differences in problem solving outcomes informed by the problem solving model defined by O’Neil (1999).

Significance of the Study

Research has examined the use of navigation maps, a particular form of graphical scaffolding, as navigation support for complex problem-solving tasks within a hypermedia environment, with the navigation map providing an overview of the 2-dimension structure which had been segmented into nodes (Chou, Lin, & Sun, 2000). Research has also examined the use of navigation maps as a navigational tool in 3-D virtual environments, but has only examined the effect of the navigation map on navigation (Cutmore, Hine, Maberly, Langford, & Hawgood, 2000) or during a complex navigation task that involved a very basic problem solving task; finding a key along the path in order to open a door at the end of the path (Galimberti, Ignazi, Vercesi, & Riva, 2001). Research has not combined these two research topics; it has not examined the use of navigation maps in relationship to a complex problem-solving task that involved navigation within a complex 3-D virtual environment.

While a number of studies on hypermedia environments have examined the issue of site maps to aid in navigation of the various nodes for problem solving tasks (e.g., Chou & Lin, 1998), no study has looked at the effect of the use of two-dimensional topological maps (a floor
Navigation Maps and Problem Solving

plan) for navigation within a 3-dimensional video game environment in relationship to complex problem solving task. It is argued here that the role of the two navigation map types (site map and topological floor plan) serve the same purpose in terms of cognitive load. However, it is also argued here that the spatial aspect of the two learning environments differ significantly, placing a larger load on the visual/spatial channel of working memory with a 3-D video game environment as compared to a 2-D hypermedia environment, thereby leaving less working memory capacity in the 3-D video game for visual stimuli; the navigation map.

As immersive 3-D video games are becoming more common as commercial video games, it is likely they will also become more common as educational media. Therefore, the role of navigation maps to reduce the load induced by navigation and, therefore, reduce burdens on working memory, is an important issue for enhancing the effectiveness of games as educational environments.

Research Question and Hypotheses

**Research Question 1:** Will the problem solving performance of participants who use a navigation map in a 3-D, occluded, computer-based video game (i.e., SafeCracker®) be better than the problem solving performance of those who do not use the map (the control group)?

**Hypothesis 1:** Navigation maps will produce a significant increase in content understanding compared to the control group.

**Hypothesis 2:** Navigation maps will produce a significant increase in problem solving strategy retention compared to the control group.

**Hypothesis 3:** Navigation maps will produce a significant increase in problem solving strategy transfer compared to the control group.
**Hypothesis 4:** There will be no significant difference in self-regulation between the navigation map group and the control group. However, it is expected that higher levels of self-regulation will be associated with better performance.

**Research Question 2:** Will the continued motivation of participants who use a navigation map in a 3-D, occluded, computer-based video game (i.e., SafeCracker®) be greater than the continued motivation of those who do not use the map (the control group)?

**Hypothesis 5:** Navigation maps will produce a significantly greater amount of optional continued game play compared to the control group.

*Overview of the Methodology*

The design of this study is an experimental with pre-, intermediate-, and post-tests for one treatment group and one control group. Subjects will be randomly assigned to either the treatment or the control group. Group sessions will involve only one group type: either all treatment participants or all control participants. The experimental design involves administration of pretest instruments, the treatment, administration of intermediate test instruments, the treatment, and administration of the posttest instruments. At the end of the session, participants will be debriefed and will be then allowed to continue playing on their own for up to 30 additional minutes (to examine continued motivation).

*Assumptions*

This research assumes the acceptance of the cognitive load theory, which describes a limited working memory with separate auditory and visual-spatial channels, an unlimited long-term memory, and the existence of schema. Also assumed is the influence of scaffolding on reducing cognitive load, by assisting in the development of schema and in distributing cognitive load.
Limitations

There are a number of potential weaknesses to the current study. First, is the nature of the main instrument; the game SafeCracker®. The game was created in 1995 and, by current standards for game graphics and dynamics, is not a particularly engaging game. While it is assumed this issue will not affect problem-solving assessments, it is assumed it will likely influence motivational outcomes—specifically, continued motivation as assessed by the desire to continue playing the game after the experimental procedure is completed.

Another weakness is the introduction of both the contiguity effect (Mayer, Moreno, Boire, & Vagge, 1999; Mayer & Sims, 1994; Moreno & Mayer, 1999), in the form of spatial contiguity, and the split-attention effect (Mayer & Moreno, 1998; Yeung, Jin, & Sweller, 1997) into the study; for the treatment group. Because the game is visual and will seen on a computer screen, and the navigation map (the floor plan) given to the treatment group, also visual but in printed format, will be spatially separate from the screen, cognitive load issues as described by both the contiguity effect and the split-attention effect will be imposed. This study will not examine the impact of this added load, and how it might influence learning outcomes, possibly offsetting the benefits of the graphical scaffolding (the navigation map).

Delimitations

All participants will be undergraduate students of a tier-1 university; one of the top one hundred universities in the United States. This suggests that the sample will not easily generalize to a larger population. Second, since participants are all volunteers, it is likely they enjoy playing video games. Therefore, they represent only the video game playing population, and study results cannot be generalized to those who are less inclined to play or to volunteer to play video games. A third delimitation is the time period of the study; summer. During summer, a large portion of
the student population is not on campus. Therefore, those who respond to the flyer, or other marketing means for soliciting study participants, will not be a true representation of the full student population. Combined, these delimitations suggest that the sample enlisted for this study will be bar generalization beyond a narrow population.

Organization of the Report

Chapter one provides an overview of the study with a brief introduction and background for the topic, the problem being addressed, the significance of the study, the hypotheses that will be tested, an overview of the methodology of the experiments, and assumptions, limitations, and delimitations related to the study. Chapter two is the literature review of the domains that inform the current research: cognitive load theory, games and simulations, assessment of problem-solving, and scaffolding. Chapter three describes the study’s methodology, with discussions of the population, the sample, the study, the instruments, the procedures, and the proposed data analysis methods.
CHAPTER II: LITERATURE REVIEW

The literature review includes information on four areas relevant to the research topic: cognitive load theory, games and simulations, assessment of problem solving, and scaffolding. The cognitive load section is comprised of an introduction to cognitive load, followed by discussions of working and long-term memory, schema development, and mental models and the role of reflection and elaboration. Next, under cognitive load theory, is a discussion of meaningful learning, including the role of metacognition and cognitive strategies, mental effort and persistence, goals and related theories, self-efficacy and several related theories and topics, and problem solving, with a discussion of O’Neil’s Problem Solving model (O’Neil, 1999). Types of cognitive load are then discussed—specifically, intrinsic cognitive load, germane cognitive load, and extraneous cognitive load—as well as learner control as informed by cognitive load theory. The cognitive load theory section ends with a summary of the section.

Following cognitive load theory is a discussion of games and simulations, beginning with defining games, simulations, and simulation-games. Next the motivational aspects of games is introduced with a discussion of the major characteristics of motivation: fantasy, control and manipulation, challenge and complexity, curiosity, competition, feedback, and fun. The final section under games and simulations is learning and other outcomes, which ends with a short discussion of the role of reflection and debriefing. Last is a summary of games and simulations.

The third section of chapter two is the assessment of problem solving focused on the three constructs established in O’Neil’s Problem Solving model (O’Neil, 1999): measurement of content understanding, measurement of problem solving strategies, and measurement of self-regulation. The section ends in with a summary of problem solving assessment.
The fourth and final section, scaffolding, begins with a general discussion of scaffolding, followed by a review of the literature on a type of scaffolding relevant to this study, graphical scaffolding. Within graphical scaffolding, navigation maps are examined, along with the relationship of the contiguity effect and the split attention effect to inclusion of a navigation map. The section ends in with a summary of scaffolding. The chapter ends with a summary of chapter two.

Cognitive Load Theory

Cognitive load theory, which began in the 1980s and underwent substantial development and expansion in the 1990s (Paas, Renkl, & Sweller, 2003), is concerned with the development of instructional methods aligned with the learners’ limited cognitive processing capacity, to stimulate their ability to apply acquired knowledge and skills to new situations (i.e., transfer). Brunken, Plass, and Leutner (2003) argued that cognitive load theory is based on several assumptions regarding human cognitive architecture: the assumption of a virtually unlimited capacity of long-term memory, schema theory of mental representations of knowledge, and limited-processing capacity assumptions of working memory (Brunken et al., 2003). Cognition is the intellectual processes through which information is obtained, represented mentally, transformed, stored, retrieved, and used. Cognitive load theory is based on the idea that a cognitive architecture exists consisting of a limited working memory, with partly independent processing units for visual-spatial and auditory-verbal information (Mayer & Moreno, 2003), and these structures interact with a comparatively unlimited long-term memory (Mousavi, Low, & Sweller, 1995).

Cognitive load is the total amount of mental activity imposed on working memory at an instance in time (Chalmers, 2003; Cooper, 1998; Sweller and Chandler, 1994, Yeung, 1999).
Researchers have proposed that working memory limitations can have an adverse effect on learning (Sweller and Chandler, 1994, Yeung, 1999). According to Paas, Tuovinen, Tabbers, & Van Gerven, (2003), *cognitive load* can be defined as a multidimensional construct representing the load that performing a particular task imposes on the learner’s cognitive system. The construct has a causal dimension reflecting the interaction between task and learner characteristics, and an assessment dimension reflecting the measurable concepts of mental load, mental effort, and performance (Paas et al., 2003). Cognitive load is a theoretical construct, describing the internal processes of information processing that cannot be observed directly (Brunken et al., 2003).

**Working Memory**

*Working memory* refers to the limited capacity for holding information in mind for several seconds in the context of cognitive activity (Gevins et al., 1998). According to Brunken et al. (2003), the Baddeley (1986) model of working memory assumes the existence of a *central executive* that coordinates two slave systems, a *visuospatial sketchpad* for visuospatial information such as written text or pictures, and a *phonological loop* for phonological information such as spoken text or music (Baddeley, 1986, Baddeley & Logie, 1999). Both slave systems are limited in capacity and independent from one another so that the processing capacities of one system cannot compensate for lack of capacity in the other (Brunken et al., 2003).

**Long-Term Memory**

According to Paas et al. (2003), working memory, in which all conscious cognitive processing occurs, can handle only a very limited number of novel interacting elements; possibly no more than two or three. In contrast, long-term memory has an unlimited, permanent capacity
(Tennyson & Breuer, 2002) and can contain vast numbers of schemas—cognitive constructs that incorporate multiple elements of information into a single element with a specific function (Paas et al., 2003). Noyes and Garland (2003) contended that information that is not held in working memory will need to be retained by the long-term memory system. Storing more knowledge in long-term memory reduces the load on working memory, which results in a greater capacity being made available for active processing.

According to cognitive load theory, multiple elements of information can be chunked as single elements in cognitive schema (Chalmers, 2003), and through repeated use can become automated. Automated information, developed over hundreds of hours of practice (Clark, 1999), can be processed without conscious effort, bypass working memory during mental processing, thereby circumventing the limitations of working memory (Clark 1999; Mousavi et al., 1995). Consequently, the primary goals of instruction are the construction (chunking) and automation of schemas (Paas et al., 2003).

Schema Development

Schema is defined as a cognitive construct that permits people to treat multiple sub-elements of information as a single element, categorized according to the manner in which it will be used (Kalyuga, Chandler, & Sweller, 1998). Schemas are generally thought of as ways of viewing the world and, in a more specific sense, ways of incorporating instruction into our cognition. Schema acquisition is a primary learning mechanism. Piaget proposed that learning is the result of forming new schemas and building upon previous schemas (as cited in Chalmers, 2003). Schemas have the functions of storing information in long-term memory and of reducing working memory load by permitting people to treat multiple elements of information as a single element (Kalyuga, et al., 1998; Mousavi et al., 1995).
With schema use, a single element in working memory might consist of a large number of lower level, interacting elements which, if processed individually, might have exceeded the capacity of working memory (Paas et al., 2003). If a schema can be brought into working memory in automated form, it will make limited demands on working memory resources, leaving more resources available to search for a possible solution problem (Kalyuga et al., 1998). Controlled use of schemas requires conscious effort, and therefore, working memory resources. However, after being sufficiently practiced, schemas can operate under automatic, rather than controlled, processing. Automatic processing of schemas requires minimal working memory resources and allows for problem solving to proceed with minimal effort (Kalyuga, Ayers, Chandler, & Sweller, 2003; Kalyuga et al., 1998; Paas et al., 2003).

**Mental Models**

*Mental models* explain human understanding of external reality, translating reality into internal representations and utilizing them in problem solving (Park & Gittelman, 1995). According to Allen (1997), mental models are usually considered the way in which people model processes. This emphasis on process distinguishes mental models from other types of cognitive organizers such as schemas. A mental model synthesizes several steps of a process and organizes them as a unit. A mental model does not have to represent all of the steps which compose the actual process (Allen, 1997). Mental models may be incomplete and may even be internally inconsistent. Models of mental models are termed *conceptual models*. Conceptual models include: metaphor; surrogates; mapping, task-action grammars, and plans. Mental model formation depends heavily on the conceptualizations that individuals bring to a task (Park & Gittelman, 1995).
Elaboration and Reflection

Elaboration and reflection are processes involved to the development of schemas and mental models. Elaborations are used to develop schemas whereby nonarbitrary relations are established between new information elements and the learner’s prior knowledge (van Merrienboer, Kirshner, & Kester, 2003). Elaboration consists of the creation of a semantic event that includes the to-be-learned items in an interaction (Kees & Davies, 1990). With reflection, learners are encouraged to consider their problem-solving process and to try to identify ways of improving it (Atkinson, Renkl, & Merrill, 2003). Reflection is reasoned and conceptual, allowing the thinker to consider various alternatives (Howland, Laffey, & Espinosa, 1997). According to Chi (2000) the self-explanation effect (aka reflection or elaboration) is a dual process that involves generating inferences and repairing the learner’s own mental model.

Meaningful Learning

Meaningful learning is defined as deep understanding of the material, which includes attending to important aspects of the presented material, mentally organizing it into a coherent cognitive structure, and integrating it with relevant existing knowledge (Mayer & Moreno, 2003). Meaningful learning is reflected in the ability to apply what was taught to new situations; problem solving transfer. Meaningful learning results in an understanding of the basic concepts of the new material through its integration with existing knowledge (Davis, & Wiedenbeck, 2001).

According to assimilation theory, there are two kinds of learning: rote learning and meaningful learning. Rote learning occurs through repetition and memorization. It can lead to successful performance in situations identical or very similar to those in which a skill was initially learned. However, skills gained through rote learning are not easily extensible to other
situations, because they are not based on deep understanding of the material learned. Meaningful learning, on the other hand, equips the learner for problem solving and extension of learned concepts to situations different from the context in which the skill was initially learned (Davis, & Wiedenbeck, 2001; Mayer, 1981). Meaningful learning takes place when the learner draws connections between the new material to be learned and related knowledge already in long-term memory, known as the assimilative context (Ausubel, 1963; Davis, & Wiedenbeck, 2001).

Meaningful learning requires mental effort. According to Clark (2003b), “mindful” mental effort requires instructional messages (feedback) that point out the novel elements of the to-be-learned material and must emphasize the need to work hard. Instructional messages must present be concrete and challenging, yet achievable, learning and performance goals. The following sections address the majority of these topics.

Metacognition

Metacognition, or the management of cognitive processes, involves goal-setting, strategy selection, attention, and goal checking (Jones, Farquhar, & Surry, 1995). According to Harp and Mayer (1998), many cognitive models include the executive processes of selecting, organizing, and integrating. Selecting involves paying attention to the relevant pieces of information. Organizing involves building internal connections among the selected pieces of information, such as causal chains. Integrating involves building external connections between the incoming information and prior knowledge existing in the learner’s long-term memory (Harp & Mayer, 1998).

Cognitive strategies. Cognitive strategies include rehearsal strategies, elaboration strategies, organization strategies, affective strategies, and comprehension monitoring strategies. These strategies are cognitive events that describe the way in which we process information
Metacognition is a type of cognitive strategy that has executive control over other cognitive strategies. Prior experience in solving similar tasks and using various strategies will affect the selection of a cognitive strategy (Jones et al., 1995).

**Mental Effort and Persistence**

*Mental effort* is the aspect of cognitive load that refers to the cognitive capacity that is actually allocated to accommodate the demands imposed by a task; thus, it can be considered to reflect the actual cognitive load. Mental effort, relevant to the task and material, appears to be the feature that distinguishes between mindless or shallow processing on the one hand, and mindful or deep processing, on the other. Little effort is expended when processing is carried out automatically or mindlessly (Salomon, 1983). *Motivation* generates the mental effort that drives us to apply our knowledge and skills. According to Clark (2003d), “Without motivation, even the most capable person will not work hard” (p. 21). However, mental effort investment and motivation should not be equated. Motivation is the driving force, but for learning to actually take place, some specific relevant mental activity needs to be activated. This activity is assumed to be the employment of nonautomatic effortful elaborations (Salomon, 1983).

**Goals**

Motivation influences both attention and maintenance processes (Tennyson & Breuer, 2002), generating the mental effort that drives us to apply our knowledge and skills. Easy goals are not motivating (Clark, 2003d). Additionally, it has been shown that individuals without specific goals (such as “do your best”), do not work as long as those with specific goals, such as “list 70 contemporary authors” (Thompson et al., 2002; Locke & Latham, 2003).

*Goal setting theory*, according to Thompson et al. (2002), is based on the simple premise that people exert effort toward accomplishing goals. Goals may increase performance as long as
a few factors are taken into account, such as acceptance of the goal, feedback on progress toward the goal, a goal that is appropriately challenging, and a goal that is specific (Thompson et al., 2002). Goal setting guides the cognitive strategies in a certain direction. Goal checking are those monitoring processes that check to see if the goal has been accomplished, or if the selected strategy is working as expected. The monitoring process is active throughout an activity and constantly evaluates the success of other processes. If a cognitive strategy appears not to be working, an alternative may then be selected (Jones et al., 1995).

*Goal orientation theory* is concerned with the prediction that those with high performance goals and a perception of high ability will exert great effort, and those with low ability perceptions will avoid effort (Miller et al., 1996). Once we are committed to a goal, we must make a plan to achieve the goal. A key element of all goal-directed planning is our personal assessment of the necessary skills and knowledge required to achieve a goal. A key aspect of self-efficacy assessment is our perception of how novel and difficult the goal is to achieve. The ongoing results of this analysis are hypothesized to determine how much effort we will invest in a goal (Clark, 1999).

**Self-Efficacy**

A number of items affect motivation and mental effort. In an extensive review of motivation theories, Eccles and Wigfield (2002) discuss Brokowski and colleagues’ motivation model that highlights the interaction of the following cognitive, motivational, and self-processes: knowledge of oneself (including goals and self perceptions); domain-specific knowledge; strategy knowledge; and personal-motivational states (including attributional beliefs, self-efficacy, and intrinsic motivation). In a study of college freshmen, Livengood (1992) found that psychological variables (i.e., effort/ability reasoning, goal choice, and confidence) are strongly
associated with academic participation and satisfaction. And Corno and Mandinah (1983) commented that students in classrooms actively engage in a variety of cognitive interpretations of their environments and themselves which, in turn, influence the amount and kind of effort they will expend on classroom tasks.

According to Clark (1999), the more novel the goal is perceived to be, the more effort we will invest until we believe we might fail. At the point where failure expectations begin, effort is reduced as we “unchoose” the goal to avoid a loss of control. This inverted U relationship suggests that mental effort problems include two broad forms: over confidence and under confidence (Clark, 1999). Therefore, the level of mental effort necessary to achieve goals can be influenced by adjusting perceptions of goal novelty and the effectiveness of the strategies people use to achieve goals (Clark, 1999).

**Self-efficacy** is defined as one’s belief about one’s ability to successfully carry out particular behaviors (Davis, & Wiedenbeck, 2001). **Perceived self-efficacy** refers to subjective judgments of how well one can execute a particular course of action, handle a situation, learn a new skill or unit of knowledge, and the like (Salomon, 1983). Perceived self-efficacy has much to do with how a class of stimuli is perceived. The more demanding the stimuli is perceived to be, the less efficacious the perceiver would feel about it. Conversely, the more familiar, easy, or shallow it is perceived, the more efficacious the perceiver would feel about handling it. It follows that perceived self efficacy should be related to the perception of demand characteristics (the latter includes the perceived worthwhileness of expending effort), and that both should affect effort investment jointly (Salomon, 1983).

**Self-efficacy theory.** Self-efficacy theory predicts that students work harder on a learning task when they judge themselves as capable versus when they lack confidence in their ability to
learn. Self-efficacy theory also predicts that students understand the material better when they have high self-efficacy than when they have low self-efficacy (Mayer, 1998). Effort is primarily influenced by specific and detailed self-efficacy assessments of the knowledge required to achieve tasks (Clark, 1999). A person’s belief about whether he or she has the skills required to succeed at a task is possibly the most important factor in the quality and quantity of mental effort that person will invest (Clark, 2003d).

**Expectancy-Value Theory.** Related to self-efficacy theories, expectancy-value theories propose that the probability of behavior depends on the value of the goal and the expectancy of obtaining that goal (Coffin & MacIntyre, 1999). Expectancies refer to beliefs about how we will do on different tasks or activities, and values have to do with incentives or reasons for doing the activity (Eccles & Wigfield, 2002). From the perspective of expectancy-value theory, goal hierarchies (the importance and the order of goals) also could be organized around aspects of task value. Different goals may be perceived as more or less useful, or more or less interesting. Eccles and Wigfield (2002) suggest that the relative value attached to the goal should influence its placement in a goal hierarchy, as well as the likelihood a person will try to attain the goal and therefore exert mental effort. Clark (2003b) commented that the more instruction supports a student’s interest and utility value for instructional goals, as well as the student’s self-efficacy for the course, the more likely the student will become actively engaged in the instruction and persist when faced with distractions.

**Task value.** Task value refers to an individual’s perceptions of how interesting, important, and useful a task is (Coffin & MacIntyre, 1999). Interest in, and perceived importance and usefulness of, a task comprise important dimensions of task value (Bong, 2001). Citing Eccles’ expectancy-value model, Townsend and Hicks (1997) stated that the perception of task
value is affected by a number of factors, including the intrinsic value of a task, its perceived utility value, and its attainment value. Thus, engagement in an academic task may occur because of interest in the task, or because the task is required for advancement in some other area (Townsend & Hicks, 1997). According to Corno and Mandinah (1983), a task linked to one’s aspirations (a “self-relevant” task) is a key condition for task value (Corno & Mandinah, 1983).

**Problem-Solving**

_Problem solving_ is the intellectual skill to propose solutions to previously unencountered problem situations (Tennyson & Breuer, 2002). A problem exists when a problem solver has a goal but does not know how to reach it, so problem solving is mental activity aimed at finding a solution to a problem (Baker & Mayer, 1999). Problem solving is associated with situations dealing with previously unencountered problems, requiring the integration of knowledge to form new knowledge (Tennyson & Breuer, 2002). A first condition of problem solving involves the differentiation process of selecting knowledge that is currently in storage using known criteria. Concurrently, this selected knowledge is integrated to form a new knowledge. Cognitive complexity within this condition focuses on elaborating the existing knowledge base (Tennyson & Breuer, 2002). Problem solving may also involve situations requiring the construction of knowledge by employing the entire cognitive system. Therefore, the sophistication of a proposed solution is a factor of the person’s knowledge base, level of cognitive complexity, higher-order thinking strategies, and intelligence (Tennyson & Breuer, 2002). According to Mayer (1998), successful problem solving depends on three components—skill, metaskill, and will—and each of these components can be influenced by instruction. Metacognition—in the form of metaskill—is central in problem solving because it manages and coordinates the other components (Mayer, 1998).
O’Neil’s Problem Solving model. O’Neil’s Problem Solving model (O’Neil, 1999, see figure 1 below) is based on Mayer and Wittrock’s (1996) conceptualization: “Problem solving is cognitive processing directed at achieving a goal when no solution method is obvious to the problem solver” (p. 47). This definition is further analyzed into components suggested by the expertise literature: content understanding or domain knowledge, domain-specific problem-solving strategies, and self-regulation (see, e.g., O’Neil, 1999, in press). Self-regulation is composed of metacognition (planning and self-checking) and motivation (effort and self-efficacy). Thus, in the specifications for the construct of problem solving, to be a successful problem solver, “one must know something (content knowledge), possess intellectual tricks (problem-solving strategies), be able to plan and monitor one’s progress towards solving the problem (metacognition), and be motivated to perform” (effort and self-efficacy; O’Neil, 1999, pp. 255-256).

Figure 1. O’Neil’s Problem Solving Model

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In problem solving, the skeletal structures are instantiated in content domains, so that a set of structurally similar models for thinking about problem solving is applied to science, mathematics, and social studies. These models may vary in the explicitness of problem representations, the guidance about strategy (if any), the demands of prior knowledge, the focus on correct procedures, the focus on convergent or divergent responses, and so on (Baker & Mayer, 1999). Domain-specific aspects of problem solving (e.g., the part that is unique to geometry, geology, or genealogy) involve the specific content knowledge, the specific procedural knowledge in the domain, any domain-specific cognitive strategies (e.g., geometric proof, test, and fix), and domain specific discourse (O’Neil, 1998, as cited in Baker & Mayer, 1999). Both domain-independent and domain-dependent knowledge are usually essential for problem solving. Domain-dependent analyses focus on the subject matter as the source of all needed information (Baker & O’Neil, 2002).

Types of Cognitive Load

Cognitive load researchers have identified up to three types of cognitive load. All agree on **intrinsic cognitive load** (Brunken et al., 2003; Paas et al., 2003; Renkl, & Atkinson, 2003), which is the load involved in the process of learning; the load required by metacognition, working memory, and long-term memory. Another load agreed upon is **extraneous cognitive load**. However, it is the scope of this load that is in dispute. To some researchers, any cognitive load that is not intrinsic cognitive load is extraneous cognitive load. To other researchers, non-intrinsic cognitive load is divided into **germane cognitive load** and extraneous cognitive load. **Germane cognitive load** is the cognitive load required to process the intrinsic cognitive load (Renkl, & Atkinson, 2003). From a non-computer-based perspective, this could include searching a book or organizing notes, in order to process the to-be-learned information. From a
computer-based perspective, this could include the interface and controls a learner must interact with in order to be exposed to, and process, the to-be-learned material. In contrast to germane cognitive load, these researchers see extraneous cognitive load as the load caused by any unnecessary stimuli, such as fancy interface designs or extraneous sounds (Brunken et al., 2003).

For each of the two working memory subsystems (visual/spatial, and auditory/verbal), the total amount of cognitive load for a particular individual under particular conditions is defined as the sum of intrinsic, extraneous, and germane load induced by the instructional materials. Therefore, a high cognitive load can be a result of a high intrinsic cognitive load (i.e., the nature of the instructional content itself). It can, however, also be a result of a high germane cognitive load (i.e., a result of activities performed on the materials that result in a high memory load) or high extraneous cognitive load (i.e., a result of inclusion of unnecessary information or stimuli that result in a high memory load; Brunken et al., 2003).

Low-element interactivity refers to environments where each element can be learned independently of the other elements, and there is little direct interaction between the elements. High-element interactivity refers to environments where there is so much interaction between elements that they cannot be understood until all the elements and their interactions are processed simultaneously. As a consequence, high-element interactivity material is difficult to understand (Paas et al., 2003). Element interactivity is the driver of intrinsic cognitive load, because the demands on working memory capacity imposed by element interactivity are intrinsic to the material being learned. Reduction in intrinsic load can occur only by dividing the material into small learning modules (Paas et al., 2003).

Germane or effective cognitive load is influenced by the instructional design. The manner in which information is presented to learners and the learning activities required of learners are
factors relevant to levels of germane cognitive load. Whereas extraneous cognitive load interferes with learning, germane cognitive load enhances learning (Renkl, & Atkinson, 2003).

Extraneous cognitive load (Renkl, & Atkinson, 2003) is the most controllable load, since it is caused by materials that are unnecessary to instruction. However, those same materials may be important for motivation. Unnecessary items are globally referred to as extraneous. However, another category of extraneous items, seductive details (Mayer, Heiser, & Lonn, 2001), refers to highly interesting but unimportant elements or instructional segments. These segments usually contain information that is tangential to the main themes of a story, but are memorable because they deal with controversial or sensational topics (Schraw, 1998). The seductive detail effect is the reduction of retention caused by the inclusion of extraneous details (Harp & Mayer, 1998) and affects both retention and transfer (Moreno & Mayer, 2000).

Complicating the issue of seductive details is the arousal theory which suggests that adding entertaining auditory adjuncts will make a learning task more interesting, because it creates a greater level of attention so that more material is processed by the learner (Moreno & Mayer, 2000). A possible solution is to leave the seductive details, but guide the learner away from them and to the relevant information (Harp & Mayer, 1998).

While attempting to focus on a mental activity, most of us, at one time or another, have had our attention drawn to extraneous sounds (Banbury, Macken, Tremblay, & Jones, 2001). On the surface, seductive details and auditory adjuncts (such as sound effects or music) seem similar. However, the underlying cognitive mechanisms are quite different. Whereas seductive details seem to prime inappropriate schemas into which incoming information is assimilated, auditory adjuncts seem to overload auditory working memory (Moreno & Mayer, 2000).
According to Brunken et al. (2003), both extraneous and germane cognitive load can be manipulated by the instructional design of the learning material (Brunken et al., 2003).

**Learner Control**

In contrast to more traditional technologies that only deliver information, computerized learning environments offer greater opportunities for interactivity and learner control. These environments can offer simple sequencing and pace control, or they can allow the learner to decide which, and in what order, information will be accessed (Barab, Young, & Wang, 1999). The term navigation refers to a process of tracking one’s position in an environment, whether physical or virtual, to arrive at a desire destination. A route through the environment consists of either a series of locations or a continuous movement along a path (Cutmore et al., 2000). Effective navigation of a familiar environment depends upon a number of cognitive factors. These include working memory for recent information, attention to important cues for location, bearing and motion, and finally, a cognitive representation of the environment which becomes part of a long-term memory, a cognitive map (Cutmore et al., 2000).

**Hypermedia** environments divide information into a network of multimedia nodes connected by various links (Barab, Bowdish, & Lawless, 1997). According to Chalmers (2003), how easily learners become disoriented in a hypermedia environment may be a function of the user interface. One area where disorientation can be a problem is in the use of links. Although links create the advantage of exploration, there is always the chance learners may become lost, not knowing where they were, where they are going, or where they are (Chalmers, 2003). In a virtual 3-D environment, Cutmore et al. (2000) argue that navigation becomes problematic when the whole path cannot be viewed at once and is largely occluded by objects in the environment.
Under these conditions, one cannot simply plot a direct visual course from the start to finish locations. Rather, knowledge of the layout of the space is required (Cutmore et al., 2000).

Message complexity, stimulus features, and additional cognitive demands inherent in hypermedia, such as learner control, may combine to exceed the cognitive resources of some learners (Daniels & Moore, 2000). Dillon and Gabbard (1998) found that novice and lower aptitude students have the greatest difficulty with hypermedia. Children are particularly susceptible to the cognitive demands of interactive computer environments. According to Howland, Laffey, and Espinosa (1997), many educators believe that young children do not have the cognitive capacity to interact and make sense of the symbolic representations of computer environments.

In spite of the intuitive and theoretical appeal of hypertext environments, empirical findings yield mixed results with respect to the learning benefits of learner control over program control of instruction (Niemiec, Sikorski, & Wallberg, 1996; Steinberg, 1989). And six extensive meta-analyses of distance and media learning studies in the past decade have found the same negative or weak results (Bernard, et al, 2003). In reference to distance learning environments, Clark (2003c) argued that when sequencing, contingencies, and learning strategies permit only minimal learner control over pacing, then “except for the most advanced expert learners, learning will be increased” (p. 14).

Summary of Cognitive Load

Cognitive Load Theory is based on the assumptions of a limited working memory with separate channels for auditory and visual/spatial stimuli, and a virtually unlimited capacity long-term memory that stores schemas of varying complexity and level of automation (Brunken et al., 2003). According to Paas et al. (2003), cognitive load refers to the amount of load placed on
working memory. Cognitive load can be reduced through effective use of the auditory and visual/spatial channels, as well as schemas stored in long-term memory. Cognitive load also reflects the measurable concepts of mental load, mental, effort and performance (Paas et al., 2003).

Meaningful learning is defined as deep understanding of the material and is reflected in the ability to apply what was taught to new situations; i.e., problem solving transfer. (Mayer & Moreno, 2003). Meaningful learning requires effective metacognitive skills: the management of cognitive processes (Jones, Farquhar, & Surry, 1995), including selecting relevant information, organizing connections among the pieces of information, and integrating (i.e., building) external connections between incoming information and prior knowledge that exists in long-term memory (Harp & Mayer, 1998). Mental effort refers to the cognitive capacity allocated to a task. Mental effort is affected by motivation, and motivation cannot exist without goals (Clark, 2003d). Goals are further affected by self-efficacy, the belief in one’s ability to successfully carry out a particular behavior (Davis & Wiedenbeck, 2001).

Problem solving is “cognitive processing directed at transforming a given situation into a desired situation when no obvious methods of solution is available to the problem solver” (Baker & Mayer, 1999, p. 272). O’Neil’s Problem Solving model (O’Neil, 1999) defines three core constructs of problem solving: content understanding, problem solving strategies, and self-regulation. Each of these components is further defined with subcomponents. There are three types of cognitive load that can be defined in relationship to a learning or problem solving task: intrinsic cognitive load, germane cognitive load, and extraneous cognitive load.

Intrinsic cognitive load refers to the cognitive load placed on working memory by the to-be-learned material (Paas et al., 2003). Germane cognitive load refers to the cognitive load
required to access and process the intrinsic cognitive load. For example, the problem solving processes that are instantiated in the learning process so that learning can occur (Renkl & Atkinson, 2003). Extraneous cognitive load refers to the cognitive load imposed by stimuli that neither support the learning process (i.e., germane cognitive load) nor are part of the to-be-learned material (i.e., intrinsic cognitive load). A specific form of extraneous cognitive load is seductive details; highly interesting but unimportant elements or instructional segment, that are often used to provide memorable or engaging experiences (Mayer et al., 2001; Schraw, 1998). An important goal of instructional design is to balance intrinsic, germane, and extraneous cognitive loads to support learning outcomes, and to recognize that the specific balance is dependent on a number of factors (Brunen et al., 2003), including the amount of prior knowledge and the need for motivation.

Learner control, which is inherent in interactive computer-based media, allows for control of pacing and sequencing (Barab, Young, & Wang, 1999). It also provides an opportunity for cognitive overload in the form of disorientation; loss of place (Chalmers, 2003). Further, Daniels and Moore (2000) argued that message complexity, stimulus features, and additional cognitive demands inherent in hypermedia (e.g., learner control) may combine to exceed the cognitive resources of some learners. Further, learner control is a potential source for extraneous cognitive load. Ultimately, these issues may be the cause of mixed reviews of learner control (Bernard, et al, 2003; Niemiec, Sikorski, & Wallberg, 1996; Steinberg, 1989).

GAMES AND SIMULATIONS

According to Ricci, Salas, and Cannon-Bowers (1996), “computer-based educational games generally fall into one of two categories: simulation games and video games. Simulation games model a process or mechanism relating task-relevant input changes to outcomes in a
simplified reality that may not have a definite endpoint” (p. 296). Ricci et al. further comment that simulation games “often depend on learners reaching conclusions through exploration of the relation between input changes and subsequent outcomes” (p. 296). Video games, on the other hand, are competitive interactions bound by rules to achieve specified goals that are dependent on skill or knowledge and often involve chance and imaginary settings (Randel, Morris, Wetzel, & Whitehill, 1992).

One of the first problems areas with research into games and simulations is terminology. Many studies that claim to have examined the use of games did not use a game (e.g., Santos, 2002). At best, they used an interactive multimedia that exhibits some of the features of a game, but not enough features to actually be called a game. A similar problem occurs with simulations. A large number of research studies use simulations but call them games (e.g., Mayer et al., 2002). Because the goals and features of games and simulations differ, it is important when examining the potential effects of the two media to be clear about which one is being examined. However, there is little consensus in the education and training literature on how games and simulations are defined.

Games

According to Garris, Ahlers, and Driskell (2002) early work in defining games suggested that there are no properties that are common to all games and that games belong to the same semantic category only because they bear a family resemblance to one another. Betz (1995-1996) argued that a game is being played when the actions of individuals are determined by both their own actions and the actions of one or more actors.

A number of researchers agree that games have rules (Crookall, Oxford, & Saunders, 1987; Dempsey, Haynes, Lucassen, & Casey, 2002; Garris et al., 2002; Ricci, 1994).
Researchers also agree that games have goals and strategies to achieve those goals (Crookall & Arai, 1995; Crookall et al. 1987; Garris et al., 2002; Ricci, 1994). Many researchers also agree that games have competition (e.g., Dempsey et al., 2002) and consequences such as winning or losing (Crookall et al., 1987; Dempsey et al., 2002).

Betz (1995-1996) further argued that games simulate whole systems, not parts, forcing players to organize and integrate many skills. Students will learn from whole systems by their individual actions, individual action being the student’s game moves. Crookall et al. (1987) also noted that a game does not intend to represent any real-world system; it is a “real” system in its own right. According to Duke (1995), games are situation specific. If well designed for a specific situation or condition, the same game should not be expected to perform well in a different environment.

Simulations

In contrast to games, Crookall and Saunders (1989) viewed a simulation as a representation of some real-world system that can also take on some aspects of reality. Similarly, Garris et al. (2002) wrote that key features of simulations are they represent real-world systems, and Henderson, Klemes, and Eshet (2000) commented that a simulation attempts to faithfully mimic an imaginary or real environment that cannot be experienced directly, for such reasons as cost, danger, accessibility, or time. Berson (1996) also argued that simulations allow access to activities that would otherwise be too expensive, dangerous, or impractical for a classroom. Lee (1999) added that a simulation is defined as a computer program that relates elements together through cause and effect relationships.

Thiagarajan (1998) argued that simulations do not reflect reality; they reflect someone’s model of reality. According to Thiagarajan, a simulation is a representation of the features and
behaviors of one system through the use of another. At the risk of introducing a bit more ambiguity, Garris et al. (2002) proposed that simulations can contain game features, which leads to the final definition: simulation-games.

**Simulation-Games**

Garris et al. (2002) argued that it is possible to consider games and simulations as similar in some respects, keeping in mind the key distinction that simulations propose to represent reality and games do not. Combining the features of the two media, Rosenorn and Kofoed (1998) described simulation/gaming as a learning environment where participants are actively involved in experiments, for example, in the form of role-plays, or simulations of daily work situations, or developmental scenarios.

This paper will use the definitions of games, simulations, and simulation-games as defined by Gredler (1996), which combine the most common features cited by the various researchers, and yet provide clear distinctions between the three media. According to Gredler,

Games consist of rules that describe allowable player moves, game constraints and privileges (such as ways of earning extra turns), and penalties for illegal (nonpermissable) actions. Further, the rules may be imaginative in that they need not relate to real-world events (p. 523).

This definition is in contrast to a simulation, which Gredler (1996) defines as “a dynamic set of relationships among several variables that (1) change over time and (2) reflect authentic causal processes” (p. 523). In addition, Gredler describes games as linear and simulations as non-linear, and games as having a goal of winning while simulations have a goal of discovering causal relationships. Gredler also defines a mixed metaphor referred to as *simulation games* or
gaming simulations, which is a blend of the features of the two interactive media: games and simulations.

Motivational Aspects of Games

According to Garris et al. (2002), motivated learners are easy to describe; they are enthusiastic, focused and engaged, they are interested in and enjoy what they are doing, they try hard, and they persist over time. Furthermore, they are self-determined and driven by their own volition rather than external forces (Garris et al., 2002). Ricci et al. (1996) defined motivation as “the direction, intensity, and persistence of attentional effort invested by the trainee toward training” (p. 297). Similarly, according to Malouf (1987-1988), continuing motivation is defined as returning to a task or a behavior without apparent external pressure to do so when other appealing behaviors are available. And more simply, Story and Sullivan (1986) commented that the most common measure of continuing motivation is whether a student returns to the same task at a later time.

With regard to video games, Asakawa and Gilbert (2003) argued that, without sources of motivation, players often lose interest and drop out of a game. However, there seems little agreement among researchers as to what those sources are—the specific set of elements or characteristics that lead to motivation in any learning environment, and particularly with educational games. According to Rieber (1996) and McGrenere (1996), motivational researchers have offered the following characteristics as common to all intrinsically motivating learning environments: challenge, curiosity, fantasy, and control (Davis & Wiedenbeck, 2001; Lepper & Malone, 1987; Malone, 1981; Malone & Lepper, 1987). Malone (1981) and others also included fun as a criteria for motivation.
For interactive games, Stewart (1997) added the motivational importance of goals and outcomes. Locke and Latham (1990) also commented on the robust findings with regards to goals and performance outcomes. They argued that clear, specific goals allow the individual to perceive goal-feedback discrepancies, which are seen as crucial in triggering greater attention and motivation. Clark (2001) further argued that motivation cannot exist without goals. The following sections will focus on fantasy, control and manipulation, challenge and complexity, curiosity, competition, feedback, and fun. The role of goals was discussed previously in this proposal in fostering effort and motivation was discussed earlier in this document.

*Fantasy*

Research suggests that material may be learned more readily when presented in an imagined context that interests the learner than when presented in a generic or decontextualized form (Garris et al., 2002). Malone and Lepper (1987) defined *fantasy* as an environment that evokes “mental images of physical or social situations that do not exist” (p. 250). Rieber (1996) commented that fantasy is used to encourage learners to imagine they are completing an activity in a context in which they are really not present. However, Rieber described two types of fantasies: endogenous and exogenous. *Endogenous* fantasy weaves relevant fantasy into a game, while *exogenous* simply sugar coat a learning environment with fantasy. An example of an endogenous fantasy would be the use of a laboratory environment to learn chemistry, since this environment is consistent with the domain. An example of an exogenous environment would be a using a hangman game to learn spelling, because hanging a person has nothing to do with spelling. Rieber (1996) noted that endogenous fantasy, not exogenous fantasy, is important to intrinsic motivation, yet exogenous fantasies are a common and popular element of many educational games.
According to Malone and Lepper (1987), fantasies can offer analogies or metaphors for real-world processes that allow the user to experience phenomena from varied perspectives. A number of researchers (Anderson and Pickett, 1978; Ausubal, 1963; Malone and Lepper, 1978; Malone and Lepper, 1987; Singer, 1973) argued that fantasies in the form of metaphors and analogies provide learners with better understanding by allowing them to relate new information to existing knowledge. According to Davis and Wiedenbeck (2001), metaphor also helps learners to feel directly involved with objects in the domain so the computer and interface become invisible.

**Control and Manipulation**

Hannafin and Sullivan (1996) define control as the exercise of authority or the ability to regulate, direct, or command something. Control, or self-determination, promotes intrinsic motivation because learners are given a sense of control over the choices of actions they may take (deCharms, 1986; Deci, 1975; Lepper & Greene, 1978). Furthermore, control implies that outcomes depend on learners’ choices and, therefore, learners should be able to produce significant effects through their own actions (Davis, & Wiedenbeck, 2001). According to Garris et al. (2002), games evoke a sense of personal control when users are allowed to select strategies, manage the direction of activities, and make decisions that directly affect outcomes, even if those actions are not instructionally relevant.

However, Hannafin & Sullivan (1996) warned that research comparing the effects of instructional programs that control all elements of the instruction (program control) and instructional programs in which the learner has control over elements of the instructional program (learner control) on learning achievement has yielded mixed results. Dillon and Gabbard (1998) commented that novice and lower aptitude students have greater difficulty when
given control, compared to experts and higher aptitude students, and Niemiec, Sikorski, and Walberg (1996) argued that control does not appear to offer any special benefits for any type of learning or under any type of condition.

**Challenge and complexity**

Challenge, also referred to as effectance, competence, or mastery motivation (Bandura, 1977; Csikszentmihalyi, 1975; Deci, 1975; Harter, 1978; White, 1959), embodies the idea that intrinsic motivation occurs when there is a match between a task and the learner’s skills. The task should not be too easy or too hard, because in either case, the learner will lose interest (Clark, 1999; Malone & Lepper, 1987). Clark (1999) describes this effect as an inverted U-shaped relationship with lack of effort existing on either side of difficulty ranging from too easy to too hard. Stewart (1997) similarly commented that games that are too easy will be dismissed quickly. According to Garris et al. (2002), there are several ways in which an optimal level of challenge can be obtained. Goals should be clearly specified, yet the probability of obtaining that goal should be uncertain, and goals must also be meaningful to the individual. Garris and colleagues argued that linking activities to valued personal competencies, embedding activities within absorbing fantasy scenarios, or engaging competitive or cooperative motivations could serve to make goals meaningful.

**Curiosity**

According to Rieber (1996), challenge and curiosity are intertwined. Curiosity arises from situations in which there is complexity, incongruity, and discrepancy (Davis & Wiedenbeck, 2001). *Sensory curiosity* is the interest evoked by novel situations and *cognitive curiosity* is evoked by the desire for knowledge (Garris et al. 2002). Cognitive curiosity motivates the learner to attempt to resolve the inconsistency through exploration (Davis, & Wiedenbeck, 2001).
Curiosity is identified in games by unusual visual or auditory effects, and by paradoxes, incompleteness, and potential simplifications (Westbrook & Braithwaite, 2002). Curiosity is the desire to acquire more information, which is a primary component of the players’ motivation to learn how to operate the game (Westbrook & Braithwaite, 2001).

Malone and Lepper (1987) noted that curiosity is one of the primary factors that drive learning and is related to the concept of mystery. Garris et al. (2002) commented that curiosity is internal, residing in the individual, and mystery is an external feature of the game itself. Thus, mystery evokes curiosity in the individual, and this leads to the question of what constitutes mystery (Garris et al. 2002). Research suggests that mystery is enhanced by incongruity of information, complexity, novelty, surprise, and violation of expectations (Berlyne, 1960), incompatibility between ideas and inability to predict the future (Kagan, 1972), and information that is incomplete and inconsistent (Malone & Lepper, 1987).

Competition

Studies on competition with games and simulations have mixed results, due to preferences and reward structures. A study by Porter, Bird, and Wunder (1990-1991) examining competition and reward structures found that the greatest effects of reward structure were seen in the performance of those with the most pronounced attitudes toward either competition or cooperation. The results also suggested that performance was better when the reward structure matched the individual’s preference. According to the authors, implications are that emphasis on competition will enhance the performance of some learners but will inhibit the performance of others (Porter et al., 1990-1991).

Yu (2001) investigated the relative effectiveness of cooperation with and without inter-group competition in promoting student performance, attitudes, and perceptions toward subject matter studied, computers, and interpersonal context. With fifth-graders as participants, Yu
found that cooperation without inter-group competition resulted in better attitudes toward the subject matter studies and promoted more positive inter-personal relationships both within and among the learning groups, as compared to competition (Yu, 2001). The exchange of ideas and information both within and among the learning groups also tended to be more effective and efficient when cooperation did not take place in the context of inter-group competition (Yu, 2001).

**Feedback**

Feedback within games can be provided for learners to quickly evaluate their progress against the established game goal. This feedback can take many forms, such as textual, visual, and aural (Rieber, 1996). According to Ricci et al. (1996), within the computer-based game environment, feedback is provided in various forms including audio cues, score, and remediation immediately following performance. The researchers argued that these feedback attributes can produce significant differences in learner attitudes, resulting in increased attention to the learning environment. Clark (2003a) argued that, for feedback to be effective, it must be based on “concrete learning goals that are clearly understood” (p. 18) and that it describe the gap between the learner’s current performance and the goal. Additionally, the feedback must not be focused on the failure to achieve the goal (Clark, 2003a).

**Fun**

Quinn (1994, 1997) argued that for games to benefit educational practice and learning, they need to combine fun elements with aspects of instructional design and system design that include motivational, learning, and interactive components. According to Malone (1981) three elements (fantasy, curiosity, and challenge) contribute to the fun in games. While fun has been cited as important for motivation and, ultimately, for learning, there is little empirical evidence
supporting the concept of *fun*. It is possible that fun is not a construct but, rather, represents other concepts or constructs. Relevant alternative concepts or constructs include play, engagement, and flow.

*Play* is entertainment without fear of present or future consequences; it is fun (Resnick & Sherer, 1994). According to Rieber, Smith, and Noah (1998), play describes an intense learning experience in which both adults and children voluntarily devote enormous amounts of time, energy, and commitment and, at the same time, derive great enjoyment from the experience; this is termed *serious play* (Rieber et al., 1998). Webster et al. (1993) found that labeling software training as play showed improved motivation and performance. According to Rieber and Matzko (2001), serious play is an example of an optimal life experience.

Csikszentmihalyi (1975; 1990) defines an *optimal experience* as one in which a person is so involved in an activity that nothing else seems to matter; termed *flow* or a *flow experience*. When completely absorbed in and activity, he or she is ‘carried by the flow,’ hence the origin of the theory’s name (Rieber and Matzko, 2001). Rieber and Matzko (2001) offered a broader definition of flow, commenting that a person may be considered in flow during an activity when experiencing one or more of the following characteristics: Hours pass with little notice; challenge is optimized; feelings of self-consciousness disappear; the activity’s goals and feedback are clear; attention is completely absorbed in the activity; one feels in control; and one feels freed from other worries (Rieber & Matzko, 2001). According to Davis and Wiedenbeck (2001), an activity that is highly intrinsically motivating can become all-encompassing to the extent that the individual experiences a sense of total involvement, losing track of time, space, and other events. Davis and Wiedenbeck also argued that the interaction style of a software package is expected to have a significant effect on intensity of flow. It should be noted that
Rieber and Matzko (2001) have contended that play and flow differ in one respect; learning is an expressed outcome of serious play but not of flow.

Engagement is defined as a feeling of directly working on the objects of interest in the worlds rather than on surrogates. According to Davis and Wiedenbeck (2001), this interaction or engagement can be used along with the components of Malone and Lepper’s (1987) intrinsic motivation model to explain the effect of an interaction style on intrinsic motivation, or flow. Garris et al. (2002) commented that training professionals are interested in the intensity of involvement and engagement that computer games can invoke, to harness the motivational properties of computer games to enhance learning and accomplish instructional objectives.

Learning and Other Outcomes for Games

Results from studies reporting on the performance and learning outcomes from games are mixed. This section is subdivided into four discussions. First will be a discussion of studies indicating positive results regarding performance and learning outcomes attributed to games and simulations. Second will be a discussion of studies indicating negative or null results regarding performance and learning outcomes attributed to games and simulations. Third will be a discussion of the relationship of instructional design to effectiveness of educational games and simulations as an explanation of mixed results from game and simulation studies. Last will be a discussion of reflection and debriefing as a necessary component to learning, with specific references to the learning instantiated in games and simulations.

Positive Outcomes from Games and Simulations

Simulations and games have been cited as beneficial for a number of disciplines and for a number of educational and training situations, including aviation training (Salas, Bowers, & Rhodenizer, 1998), aviation crew resource management (Baker, Prince, Shrestha, Oser, & Salas,
1993), military mission preparation (Spiker & Nullmeyer, n.d.), laboratory simulation (Betz, 1995-1996), chemistry and physics education (Khoo & Koh, 1998), urban geography and planning (Adams, 1998; Betz, 1995-1996), farm and ranch management (Cross, 1993), language training (Hubbard, 1991), disaster management (Stolk, Alexandrian, Gros, & Paggio, 2001), and medicine and health care (Westbrook & Braithwaite, 2001; Yair, Mintz, & Litvak, 2001). For business, games and simulations have been cited as useful for teaching strategic planning (Washburn & Gosen, 2001; Wolfe & Roge, 1997), finance (Santos, 2002), portfolio management (Brozik, & Zapalska, 2002), marketing (Washburn & Gosen), knowledge management (Leemkuil, de Jong, de Hoog, & Christoph, 2003), and media buying (King & Morrison, 1998).

In addition to teaching domain-specific skills, games have been used to impart more generalizable skills. Since the mid 1980s, a number of researchers have used the game Space Fortress, a 2-D, simplistic arcade-style game, with a hexagonal “fortress” in the center of the screen surrounded by two concentric hexagons, and a space ship, to improve spatial and motor skills that transfer far outside gameplay, such as significantly improving the results of fighter pilot training (Day, Arthur, and Gettman, 2001). Also, in a series of five experiments, Green and Bavelier (2003) showed the potential of video games to significantly alter visual selection attention. Similarly, Greenfield, DeWinstanley, Kilpatrick, & Kaye (1994) found, with experiments involving college students, that video game practice could significantly alter the participants’ strategies of spatial attentional deployment.

According to Ricci et al. (1996), results of their study provided evidence that computer-based gaming can enhance learning and retention of knowledge. They further commented that positive trainee reaction might increase the likelihood of student involvement with training (i.e., devote extra time to training). In a more guarded position, Leemkuil et al. (2003) commented
that much of the work on the evaluation of games has been anecdotal, descriptive, or judgmental, yet there are some indications that they are effective and superior to case studies in producing knowledge gains, especially in the area of strategic management (Wolfe, 1997).

**Negative or Null Outcomes from Games and Simulations**

A number of researchers have addressed the issue of the motivational aspects of games, arguing that the motivation attributed to enjoyment of educational games may not necessarily indicate learning and, possibly, might indicate less learning. Garris et al. (2002) noted that, although students generally seem to prefer games over other, more traditional, classroom training media, reviews have reported mixed results regarding the training effectiveness of games. Druckman (1995) concluded that games seem to be effective in enhancing motivation and increasing student interest in subject matter, yet the extent to which that translates into more effective learning is less clear. With caution, Brougere (1999) commented that anything that contributes to the increase of emotion (such as the quality of the design of video games) reinforces the attraction of the game but not necessarily its educational interest. Similarly, Salas et al. (1998) commented that liking a simulation does not necessarily transfer to learning. Salomon (1984) went even further, by commenting that a more positive attitude can actually indicate less learning. And in an early meta-analysis of the effectiveness of simulation games, Dekkers and Donatti (1981) found a negative relationship between duration of training and training effectiveness. Simulation games became less effective the longer the game was used (suggesting that perhaps trainees became bored over time).

**Relationship of Instructional Design to Effective Games and Simulations**

de Jong and van Joolingen (1998), after reviewing a large number of studies on learning from simulations, concluded, “there is no clear and univocal outcome in favor of simulations. An
explanation why simulation based learning does not improve learning results can be found in the intrinsic problems that learners may have with discovering learning” (p. 181). These problems are related to processes such as hypothesis generation, design of experiments, interpretation of data, and regulation of learning. After analyzing a large number of studies, de Jong and van Joolingen (1998) concluded that adding instructional support to simulations might help to improve the situation.

The generally accepted position is that games themselves are not sufficient for learning but there are elements in games that can be activated within an instructional context that may enhance the learning process (Garris et al., 2002). In other words, outcomes are affected by the instructional strategies employed (Wolfe, 1997). Leemkuil et al. (2003), too, commented that there is general consensus that learning with interactive environments such as games, simulations, and adventures is not effective when no instructional measure or support is added. In meta-analyzing a number of studies and meta-analyses of video games,

According to Thiagarajan (1998), if not embedded with sound instructional design, games and simulations often end up truncated exercises often mislabeled as simulations. Gredler (1996) further commented that poorly developed exercises are not effective in achieving the objectives for which simulations are most appropriate—that of developing students’ problem-solving skills. Lee (1999) commented that effect size never tells us under what conditions students learn more, less, or not at all compared with the comparison group. For instructional prescription, we need information dealing with instructional variables, such as instructional mode, instructional sequence, knowledge domain, and learner characteristics (Lee, 1999).
Reflection and Debriefing

Instructional strategies that researchers have suggested as beneficial to learning from games and simulations are reflection and debriefing. Brougere (1999) argued that a game cannot be designed to directly provide learning. A moment of reflexivity is required to make transfer and learning possible. Games require reflection, which enables the shift from play to learning. Therefore, debriefing (or after action review), which includes reflection, appears to be an essential contribution to research on play and gaming in education (Brougere, 1999; Leemkuil et al., 2003; Thiagarajan, 1998). According to Garris et al. (2002), debriefing is the review and analysis of events that occurred in the game. Debriefing provides a link between what is represented in the simulation or gaming experience and the real world. It allows the learners to draw parallels between game events and real-world events. Debriefing allows learners to transform game events into learning experiences. Debriefing may include a description of events that occurred in the game, analysis of why they occurred, and the discussion of mistakes and corrective actions. Garris et al. (2002) argued that learning by doing must be coupled with the opportunity to reflect and abstract relevant information for effective learning to occur.

Summary of games and simulation section.

Computer-based educational games fall into three categories: games, simulations, and simulation games. Games consist of rules, can contain imaginative contexts, are primarily linear, and include goals as well as competition, either against other players or against a computer (Gredler, 1996). Simulations display the dynamic relationship among variables which change over time and reflect authentic causal processes. Simulations are non-linear and have a goal of discovering causal relationships through manipulation of independent variables. Simulation games are a blend of games and simulations (Gredler, 1996).
Clark (2003d) argued that mental effort is affected by motivation. Beginning with the work of Malone (1981), a number of constructs have been described as providing the motivational aspects of games: fantasy, control and manipulation, challenge and complexity, curiosity, competition, feedback, and fun. Fantasy is defined as an environment that evokes “mental images of physical or social situations that do not exist” (Malone & Lepper, 1987, p. 250). Malone & Lepper (1987) also commented that fantasies can offer analogies and metaphors, and Davis and Wiedenbeck (2001) argued that metaphors can help learners feel more directly involved in the domain.

Control and manipulation promote intrinsic motivation, because learners are given a sense of control over their choices and actions (deCharms, 1986, Deci, 1975). Challenge embodies the idea that intrinsic motivation occurs when there is a match between a task and the learner’s skills (Bandura, 1977, Csikszentmihalyi, 1975; Harter, 1978). The task should be neither too hard nor too easy, otherwise, in both cases, the learner would lose interest (Clark, 1999; Malone & Lepper, 1987). According to Rieber (1996), curiosity and challenge are intertwined. Curiosity arises from situations in which there is complexity, incongruity, and discrepancy (Davis & Wiedenbeck, 2001) and Malone and Lepper (1997) argued that curiosity is one of the primary factors that drive learning.

While Malone (1981) defines competition as important to motivation, studies on competition with games and simulations have resulted in mixed findings, due to individual learner preferences, as well as the types of reward structures connected to the competition (e.g., Porter, Bird, & Wunder, 1990-1991; Yu, 2001). Another motivational factor in games, feedback, allows learners to quickly evaluate their progress and can take many forms, such as textual, visual, and aural (Rieber, 1996). Ricci et al. (1996) argued that feedback can produce significant
differences in learner attitudes, resulting in increased attention to a learning environment. However, Clark (2003a) commented that feedback must be focused on clear learning goals and current performance results.

The last category contributing to motivation, fun, is possibly an erroneous category. Little empirical evidence exists for the construct. However, evidence does support the related constructs of play, engagement, and flow. Play is entertainment without fear of present of future consequences (Resnick & Sherer, 1994). Webster et al. (1993) found that labeling software training as play improved motivation and performance. Csikszentmihalyi (1975; 1990) defines flow as an optimal experience in which a person is so involved in an activity that nothing else seems to matter. According to Davis and Wiedenbeck (2001), engagement is the feeling of working directly on the objects of interest in a world, and Garris et al. (2002) argued that engagement can harness the motivational properties of computer games to enhance learning and accomplish instructional objectives.

While numerous studies have cited the learning benefits of games and simulations (e.g., Adams, 1998; Baker et al., 1997; Betz, 1995-1996; Khoo & Koh, 1998), others have found mixed, negative, or null outcomes from games and simulations, specifically in relationship to the enjoyment of a game to learning from the game (e.g., Brougere, 1999; Dekkers & Donatti, 1981; Druckman, 1995). There appears to be consensus among a large number of researcher with regards to the negative, mixed, or null findings, suggesting that the cause might be a lack of sound instructional design embedded in the games (de Jong & van Joolingen, 1998; Garris et al., 2002; Gredler, 1996; Lee, 1999; Leemkuil et al., 2003; Thiagarajan, 1998; Wolfe, 1997).

Among the various instructional strategies, reflection and debriefing have been cited as critical to learning with games and simulations. Brougere (1999) argued that games cannot be
designed to directly provide learning; reflection is required to make transfer and learning possible. Debriefing provides an opportunity for reflection (Brougere, 1999, Garris et al., 2002; Thiagarajan, 1998).

ASSESSMENT OF PROBLEM SOLVING

According to O’Neil’s Problem Solving model (1999), successful problem solving requires content understanding, problem solving strategies, and self-regulation. Therefore, proper assessment of problem solving should address all three constructs.

Measurement of Content Understanding

According to Mayer and Moreno (2003), meaningful learning is reflected in retention and transfer. Transfer refers to the ability to apply what was taught to new situations. According to Day et al. (2001), declarative knowledge, which is an indication of retention, reflects the amount of knowledge or facts learned. Similarly, Davis and Wiedenbeck (20010 commented that meaningful learning results in an understanding of the basic concepts of the new material through its integration with existing knowledge. Mayer and Moreno (1998) assessed content understanding with retention and transfer questions. In their study on the split-attention effect in multimedia learning, they used a retention test and a matching test containing a series of questions to assess the extent to which participants retained knowledge delivered by the multimedia.

Day et al. (2001), proposed knowledge maps as an alternative method to measure content understanding. A knowledge map is a structural representation that consists of nodes and links. Each node represents a concept in the domain of knowledge. Each link, which connects two nodes, represents the relationship between the nodes; that is, the relationship between the two concepts (Schau & Mattern, 1997). Knowledge structures are based on the premise that people
organize information into patterns that reflect the relationships which exist between concepts and the features that define them (Day et al., 2001). Day et al. further argued that, in contrast to declarative knowledge which reflects the amount of knowledge or facts learned, knowledge structures represent the organization of the knowledge.

As Schau and Mattern (1997) point out, learners should not only be aware of the concepts but also of the connections among them. In a training context, knowledge structures reflect the degree to which trainees have organized and comprehended the content of training (Day et al., 2001). Knowledge maps, which are graphical representations of knowledge structures, have been used as an effective tool to learn complex subjects (Herl et al., 1996) and to facilitate critical thinking and (West, Pomeroy, Park, Gerstenberger, & Sandoval, 2000). Several studies also revealed that knowledge maps are not only useful for learning, but are a reliable and efficient measurement of content understanding, as well (Herl et al., 1999; Ruiz-Primo, Schultz, & Shavelson, 1997). The results of a study by Day et al. (2001) indicated that knowledge structures are predictive of both skill retention and skill transfer and can therefore be a viable indices of training outcomes, and Ruiz-Primo et al. (1997) proposed a framework for conceptualizing knowledge maps as a potential assessment tool in science, because it allows for organization and discrimination between concepts.

Ruiz-Primo et al. (1997) claimed that as an assessment tool, knowledge maps are identified as a combination of three components: (a) a task that allows a student to perform his or her content understanding in the specific domain (b) a format for student’s responses, and (c) a scoring system by which the student’s knowledge map could be accurately evaluated. Chuang (2003) modified this framework to serve as an assessment specification using a concept map.

Researchers have successfully applied knowledge maps to measure students’ content
understanding in science for both high school students and adults (e.g., Chuang, 2003; Herl et al., 1999; Schacter et al., 1999; Schau et al., 2001). For example, Schau et al. (2001) used select-and-fill-in knowledge maps to measure secondary and postsecondary students’ content understanding of science in two studies. The results of the participant’s performance on the knowledge maps correlated significantly with that of a multiple choice test, a traditional measure of learning (r= .77 for eighth grade and r=. 74 for seventh grade), providing validity to the use of knowledge maps to assess learning outcomes. CRESST developed a computer-based knowledge mapping system, which measures the deeper understanding of individual students and teams, reflects thinking processes in real-time, and economically reports student thinking process data back to teachers and student (Chung et al., 1999; O’Neil, 1999; Schacter et al., 1999). The computer-based knowledge map has been used successfully in a number of studies (e.g., Chuang, 2003; Chung et al., 1999; Hsieh, 2001; Schacter et al., 1999).

In the four studies, the map contained 18 concepts of environmental science, and seven links for relationships, such as “cause,” “influence,” and “used for.” Subjects were asked to create a knowledge map in the computer-based environment. In the study conducted by Schacter et al. (1999) students were evaluated by creating individual knowledge map, after searching a simulated World Wide Web environment. In the studies conducted by Chung et al. (1999), Hsieh (2001), and Chuang (2003) two students constructed a group map cooperatively through networked computers. Results of the cooperative studies showed that using networked computers to measure group processes was feasible. Figures 2 and 3 show the knowledge map used for the three studies.
As seen in Figure 2, the screen of computer was divided into three major parts. The bottom section was for communication between the two team members. The middle section is where the one of the team members constructed the knowledge map. The top section contains four menu items: “Session,” “Add Concept,” “Available Links,” and “About.” Figure three shows the drop-down menu that appears when “Add Concept” is clicked. Clicking when the mouse pointer is over a concept adds that link to the knowledge map. Figure 2 shows three concepts that were added: desk, safe, and key. Figure 2 also shows links that were added to the concept map by (A) clicking on one concept on the screen, holding the shift-key down and clicking a second concept, so that both concepts are “selected,” then clicking on the “Available Links” menu and selection the appropriate link type from the drop-down menu that appeared.
Measurement of Problem Solving Strategies

According to Baker and Mayer (1999), “Problem solving is cognitive processing directed at transforming a given situation into a desired situation when no obvious method of solution is available to the problem solver” (p. 272). Simply put, problem solving is mental activity aimed at finding a solution to a problem. According to Baker and Maker, a promising direct approach to knowledge representation, “more parsimonious than a traditional performance assessment,” is knowledge or concept mapping, in which “the learner constructs a network consisting of nodes (e.g., key words or terms) and links (e.g., ‘is part of’, ‘led to’, ‘is an example of’)” (p. 274).

Problem solving strategies can be categorized as *domain-independent* (-general) and *domain-dependent* (-specific) (Alexander, 1992; Bruning, Schraw, & Ronning, 1999; O’Neil, 1999; Perkins & Salomon, 1989). *Domain-specific* knowledge is knowledge about a particular
field of study or a subject, such as the application of equations in a math question, the application of a formula in a chemistry problem, or the specific strategies to be successful in a game.

*Domain-general* knowledge is the broad array of problem solving knowledge that is not linked with a specific domain, such as the application of multiple representations and analogies in a problem-solving task or the use of Boolean search strategies in a search task (Chuang, 2003).

Transfer *questions* have been examined as an alternative to performing transfer tasks. For example, in a recent study, Mayer and Moreno (1998) assessed participants’ problem-solving strategies with a list of transfer questions. Responses to the transfer questions were positively correlated with performance as measured by retention and transfer, indicating that transfer questions are a viable alternative to transitions methods of measuring retention and transfer, such as tests and novel problem solving (Mayer & Moreno, 1998).

*Measure of Self-Regulation*

While Bruning, Schraw, and Ronning (1999), commented that some researchers believe self-regulation includes three core components—metacognitive awareness, strategy use, and motivational control—, according to O’Neil’s Problem Solving model (O’Neil, 1999), self-regulation is composed of only two core components: *metacognition* and *motivation*. *Strategy use* is a separate construct that encompasses domain-specific and domain-general knowledge. Within O’Neil’s model, metacognition encompasses two subcategories, *planning* and *self-checking/monitoring* (Hong & O’Neil, 2001; O’Neil & Herl, 1998; Pintrich & DeGroot, 1990), and motivation is indicated by *mental effort* and *self-efficacy* (Zimmerman, 1994; 2000).

O’Neil and Herl (1998) developed a *trait* self-regulation questionnaire examining the four components of self-regulation (planning, self-checking/monitoring, mental effort, and self-efficacy). Of the four components, planning is the first step, since learners must have a plan to
achieve the proposed goal. Self-efficacy is one’s belief in his or her capability to accomplish a task, and effort is amount of mental effort exerted on a task. In the trait self-regulation questionnaire developed by O’Neil and Herl, planning, self-checking, self-efficacy, and effort are assessed using eight questions each. The reliability of this self-regulation inventory has been established in previous studies (e.g., Hong & O’Neil, 2001). For example, in the research conducted by Hong and O’Neil (2001), the reliability estimates (coefficient á) of the four subscales of self-regulation, planning, self-checking, effort, and self-efficacy were .76, .06, .83, and .85 respectively; Research also provided evidence for construct validation. To evaluate problem-solving ability, previous researchers (e.g., Baker & Mayer, 1999; Baker & O’Neil, 2002; Mayer, 2002; O’Neil, 1999) argued that computer-based assessment has the merit of integrating validity to generate test items and the efficiency of computer technology as a means of presenting and scoring tests.

**Summary of Problem Solving Assessment**

Problem solving is cognitive processing directed at achieving a goal when no solution method is obvious to the problem solver (Baker & Mayer, 1999). In O’Neil’s Problem Solving model (O’Neil, 1999), problem solving strategies can be categorized into two types: domain-independent (-general) and domain-dependent (-specific) problem solving strategies. Self-regulation includes two sub-categories: metacognition and motivation. Metacognition is composed of self-checking/monitoring and planning. Motivation is comprised of effort and self-efficacy.

Knowledge maps are reliable and efficient for the measurement of content understanding. CRESST has developed a simulated Internet Web space to evaluate problem solving strategies such as information searching strategies and feedback inquiring strategies. Computer-based
problem-solving assessments are economical, efficient and valid measures that employ contextualized problems that require students to think for extended periods of time and to indicate the problem-solving heuristics they were using and why.

SCAFFOLDING

As discussed in earlier, cognitive load theory is concerned with methods for reducing the amount of cognitive load placed on working memory during learning and problem solving activities. Clark (2003b) commented that instructional methods must also keep the cognitive load from instructional presentations to a minimum. Scaffolding is considered a viable instructional method that assists in cognitive load reduction. There are a number of definitions of scaffolding in the literature. Chalmers (2003) defines scaffolding as the process of forming and building upon a schema (Chalmers, 2003). In a related definition, van Merrienboer, Kirshner, and Kester (2003) defined the original meaning of scaffolding as all devices or strategies that support students’ learning. More recently, van Merrienboer, Clark, and de Croock (2002) defined scaffolding as the process diminishing support as learners acquire more expertise. Allen (1997) defined scaffolding as the process of training a student on core concepts and then gradually expanding the training. Ultimately, the core principle embodied in each of these definitions is that scaffolding is concerned with the amount of cognitive load imposed by learning and provides methods for reducing that load. Therefore, for the purposes of this review, all four definitions of scaffolding will be considered.

As defined by Clark (2001), instructional methods are external representations of internal cognitive processes that are necessary for learning but which learners cannot or will not provide for themselves. They provide learning goals (e.g., demonstrations, simulations, and analogies: Alessi, 2000; Clark 2001), monitoring (e.g., practice exercises: Clark, 2001), feedback (Alessi,
2000; Clark 2001; Leemkuil, de Jong, de Hoog, & Christoph, 2003), and selection (e.g.,
highlighting information: Alessi, 2000; Clark, 2001). In addition, Alessi (2000) adds: giving
hints and prompts before student actions; providing coaching, advice, or help systems; and
providing dictionaries and glossaries. Jones et al. (1995) added advance organizers, graphical
representations of problems, and hierarchical knowledge structures. Each of these examples is a
form of scaffolding.

In learning by doing in a virtual environment, students can actively work in realistic
situations that simulate authentic tasks for a particular domain (Mayer et al., 2002). A major
instructional issue in learning by doing within simulated environments concerns the proper type
of guidance, that is, how best to create cognitive apprenticeship (Mayer et al. 2002). Mayer et al.
(2002) also commented that their research shows that discovery-based learning environments can
be converted into productive venues for learning when appropriate cognitive scaffolding is
provided; specifically, when the nature of the scaffolding is aligned with the nature of the task,
such as pictorial scaffolding for pictorially-based tasks and textual-based scaffolding for
textually-based tasks. For example, in a recent study, Mayer et al. (2002) found that students
learned better from a computer-based geology simulation when they were given some support
about how to visualize geological features, versus textual or auditory guidance.

Graphical Scaffolding

According to Allen (1997), selection of appropriate text and graphics can aid the
development of mental models, and Jones et al. (1995) commented that visual cues such as maps
and menus as advance organizers help learners conceptualize the organization of the information
in a program (Jones et al., 1995). A number of researchers support the use of maps as visual aids


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and menus as advance organizers help learners conceptualize the organization of the information
in a program (Jones et al., 1995). A number of researchers support the use of maps as visual aids
and organizers (Benbasat & Todd, 1993; Chou & Lin, 1998; Chou, Lin, & Sun, 2000; Farrell & Moore, 2000-2001; Ruddle et al, 1999)

Chalmers (2003) defines graphic organizers is organizers of information in a graphic format, which act as spatial displays of information that can also act as study aids. Jones et al. (1995) argued that interactive designers should provide users with visual or verbal cues to help them navigate through unfamiliar territory. Overviews, menus, icons, or other interface design elements within the program should serve as advance organizers for information contained in the interactive program (Jones et al., 1995). In addition, the existence of bookmarks enables recovering from the possibility of disorientation; loss of place (Dias, Gomes, & Correia, 1999).

However, providing such support devices does not guarantee learners will use them. For example, in an experiment involving a virtual maze, Cutmore et al. (2000) found that, while landmarks provided useful cues, males utilized them significantly more often than females did.

**Navigation maps**

Cutmore et al. (2000) define navigation as “…a process of tracking one’s position in a physical environment to arrive at a desired destination” (p. 224). A route through the environment consists of either a series of locations or a continuous movement along a path. Cutmore et al. further commented that “Navigation becomes problematic when the whole path cannot be viewed at once but is largely occluded by objects in the environment” (p. 224). These may include internal walls or large environmental features such as trees, hills, or buildings. Under these conditions, one cannot simply plot a direct visual course from the start to finish locations. Rather, knowledge of the layout of the space is required. Navigation maps or other descriptive information may provide that knowledge (Cutmore et al. 2000).
Effective navigation of a familiar environment depends upon a number of cognitive factors. These include working memory for recent information, attention to important cues for location, bearing and motion, and finally, a cognitive representation of the environment which becomes part of a long-term memory, a cognitive map (Cutmore et al., 2000). According to Yair, Mintz, and Litvak (2001), the loss of orientation and “vertigo” feeling which often accompanies learning in a virtual-environment is minimized by the display of a traditional, two-dimensional dynamic map. The map helps to navigate and to orient the user, and facilitates an easier learning experience. Dempsey et al. (2002) also commented that an overview of player position was considered an important feature in adventure games.

A number of experiments have examined the use of navigation maps in virtual environments. Chou and Lin (1998) and Chou et al. (2000) examined various navigation map types, with some navigation maps offering global views of the environment and others offering more localized views, based on the learner’s current location. In their experiments using over one hundred college students, they found that any form of navigation map produced more efficient navigation of the site as well as better development of cognitive maps (concept or knowledge maps), compared to having no navigation map. Additionally, the global navigation map results for navigation and concept map creation were significantly better than any of the local navigation map variations or the lack of navigation map, while use of the local navigation maps was not significantly better than not having a navigation map. This suggests that, while the use of navigation maps is helpful, the nature or scope of the navigation map influences its effectiveness (Chou & Lin, 1998).

According to Tkacz (1998), soldiers use navigation maps as tools, which involves spatial reasoning, complex decision making, symbol interpretation, and spatial problem solving. In her
study, Tkacz (1998) examined the procedural components of cognitive maps required for using and understanding topographic navigation maps, stating that navigation map interpretation involves both top-down (retrieved from long-term memory) and bottom-up (retrieved from the environment and the navigation map) procedures. Therefore, Tkacz examined the cognitive components underlying navigation map interpretation to assess the influence of individual differences on course success and on real world position location. In addition, Tkacz, related position location ability to video game performance in a simulated environment. The learning goal of the study was for 105 marines (non-random assignment) to learn to match their position in the real world with a navigation map. From the results of the study, Tkacz argued that spatial orientation is the most important cognitive component of terrain association and that orientation and, to a lesser extent, reasoning ability are important in navigation map interpretation and course performance. It should be noted that, while Tkacz referred to the instrument as a game, it appears to fit the Gredler’s (1996) definition of a simulation, not a game or simulation game.

Mayer et al. (2002) commented that a major instructional issue in learning by doing within simulated environments concerns the proper type of guidance, which they refer to as *cognitive apprenticeship*. The investigators used a geological gaming simulation, the Profile Game, to test various types of guidance structures (i.e., strategy modeling), ranging from no guidance to illustrations (i.e., pictorial aids) to verbal descriptions to pictorial and verbal aids combined. The Profile Game is based on the premise, “Suppose you were visiting a planet and you wanted to determine which geological feature is present on a certain portion of the planet’s surface” (Mayer et al., p. 171). While exploring, you cannot directly see the features, so you must interpret data indirectly, through probing procedures. The experimenters focused on the amount and type of guidance needed within the highly spatial simulation.
Though a series of experiments, Mayer et al. (2002) found that pictorial scaffolding, as opposed the verbal scaffolding, is needed to enhance performance in a visual-spatial task. In the final experiments, participants were divided into verbal scaffolding, pictorial scaffolding, both, and no scaffolding. Participants who received pictorial scaffolding solved significantly more problems than those who did not receive pictorial scaffolding. Students who received strategic scaffolding did not solve significantly more problems than students who did not receive strategic scaffolding. While high-spatial participants performed significantly better than low-spatial students, adding pictorial scaffolding to the learning materials helped both low- and high-spatial students learn to use the Profile Game. Students in the pictorial-scaffolding group correctly solved more transfer problems than students in the control group. However, pictorial scaffolding did not significantly affect the solution time (speed) of either low- or high-spatial participants. Overall, adding pictorial scaffolding to the learning materials lead to improved performance on a transfer task for both high- and low-spatial students in the Profile Game (Mayer et al., 2002).

**Contiguity effect**

The contiguity effect addresses the cognitive load imposed when multiple sources of information are separated (Mayer & Moreno, 2003; Mayer, Moreno, Boire, & Vagge, 1999; Mayer & Sims, 1994; Moreno & Mayer, 1999). There are two forms of the contiguity effect: spatial contiguity and temporal contiguity. Temporal contiguity occurs when one piece of information is presented prior to other pieces of information (Mayer & Moreno, 2003; Mayer et al., 1999; Moreno & Mayer, 1999). Spatial contiguity occurs when modalities are physically separated (Mayer & Moreno, 2003). This study is concerned with spatial contiguity, since the printed navigation maps will be spatially separated from the 3-D video game environment. Contiguity results in split-attention (Moreno & Mayer, 1999).
**Split Attention Effect**

When dealing with two or more related sources of information (e.g., text and diagrams), it’s often necessary to integrate mentally corresponding representations (verbal and pictorial) to construct a relevant schema to achieve understanding. When different sources of information are separated in space or time, this process of integration may place an unnecessary strain on limited working memory resources (Atkinson et al., 2000; Mayer & Moreno, 1998). In this study, the printed navigation maps are spatially separated from the 3-D video game environment, thereby inducing the split-attention effect.

**Summary of scaffolding**

Depending upon the researcher, scaffolding has several meanings: the process of forming and building upon a schema (Chalmers, 2003); all devices or strategies that support learning (van Merriënboer et al., 2003), the process of diminishing support as learners acquire expertise (van Merriënboer et al., 2002); and the process of training a student on core concepts and then gradually expanding the training. What these four definitions have in common is that scaffolding is related to providing support during learning.

Clark (2001) described instructional methods as external representations the external processes of selecting, organizing, and integrating. Instructional methods also provide learning goals (Alessi, 2000; Clark, 2001), monitoring (Clark, 2001), feedback (Alessi, 2000; Clark, 2001; Leemkuil et al., 2003), selection (Alessi, 2000; Clark, 2001), hints and prompts (Alessi, 2000), and various advance organizers (Jones et al., 1995). Each of these components either reflects a form of scaffolding or reflects a need for scaffolding.

Mayer et al (2002) argued that a major instructional issue in learning by doing within simulated environments concerns the proper type of guidance (i.e., scaffolding). One form of
scaffolding is graphical scaffolding. According to Allen (1997), selection of appropriate text and graphics can aid the development of mental models, and Jones et al. (1997) commented that visual cues such as maps help learners conceptualize the organization of the information in a program (i.e., the learning space). A number of studies have supported the use of maps as visual aids and organizers (Benbasat & Todd, 1993; Chou & Lin, 1998; Ruddle et al, 1999, Chou et al., 2000; Farrell & Moore, 2000-2001)

Graphic organizers organize information in a graphic format, which act as spatial displays of information that can also act as study aids (Chalmers, 2003), and Jones et al. (1995) argued that interactive designers should provide users with visual or verbal cues to help them navigate through unfamiliar territory. Cobb argued that cognitive load can be distributed to external media (Cobb, 1997). In virtual environments, navigation maps help to navigate and to orient the user, and facilities an easier learning experience (Yair et al, 2001). While navigation maps provide external representations of information needed to complete tasks and to learn, thereby reducing or distributing cognitive load (Cobb, 1997), they also have the potential to add load, ultimately counteracting their positive effects. The contiguity effect addresses the cognitive load imposed when multiple sources of information are separated (Mayer et al., 1999). Spatial contiguity occurs when modalities are physically separated (Mayer & Moreno, 2003), such as a video game screen and a printed navigation map. The split attention effect, which is related to the contiguity effect, occurs when dealing with two or more related sources of information (e.g., information on a screen and information on a printed navigation map). When different sources of information are separated in space or time, this process of integration may place an unnecessary strain on limited working memory resources (Atkinson et al., 2000). Therefore, when working with
navigation maps, careful consideration must be included for the potential adverse effects of having the navigation map separated from the learning environment.

Summary of the Literature Review

Cognitive Load Theory is based on the assumptions of a limited working memory with separate channels for auditory and visual/spatial stimuli, and a virtually unlimited capacity long-term memory that stores schemas of varying complexity and level of automation (Brunken et al., 2003). According to Paas et al. (2003), cognitive load refers to the amount of load placed on working memory. Cognitive load can be reduced through effective use of the auditory and visual/spatial channels, as well as schemas stored in long-term memory.

Meaningful learning is defined as deep understanding of the material and is reflected in the ability to apply what was taught to new situations; i.e., problem solving transfer. (Mayer & Moreno, 2003). Meaningful learning requires effective metacognitive skills: the management of cognitive processes (Jones, Farquhar, & Surry, 1995), including selecting relevant information, organizing connections among the pieces of information, and integrating (i.e., building) external connections between incoming information and prior knowledge that exists in long-term memory (Harp & Mayer, 1998). Related to meaningful learning is problem solving, “cognitive processing directed at transforming a given situation into a desired situation when no obvious methods of solution is available to the problem solver” (Baker & Mayer, 1999, p. 272). O’Neil’s Problem Solving model (O’Neil, 1999) defines three core constructs of problem solving: content understanding, problem solving strategies, and self-regulation. Each of these components is further defined with subcomponents.

There are three types of cognitive load that can be defined in relationship to a learning or problem solving task: intrinsic cognitive load (load from the actual mental processes involved in
creating schema), germane cognitive load (load from the instructional processes that deliver the to-be-learned content), and extraneous cognitive load (all other load). An important goal of instructional design is to balance intrinsic, germane, and extraneous cognitive loads to support learning outcomes (Brunen et al., 2003).

Learner control, which is inherent in interactive computer-based media, allows for control of pacing and sequencing (Barab, Young, & Wang, 1999). It also can induce cognitive overload in the form of disorientation; loss of place (Chalmers, 2003), and is a potential source for extraneous cognitive load. These issues may be the cause of mixed reviews of learner control (Bernard, et al, 2003; Niemiec, Sikorski, & Wallberg, 1996; Steinberg, 1989), particularly in relationship to novices versus experts (Clark, 2003c).

Computer-based educational games fall into three categories: games, simulations, and simulation games. Games are linear, consist of rules, can contain imaginative contexts, are primarily linear, and include goals as well as competition, either against other players or against a computer (Gredler, 1996). Simulations display the dynamic relationship among variables which change over time and reflect authentic causal processes and have a goal of discovering causal relationships through manipulation of independent variables. Simulation games are a blend of games and simulations (Gredler, 1996).

Clark (2003d) argued that mental effort is affected by motivation, and beginning with the work of Malone (1981), a number of constructs have been described as providing the motivational aspects of games: fantasy, control and manipulation, challenge and complexity, curiosity, competition, feedback, and fun. Fantasy evokes “mental images of physical or social situations that do not exist” (Malone & Lepper, 1987, p. 250). Control and manipulation promote intrinsic motivation, because learners are given a sense of control over their choices and actions
(deCharms, 1986, Deci, 1975). Challenge embodies the idea that intrinsic motivation occurs when there is a match between a task and the learner’s skills (Bandura, 1977, Csikszentmihalyi, 1975; Harter, 1978). For challenge to be effective, the task should be neither too hard nor too easy, otherwise the learner would lose interest (Clark, 1999; Malone & Lepper, 1987). Curiosity is related to challenge and arises from situations in which there is complexity, incongruity, and discrepancy (Davis & Wiedenbeck, 2001).

Studies on competition with games and simulations have resulted in mixed findings, due to individual learner preferences, as well as the types of reward structures connected to the competition (e.g., Porter, Bird, & Wunder, 1990-1991; Yu, 2001). Another motivational factor in games, feedback, allows learners to quickly evaluate their progress and can take many forms, such as textual, visual, and aural (Rieber, 1996). Ricci et al. (1996) argued that feedback can produce significant differences in learner attitudes, resulting in increased attention to a learning environment. However, Clark (2003a) commented that feedback must be focused on clear performance goals and current performance.

The last category contributing to motivation, fun, is possibly an erroneous category. Little empirical evidence exists for the construct. However, evidence does support the related constructs of play, engagement, and flow. Play is entertainment without fear of present of future consequences (Resnick & Sherer, 1994). Csikszentmihalyi (1975; 1990) defines flow as an optimal experience in which a person is so involved in an activity that nothing else seems to matter. According to Davis and Wiedenbeck (2001), engagement is the feeling of working directly on the objects of interest in a world, and Garris et al. (2002) argued that engagement can help to enhance learning and accomplish instructional objectives.
While numerous studies have cited the learning benefits of games and simulations (e.g., Adams, 1998; Baker et al., 1997; Betz, 1995-1996; Khoo & Koh, 1998), others have found mixed, negative, or null outcomes from games and simulations, specifically in relationship to the enjoyment of a game to learning from the game (e.g., Brougere, 1999; Dekkers & Donatti, 1981; Druckman, 1995). There appears to be consensus among a large number of researchers with regards to the negative, mixed, or null findings, suggesting that the cause might be a lack of sound instructional design embedded in the games (de Jong & van Joolingen, 1998; Garris et al., 2002; Gredler, 1996; Lee, 1999; Leemkuil et al., 2003; Thiagarajan, 1998; Wolfe, 1997). Among the various instructional strategies, reflection and debriefing have been cited as critical to learning with games and simulations.

An important component of research on the effectiveness of educational games and simulations is the measurement and assessment of performance outcomes from the various instructional strategies embedded into the games or simulations, such as problem solving tasks. Problem solving is cognitive processing directed at achieving a goal when no solution method is obvious to the problem solver (Baker & Mayer, 1999). O’Neil’s Problem Solving model (O’Neil, 1999), includes the components: content understanding; solving strategies—domain-independent (-general) and domain-dependent (-specific); and self-regulation which is comprised of metacognition and motivation. Metacognition is further composed of self-checking/monitoring and planning, and motivation is comprised of effort and self-efficacy. Knowledge maps are reliable and efficient for the measurement of the content understanding portion of O’Neil’s Problem Solving model, and CRESST has developed a simulated Internet Web space to evaluate problem solving strategies such as information searching strategies and feedback inquiring strategies.
Problem-solving can play a large amount of cognitive load on working memory. Instructional strategies have been recommended to help control or reduce that load. One such strategy is scaffolding. While there are a number of definitions of scaffolding (e.g., Chalmers, 2003; van Merrionboer et al., 2002; van Merrionboer et al., 2003), what they all have in common is that scaffolding is an instructional method that provides support during learning. Clark (2001) described instructional methods as external representations the external processes of selecting, organizing, and integrating. They provide learning goals, monitoring, feedback, selection, hints, prompts, and various advance organizers (Alessi, 2000; Clark, 2001; Jones et al., 1995; Leemkuil et al., 2003). Each of these components either reflects a form of scaffolding or reflects a need for scaffolding.

One form of scaffolding is graphical scaffolding. A number of studies have reported the benefits of maps, which is a type of graphical scaffolding (Benbasat & Todd, 1993: Chou & Lin, 1998; Ruddle et al, 1999, Chou et al., 2000; Farrell & Moore, 2000-2001). In virtual environments, navigation maps help to navigate and to orient the user, and facilities an easier learning experience (Yair et al, 2001). While navigation maps can reduce or distribute cognitive load (Cobb, 1997), they also have the potential to add load, ultimately counteracting their positive effects. The spatial contiguity effect addresses the cognitive load imposed when multiple sources of information are separated (Mayer & Moreno, 2003) and the split attention effect, which is related to the contiguity effect, occurs when dealing with two or more related sources of information (Atkinson et al., 2000). Navigation maps can provide value cognitive support for navigating virtual environments, such as computer-based video games. This can be particularly useful when using the gaming environment to accomplish a complex problem-solving task.
CHAPTER III: METHODOLOGY

Research Design

Following USC Human Subject approval, data in the study will be collected in July, 2004. The design of this study is an experimental with pre-, intermediate-, and post-tests for one treatment group and one control group. Subjects will be randomly assigned to either the treatment or the control group. Group sessions will involve only one group type: either all treatment participants or all control participants. The experimental design involves administration of pretest instruments, the treatment, administration of intermediate test instruments, the treatment, and administration of the posttest instruments. At the end of the session, participants will be debriefed and will be then allowed to continue playing on their own for up to 30 additional minutes (to examine continued motivation).

Research Questions and Hypotheses

Research Question 1: Will the problem solving performance of participants who use a navigation map in a 3-D, occluded, computer-based video game (i.e., SafeCracker®) be better than the problem solving performance of those who do not use the map (the control group)?

Hypothesis 1: Navigation maps will produce a significant increase in content understanding compared to the control group.

Hypothesis 2: Navigation maps will produce a significant increase in problem solving strategy retention compared to the control group.

Hypothesis 3: Navigation maps will produce a significant increase in problem solving strategy transfer compared to the control group.
**Hypothesis 4:** There will be no significant difference in self-regulation between the navigation map group and the control group. However, it is expected that higher levels of self-regulation will be associated with better performance.

**Research Question 2:** Will the continued motivation of participants who use a navigation map in a 3-D, occluded, computer-based video game (i.e., SafeCracker®) be greater than the continued motivation of those who do not use the map (the control group)?

**Hypothesis 5:** Navigation maps will produce a significantly greater amount of optional continued game play compared to the control group.

**Sample**

Twenty to thirty English-speaking adults will participate in the study. These young adults will be aged from 18-25. All of the participants will be undergraduate students from the University of Southern California. All students must have no prior experience playing the personal computer (PC)-based video game SafeCracker® (Daydream Interactive, 1995). Each person will be assigned to either the treatment or control group. Those in the treatment group will receive a navigation map of the gaming environment. Those in the control group will not receive the navigation map. The location for the study is to be determined.

**Instruments**

A number of instruments will be included in the study: a demographic/game preference/task completion questionnaire; self-regulation questionnaire; SafeCracker®; navigation map of the game’s environment; problem-solving questionnaire; and knowledge mapping software.
Demographic, game preference, and task completion questionnaire

At the start of the experiment, this questionnaire will gather information on gender and a list of preferred game types. Game types include: PC, Console, Handheld, RTS, Action, Adventure, FPS, Strategy, and Puzzle. Participants will be told to check all game types they enjoy playing and to not check a type if they are not familiar with the terminology. At the end of each game, players will mark check boxes indicating which rooms they visited and which safes they opened. The tasks listed are the name of the room to visit and the safe to be open. If the player completes all tasks before the allotted time, he or she will mark the time (hour and minute) when the tasks were completed. During game play, the task listings will also serve as task reminders.

Self-Regulation Questionnaire

The trait self-regulation questionnaire (Appendix A) designed by O’Neil and Herl (1998) will be applied in this study to access participants’ degree of self-regulation, which is one of the three components of problem-solving ability as defined by O’Neil (1999). Reliability of the instrument ranges from .89 to .94, as reported by O’Neil & Herl (1998). The 32 items on the questionnaire are composed of eight items each of the four self-regulation factors in the O’Neil (1999) Problem Solving model: planning, self-checking/monitoring, self-efficacy, and effort. For example, item 1 “I determine how to solve a task before I begin.” is designed to access participants’ planning ability; and item 2 “I check how well I am doing when I solve a task” is to evaluate participants’ self-efficacy. The response for each item utilizes a Likert-type scale with four possible responses; almost never, sometimes, often, and almost always.
SafeCracker

The non-violent, PC-based video game SafeCracker® (Daydream Interactive, 1995) was selected for this study, as a result of a feasibility study by Wainess and O’Neil (2003). The purpose of the feasibility study was to recommend a video game for use as a platform for research on cognitive and affective components of problem solving, based on the O’Neil (1999) Problem Solving Model. The following requirements were established for a game to be considered as a potential platform.

Required characteristics:

- Adult oriented (college age and above)
- Appeal to both genders and with broad audience appeal
- Single user play
- Suitable for problem solving research
- Game to support practice and include problem solving feedback
- Interface, controls, and navigation can be adequately mastered in half an hour or less
- Can be played multiple times (or multiple stages) in one hour
- Compatible with X-Box, Playstation 2, or PC
- Expert support available for analysis of play/problem solving

The following additional criteria are preferred, but not required.

- Non-violent game
- User controlled pacing of game action
- Multi-user (multiplayer) capable
- Suitable for study of retention and transfer
- Provides multiple conditions or can be programmed with varying conditions
The feasibility study by Wainess and O’Neil (2003) involved four phases: 1) selection of relevant game types, based on simple search criteria; 2) in-depth analysis of the most relevant game selections; 3) removal of similar games by selecting the most appropriate game among the equivalent games; 4) play testing of each remaining game to determine the final selection. Phase 1 began with selection of 525 potential games and phase 1 ended with the selection of 12 possible games. Phase 2 ended with the selection of four possible games, and phase 3 ended with the selection of three possible games: SafeCracker for Windows®, Myst III®: Exile for Windows/PS2/Xbox®, and Jewels of the Oracle for Windows®. Phase 4 resulted in the selection of SafeCracker® (Wainess & O’Neil, 2003).

According to Wainess and O’Neil (2003), the primary factor for selecting SafeCracker® over the other two possible games selected during phase 3 was time constraints. During the feasibility study, it had been decided that the participants should not be required to spend more than one and a half hours on the study. In addition, it was desirable to include multiple iterations of gameplay within that time period. In Phase 4, Myst III®: Exile© and Jewels of the Oracle© were both eliminated due to the number of hours required for problem solving research. The games are designed with large environments, numerous buildings and other structures, and myriad, complex clues that would require multiple hours of play time to accomplish a problem solving task. With SafeCracker, players would be able to learn the controls and interface, and enter the main environment (a mansion), within a matter of minutes. Because only two or three of the mansion’s approximately 50 rooms are needed for an effective study, problem solving events could occur in 10 or 20 minutes, allowing for multiple problem-solving tasks using different room combinations.
Navigation map

Gameplay in SafeCracker takes place in a two story mansion. For the purposes of this study, only a small number of rooms on the first floor will be utilized. A navigation map, in the form of a topological floor plan of the first floor, was downloaded from http://www.gameboomers.com/wtcheats/pcSs/Safecracker.htm. The navigation map was modified in Adobe® Photoshop® 6.5 to alter the view of the navigation map from one-point perspective to a flat 2-D image, to remove unnecessary artifacts, and to add a number and name to each room in accordance with the numbers and names displayed on the game’s interface (figure 4).

Figure 4: Navigation Map
Knowledge Map

In this research, participants will be asked to create a knowledge map in a computer-based environment to evaluate their content understanding before, during, and after playing SafeCracker and receiving the feedback of domain-specific strategies. The computerized knowledge map that will be used in this study has been successfully applied to other studies (e.g., Chuang, 2003; Chung et al., 1999; Hsieh, 2001; Schacter et al., 1999). Appendix B lists the knowledge map specification that will be used in this study (adapted from Chen, in preparation).

Content understanding measure.

Content understanding measures will be computed by comparing the semantic content score of a participant’s knowledge map to the average semantic score of two experts. The experts for this study are Richard Wainess and Hsin-Hu (Claire) Chen. Appendix C shows the concept map developed for this study. It is based on the general concepts and propositions relevant to problem solving in the game, not the concepts and propositions specific to a room or a safe. An example of the knowledge map for one room in this study is shown in Figure 5.

Figure 5: Knowledge map for one SafeCracker® room
The following describes how these outcomes will be scored. First, the semantic score is calculated based on the semantic propositions—two concepts connected by one link, in experts’ knowledge map. Every proposition in a participant’s knowledge map will be compared against each proposition in the experts’ map. A match would be scored as one point. The average score of the two experts would be the semantic score for the student map. For example, as seen in Table 1, if a participant made a proposition such as “room”, this proposition would then compared against the experts’ propositions.

Table 1: An Example of Scoring Map

<table>
<thead>
<tr>
<th>CONCEPT1</th>
<th>LINKS</th>
<th>CONCEPT2</th>
<th>EXPERT 1</th>
<th>EXPERT 2</th>
<th>AVERAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room</td>
<td>contains</td>
<td>key</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Crack</td>
<td>results from</td>
<td>Key</td>
<td>1</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>Clue</td>
<td>causes</td>
<td>Crack</td>
<td>0</td>
<td>1</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Total 2.00

The participant can only receive one of two scores: the average score of the two experts or a score of zero. In the case of “room,” a score of one (the average score of the two experts) would mean the participant’s proposition was the same as the proposition of at least one expert. A score of zero would mean the proposition does not match either expert’s proposition. If the participant then created the link “room contains key” he or she would receive an addition score of one point to reflect the average score of the two experts, for a total of two points (one point for the semantic link “room” and one point for the proposition “room contains key”). Selecting “crack” would receive one point (for matching at least one expert). Creating the link (the
proposition) “crack results in key” would garner an additional half-point (the average score of
the two experts), for a total of one and one-half points.

Domain-Specific Problem-Solving Strategies Measure

In this study, the researcher will modify Mayer and Moreno’s (1998) problem-solving
question list to measure domain specific problem-solving strategies. In Mayer and Moreno’s
(1998) research on the split-attention effect in multimedia learning and the dual processing
systems in working memory, participants’ problem-solving strategies were assessed with a set of
retention and transfer questions. Mayer and Moreno (1998) judged a participant’s retention
score by counting the number of predefined major idea units correctly stated by the participant,
regardless of wording. Examples of the predefined answer units for retention were “air rises”,
“water condenses”, “water and crystals fall”, and “wind is dragged downward” (p. 315).

Similarly, Mayer and Moreno (1998) scored the transfer questions by counting the
number of acceptable answers that the participant produced across all of the transfer problems.
For example, an acceptable answer for the first transfer question about decreasing lightning
intensity was “removing positive ions from the ground”, and one of the acceptable answers for a
question about the reason for the presence of clouds without lightning was that “the tops of the
clouds might not be high enough to freeze” (p. 315).

The problem-solving strategies questions designed for this dissertation research have
been adapted for relevance to the tasks associated with Safecracker: finding and opening safes.
Furthermore, the questions are related to the application of strategies relevant to the puzzles and
safes, and solving or cracking, strategies participants may acquire after trying to solve the
problems in the rooms they were assigned. Figure 6 shows the problem solving strategy
questions for retention and transfer which will be used in this dissertation research (modified from the questions developed by Chen, in preparation).

Figure 6: Retention and Transfer Questions

<table>
<thead>
<tr>
<th>Retention questions:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. List how you opened the safe in the first room.</td>
</tr>
<tr>
<td>2. List how you opened the safe in the second room.</td>
</tr>
<tr>
<td>Transfer questions:</td>
</tr>
<tr>
<td>1. List some ways to improve the way you solved opening the safe in room 1</td>
</tr>
<tr>
<td>2. List some ways to improve the way you solved opening the safe in room 2</td>
</tr>
<tr>
<td>3. List some ways to improve the way you navigated from room 1 to room 2</td>
</tr>
</tbody>
</table>

Participants’ retention scores will be counted by the number of predefined major idea units correctly stated by the participant regardless of wording. The example of the answer units for the retention were “follow map”, “find clues”, “find key”, “differentiate rooms” and “tools are cumulative”. Participants’ transfer questions will be scored by counting the number of acceptable answers that the participant produced across all transfer problems. For example, the acceptable answers for the first transfer question in figure 5 include “jot down notes”, and one of the acceptable answers for question three for non-navigation map users would be “use the compass.”

Procedure for the Study

The study will consist of introducing the participants to the objective of the experiment, describing the experiment as an examination of performance in a video game environment, but not discussing the issue of navigation maps. Following the introductions, participants will fill out the demographic and self-regulation questionnaires, after which they will be introduced to the knowledge mapping software and guided through its use.

Next the participants will be introduced to the game. They will be guided through starting the game, use of the interface, navigation to the mansion, opening the lock on the gate outside
the mansion, opening the mansion’s front door, and entering the first room of the mansion. The first room of the mansion contains two safes. One of the safes will already be open. Participants will be guided though searching the room and acquiring at least one item.

Next the participants will fill out a knowledge map related to the game (the pre-test). Following that, at a prescribed time, participants will begin playing the game; continuing the search of the first room and finding the second room, where they will collect additional items any safes that are found. They will again use the knowledge map (intermediate-test) and again fill out the problem-solving strategy questionnaire (intermediate-test). In addition, they will check off the task list for all tasks completed.

Once again, the participants will be given the task of locating two or three rooms and opening any safes that are found. And once again, they will use the knowledge map (post-test), fill out the problem-solving questionnaire (post-test), and check off the task list. A final step will be to debrief the participants, during which participants will be asked if they would like to continue playing on their own. If they say yes, they will be given up to an additional half-hour to play. The purpose of this phase is to examine the motivational effects of the game, to determine the relationship between navigation maps and continued motivation.

Timing Chart

Table 2 lists the activities encompassing the experiment and the times allocated with each activity, and ending with total time.

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>TIME ALLOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>3 minutes</td>
</tr>
<tr>
<td>Self-regulation questionnaire and demographic data</td>
<td>8 minutes</td>
</tr>
<tr>
<td>Activity</td>
<td>Time</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Introduction on knowledge mapping</td>
<td>10 minutes</td>
</tr>
<tr>
<td>Game introduction</td>
<td>10 minutes</td>
</tr>
<tr>
<td>Knowledge map (pre)</td>
<td>5 minutes</td>
</tr>
<tr>
<td>Problem-solving strategy questions (pre)</td>
<td>3 minutes</td>
</tr>
<tr>
<td>Game playing (room 1 &amp; 2)</td>
<td>15 minutes</td>
</tr>
<tr>
<td>Knowledge map (intermediate)</td>
<td>5 minutes</td>
</tr>
<tr>
<td>Problem-solving strategy questions (intermediate)</td>
<td>3 minutes</td>
</tr>
<tr>
<td>Task completion questionnaire for first game</td>
<td>.5 minutes</td>
</tr>
<tr>
<td>Game playing of next two or three rooms</td>
<td>15 minutes</td>
</tr>
<tr>
<td>Knowledge map (post)</td>
<td>5 minutes</td>
</tr>
<tr>
<td>Problem-solving strategy questions (post)</td>
<td>3 minutes</td>
</tr>
<tr>
<td>Task completion questionnaire for first game</td>
<td>.5 minutes</td>
</tr>
<tr>
<td>Debriefing</td>
<td>4 minutes</td>
</tr>
<tr>
<td>TOTAL</td>
<td>90 minutes</td>
</tr>
<tr>
<td>Additional play time</td>
<td>Up to 30 minutes</td>
</tr>
</tbody>
</table>

Data Analysis

Descriptive statistics (e.g., means and standard deviations) will be used throughout the study to describe all measures. The relationship of self-regulation and of presence or absence of a navigation map to task difficulty, as measured by task completion, will be analyzed using correlation analyses.

**Hypothesis 1:** Navigation maps will produce a significant increase in content understanding compared to the control group.
A t-test will be used to compare the effect of a navigation map on content understanding as compared to no map.

**Hypothesis 2:** Navigation maps will produce a significant increase in problem solving strategy retention compared to the control group.

A t-test will be used to compare the effect of a navigation map on problem strategy retention as compared to no map.

**Hypothesis 3:** Navigation maps will produce a significant increase in problem solving strategy transfer compared to the control group.

A t-test will be used to compare the effect of a navigation map on problem strategy transfer as compared to no map.

**Hypothesis 4:** There will be no significant difference in self-regulation between the navigation map group and the control group. However, it is expected that higher levels of self-regulation will be associated with better performance.

Pearson’s correlation will be used to assess the effect of the four self-regulation variables (planning, self-checking/monitoring, self-efficacy, and effort) on the navigation map group as compared to the control group.

**Hypothesis 5:** Navigation maps will produce a significantly greater amount of optional continued game play compared to the control group.

A t-test will be used to compare the effect of a navigation map on continued motivation as compared to no map.
REFERENCES


APPENDIX A

Self-Regulation Questionnaire

Name (please print): _________________________________________________________________

Directions: A number of statements which people have used to describe themselves are given below. Read each statement and indicate how you generally think or feel on learning tasks by marking your answer sheet. There are no right or wrong answers. Do not spend too much time on any one statement. Remember, give the answer that seems to describe how you generally think or feel.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Almost Never</th>
<th>Sometimes</th>
<th>Often</th>
<th>Almost Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I determine how to solve a task before I begin.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2. I check how well I am doing when I solve a task.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3. I work hard to do well even if I don't like a task.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4. I believe I will receive an excellent grade in this course.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5. I carefully plan my course of action.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>6. I ask myself questions to stay on track as I do a task.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>7. I put forth my best effort on tasks.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>8. I’m certain I can understand the most difficult material presented in the readings for this course.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>9. I try to understand tasks before I attempt to solve them.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>10. I check my work while I am doing it.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>11. I work as hard as possible on tasks.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>12. I’m confident I can understand the basic concepts taught in this course.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>13. I try to understand the goal of a task before I attempt to answer.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
14. I almost always know how much of a task I have to complete.  
15. I am willing to do extra work on tasks to improve my knowledge.  
16. I’m confident I can understand the most complex material presented by the teacher in this course.  
17. I figure out my goals and what I need to do to accomplish them.  
18. I judge the correctness of my work.  
19. I concentrate as hard as I can when doing a task.  
20. I’m confident I can do an excellent job on the assignments and tests in this course.  
21. I imagine the parts of a task I have to complete.  
22. I correct my errors.  
23. I work hard on a task even if it does not count.  
24. I expect to do well in this course.  
25. I make sure I understand just what has to be done and how to do it.  
26. I check my accuracy as I progress through a task.  
27. A task is useful to check my knowledge.  
28. I’m certain I can master the skills being taught in this course.  
29. I try to determine what the task requires.  
30. I ask myself, how well am I doing, as I proceed through tasks.  
31. Practice makes perfect.  
32. Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this course.

APPENDIX B

SafeCracker® Expert Map
APPENDIX C

Knowledge Map Specifications

<table>
<thead>
<tr>
<th>General Domain Specification</th>
<th>This Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario</td>
<td>Create a knowledge map on the content understanding of SafeCracker, a computer puzzle-solving game.</td>
</tr>
<tr>
<td>Participants</td>
<td>College students or graduate students. Each works on his/her own knowledge map about SafeCracker, after both the first time and the second time of playing the game.</td>
</tr>
<tr>
<td>Knowledge map concepts/nodes</td>
<td>Fifteen predefined key concepts identified in the content of SafeCracker, by experts of the game and knowledge map professionals. The fifteen predefined concepts are: book, catalog, clue, code, combination, compass, desk, direction, floor plan, key, room, safe, searching, trial-and-error, and tool.</td>
</tr>
<tr>
<td>Knowledge map links</td>
<td>Seven predefined important links of relationships identified in the content of SafeCracker by experts of the game and knowledge map professionals. The seven predefined links are: causes, contains, leads to, part of, prior to, requires, and used for.</td>
</tr>
<tr>
<td>Knowledge map domain/content: SafeCracker</td>
<td>SafeCracker is a computer puzzle-solving game. There are over 50 rooms with about 30 safes; each safe is a puzzle to solve. To solve the puzzles, players need to find out clues and tools hidden</td>
</tr>
</tbody>
</table>
in the rooms, deliberate and reason out the logic and sequence, try to apply what they have found.

| Training of the computer knowledge mapping system | All students will go through the same training session. The training included the following elements:  
• How to construct a knowledge map using the computer mapping system  
• How to play SafeCracker, which is the target domain/content of the programmed knowledge mapper. |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of knowledge to be learned</td>
<td>Problem solving</td>
</tr>
</tbody>
</table>
| Three problem solving measures                | 1. Knowledge map used to measure content understanding and structure, including (a) semantic content score; (b) the number of concepts; and (c) the number of links  
2. Domain specific problem-solving strategy questionnaire, including questions to measure problem-solving retention and transfer  
3. Trait self-regulation questionnaire used to measures the four elements of trait self-regulation: planning, self-checking, self-efficacy, and effort |