BEYOND ENGAGEMENT: INSTRUCTIONAL STRATEGIES THAT FACILITATE
LEARNERS’ COGNITIVE PROCESSES AND PRODUCE EFFECTIVE AND
INSTRUCTIONALLY EFFICIENT E-LEARNING

by

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Abstract

Interactivity has been a focus of e-learning since its inception and remains a critical topic today. However, the technology component of interactivity has often taken center stage with less focus on the learner and the benefits interactivity can have on the learning process. This is despite consistent research (e.g., Hooper & Hannafin, 1991; Kennedy, 2004) that reinforces the idea that instruction will be effective, enjoyable, and intrinsically motivating only if it is interactive at the cognitive level (regardless of modality). Within the corporate environment specifically, there is little evidence of the impact of interactions on enhancing cognition. Within this context, the purpose of this study was to implement instructional strategies that facilitate cognitive processes and apply cognitive load theory in order to create an effective and instructionally efficient e-learning course. Using a series of theory-based interactions embedded within an e-learning course, 2 sets of data were collected. The first set was the performance scores to determine the effectiveness of the e-learning course and the interactions. This data was collected during 5 learner-content interactions, 3 workplace scenarios, and a posttest. The second set of data consisted of the mental effort scores collected immediately following each scored learner-content interaction, workplace scenario, and the posttest. This data was used along with the performance scores to determine the instructional efficiency of each interaction and the e-learning course, through the application of both the 2-dimensional and 3-dimensional efficiency metrics (Tuovinen & Paas, 2004). Unlike previous comparison studies, this study explored the impact of designing an entire course, which included instructional strategies that facilitated cognitive processes and applied cognitive load theory. The results of this study supported the notion that the application
of instructional strategies that facilitate cognitive processes and apply cognitive load theory enable learners to achieve learning outcomes and result in an instructionally efficient e-learning course. The results also support the idea that through the application of these instructional strategies, learners are able to apply the principles learned within simulated workplace scenarios. However, the results for each interaction specific to the 2-dimensional instructional efficiency rating were not as clear-cut. The idea that these instructional strategies would enable instructionally efficient interactions was rejected for 4 of the interactions within the e-learning course when the 2-dimensional instructional efficiency metric was applied. These same interactions produced positive 3-dimensional instructional efficiency ratings indicating that these interactions in fact were or could be deemed instructionally efficient, according to this metric.
Dedication

I dedicate this to my mother, Nancy. Although she did not make it through this journey with me, I know she was by my side during all of its challenges. Without the confidence, perseverance, and courage she was able to instill in me, this lofty academic journey would not have been possible. Love and miss you, Mom!
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It is an understatement when I say it takes a village to reach this height of academic success. If it were not for the loving support of my family and friends, this journey would not have been possible. I am so lucky to have a supportive and understanding husband that stepped in when necessary to make it possible for me to be successful in this academic journey. He picked up the slack for months at a time, allowing for me to be successful in fulfilling this lifetime goal.

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their business need for training made the design and development of the e-learning course possible. Katy Schinas provided graphics and the development of all the interactions at a very, very, reduced rate. TelSim Software and their CEO Tim Freriks provided me with a learning management system (LMS) free of charge to track learners’ progress through the e-learning course and collect the data necessary to do the research. At a reduced rate, Randy Poole of TelSim Software provided me with the programming expertise necessary to tweak the sharable content object reference model (SCORM) code for each interaction and enable the data collection through their LMS. TelSim Software also provided me with the interactive learning agent technology, also free of charge, which made it possible to integrate many of the instructional strategies that facilitated cognitive processes, reduced extraneous cognitive load, and increased germane cognitive load.

Finally, I would like to thank all of the individuals involved with the evaluation of this course, including the subject matter experts provided by Snake Tray, Dr. Ruth Colvin Clark, and Zulma Cintron. Zulma took time away from her busy instructional design and development schedule and concentrated on the interface design and interactivity constructs, and Dr. Ruth Colvin Clark took time out of her very busy research schedule and concentrated on the appropriate application of cognitive load theory.
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CHAPTER 1. INTRODUCTION

Introduction to the Problem

The proliferation of the term *interactivity* throughout academia and the training industry is difficult to ignore. However, if one were to ask 10 people in either profession to explain the benefits of interactivity, each would respond with many different answers. It also seems both professions have become entranced with the technology side of interactivity in e-learning. Some 17 years ago, Hooper and Hannafin (1991, p. 70) argued that, “the underlying problem with ‘technocentric’ perspectives is the attempt to optimize the capabilities of technology rather than learners” and more recently Green and McNeese (2007) agreed, “there is an over emphasis on using technology for technology’s sake rather than using technology to improve learning outcomes” (p. 7).

As evidenced by the literature, interactivity is effective when it moves beyond functional interactivity (the physical clicks) and toward higher-level cognitive interactions (Aldrich, Rogers, & Scaife, 1998; Borsook & Higginbotham-Wheat, 1991; Brady, 2004; Jonassen, 1988; Liaw, 1999; Schwier & Misanchuk, 1993; Sims, 1997, 2000a, 2006). According to Liaw, these types of interactions “involve complex activities by the learners, such as engaging and reflecting, annotating, questioning, answering, pacing, elaborating, discussing, inquiring, problem-solving, linking, constructing, analyzing, evaluating, and synthesizing” (p. 6).
However, Gao and Lehman (2003) found that additional cognitive engagement does not always increase the effectiveness of an interaction. Using reactive and proactive interactions (Schwier, 1993), they found that although the reactive interactions, which provided immediate feedback, increased the effectiveness, the proactive generative interactions did not further increase the effectiveness. They determined that although students spent more time on these interactions, and they did score higher on the posttest, the results were not statistically significant. Gao and Lehman’s findings could be related to the experience levels of their learners. Although the study stated that all learners were familiar with WebCT, there was no indication of their exact experience levels (2003, p. 375). As a result, the proactive generative interactions could have exceeded some of the learners’ working memory capacity, which may explain why the exam scores and motivation findings did not support their hypothesis. More recent research suggests (Clark, 2003; Clark, Nguyen, & Sweller, 2006; Garrison & Cleveland-Innes, 2005; Kennedy, 2004) that cognitive engagement is not enough and interactivity should facilitate a learner’s cognitive processes including organization, integration, metacognition, self-explanations, and elaboration, in order to allow learners to process new information at a deeper level, achieve learning outcomes, and improve performance. One component that must also be applied in order to facilitate cognitive processes effectively is known as cognitive load theory.

According to cognitive load theory (Sweller, 1988), working memory for all learners has limitations, which are dependent on the learner’s existing knowledge and experience. Clark (2003) cites the following example to illustrate this: A novice driver, or an experienced driver on a new route, can experience extraneous cognitive load if they
are distracted from the task of driving. However, experienced drivers who have traveled the same route for years will sometimes find themselves at that destination without remembering how they got there. This phenomenon is referred to as automaticity; the experienced driver was able to extract the knowledge necessary to drive directly from long-term memory and at the same time think of many other unrelated tasks or concepts while driving, therefore leaving them unable to remember how they got there. The continuum of working memory resources leading up to automaticity affects the acceptable levels of extraneous cognitive load, cognitive resources dedicated to portions of a course not related to the learning goals, and germane cognitive load, cognitive resources dedicated to the learning goal. Both can play a large role in the ability of learners to achieve learning outcomes and improve on-job performance. Therefore, the application of cognitive load theory is a critical component to the successful implementation of any learning, regardless of the delivery modality, and becomes a key component for research into the effectiveness of interactivity.

As Kennedy (2004) indicates:

The implication for interactivity researchers is that while the bells and whistles of multimedia may trigger situational interest, the ability of instructional events to promote meaningful cognitive processes (cognitive interactivity) is vital in determining whether a student’s interest is maintained. (p. 52)

It seems however, that interactivity research is either being misinterpreted or simply overlooked by the practitioners. For example, Fisk (2005) cites an instructional designer responsible for designing the course that won top honors, who stated “as we move towards using a higher level of interactivity, we need to create a balance between the student learning and playing games” (p. 5). This suggests that instructional designers are under the impression that they need to select between instruction and games, but this
is contradictory to the research. For example, Kennedy (2004) describes interactions, including games, which are designed to promote cognitive processes and therefore are more effective as instructional tools. Therefore, an e-learning course, which includes several interactions designed and developed through the implementation of several instructional strategies, cited within the literature to facilitate cognitive processes and apply cognitive load theory was created for this study. This e-learning course will also address a specific business goal and will be developed for a corporation, which has identified a need for training.

Background of the Study

Interactivity has been a research focus since the inception of computers as a resource to support education and training. Initially interactivity was aligned with communication and subsequent communication theories (Glaser, 1962, 1963). In the 1960s, there was a move away from instructional television in the classroom with the recognition that this media was expensive and could not replace teachers (Reiser, 2001). In the 1970s the term instructional technology was coined and in the 1980s the term computer-assisted instruction (CAI) was coined with the advent of the personal computer. During this period, researchers began studying interactivity and its instructional implications (Hannafin, 1989; Jonassen, 1988; Moore, 1989).

Within academic environments the focus has been on defining interactivity in terms of levels and dimensions, as well as within collaborative online learning environments which include: learner-to-learner, instructor-to-learner, and learner-content interactions (Aldrich et al., 1998; Kennedy, 2004; Liaw, 1999; Moore, 1989; Petraglia,
Within corporate environments however, interactivity research has been limited, although there have been studies focusing on cognitive load theory and e-learning. This research studied the effect of intrinsic, extraneous, and germane cognitive load through the use of quantitative methods, including, pre- and post-assessments (Allen, 2003; Clark, 2003; Clark & Mayer, 2003; Tuovinen & Paas, 2004; Clark et al., 2006; Sweller, 1988). Within these studies, the measurement of interaction success was determined by the application of an efficiency metric (Paas & van Merriënboer, 1993), which measured instructional efficiency by utilizing the algorithm:

\[
\text{Instructional efficiency} = \frac{\text{performance(zscores)} - \text{mentaleffort(zscores)}}{\sqrt{2}}
\]

As a learner’s mental effort decreases and performance increases the instructional efficiency is high, where as if the mental effort of a learner increases and performance decreases than instructional efficiency is low (Paas, Tuovinen, Tabbers, & van Gerven, 2003). Within these studies, performance effort was recorded through an assessment given after the learning interaction and mental effort was determined through a mental effort survey where learners reported the mental effort required for a specific interaction or performance (Paas, 1992).

Cognitive load theory is needed as a framework for the effective implementation of cognitive interactivity; however, based on the literature review, studies addressing Cognitive Load have focused on individual interactions or lessons rather than the whole course. Much of the research specific to cognitive load theory compared the instructional efficiency of two different methods of instruction, whereas this study will compare the
effectiveness and instructional efficiency of individual interactions for an entire e-
learning course. This study will also combine the application of instructional strategies
for the facilitation of cognitive processes and the adherence to cognitive load theory
specific to an asynchronous e-learning course within a corporate environment.

begin to reflect deeper levels of processing. It is exactly this level of meaningful learning
that is most frequently missing from tutorial types of courseware” (p. 153). Jonassen
suggested that activities utilized within computer-assisted instruction (CAI) were those
that asked learners to recall information and did not require the integration of new
information with existing knowledge. This type of interaction only dealt with a learner’s
working memory, referred to as surface processing (1988). Whereas cognitive strategies
that allow for learners to encode new information into long-term memory, through the
integration of new information with existing knowledge, requires deep meaningful
processing.

“The quest for a meaningful perspective from which to understand and guide
interaction in the face of rapidly evolving technology is no small matter” (Hooper &
Hannafin, 1991, p. 178). Hooper and Hannafin (1991) also note that although technology-
centered interactions can be effective, it is more likely due to the underlying instructional
strategies grounded in instructional theory and they identify specific instructional
strategies that would facilitate learners’ cognitive processes. The instructional strategies
recommended by Hooper and Hannafin (1991) include: (a) organization for improved
retrieval, (b) cueing through the introduction of learning objectives, (c) replication of
real-world challenges, (d) facilitating integration through the introduction of new
knowledge in context of existing knowledge; (e) creating a structure for retrieval by either replicating what a learner will need to do, or by allowing learners to practice the application of key concepts or rules within many different scenarios, and (f) games or simulations that replicate real-world environments or challenges.

However, the importance of interactivity remains an issue for instructional designers. For example, Allen (2003) emphasizes, “instructional interactivity—interaction that actively stimulates the learner’s mind to do those things that improve ability and readiness to perform effectively” (p. 94). This concept moves interactivity to the next level and can be compared to germane cognitive load, which is discussed when applying cognitive load theory (Sweller, 1988). For example, Paas et al. (2003) state “germane cognitive load is the load related to processes that contribute to the construction and automation of schemas” (p. 65). Cognitive load theory also discusses intrinsic and extraneous cognitive load. Intrinsic load is described as the interaction between elements of what a learner already knows and what is being taught (Paas et al., 2003). For example, throughout the literature on cognitive load theory the experiment done with novice and expert chess players (Clark, 2003; Clark, Nguyen, & Sweller, 2006) specific to intrinsic load, the expert sees the entire board as a whole and the novice sees many different chess pieces randomly placed on a board. Therefore, the novice will quickly exceed their cognitive load where the expert, because they see the chess pieces as one chunk, can take on many other elements without overloading their working memory.

On the other hand, extraneous cognitive load is “work imposed on working memory that uses mental capacity but does not contribute to learning” (Clark et al., 2006, p. 346). Instructional designers can directly affect germane and extraneous cognitive
load. Interface design is one of the key elements an instructional designer can leverage in the reduction of extraneous load, the interface should facilitate the learning process, not detract from it by following simple interface design principles (see Head, 1999, pp. 62–64). However, instructional designers can only manage intrinsic cognitive load, by understanding their audience’s content and modality experience. Kennedy (2004) also argues that if instructional interactions are engaging learners cognitively, they will be motivated to continue. Once learners are engaged and therefore intrinsically motivated, he emphasizes that it is important to facilitate learners’ cognitive processes to enable a deeper understanding and therefore achievement of learning outcomes.

Based on these outcomes, and in the context of the corporate sector, it is therefore important to investigate the effectiveness and instructional efficiency of interactions designed to:

1. Facilitate cognitive processes
2. Increase germane cognitive load
3. Decrease extraneous load
4. Manage intrinsic cognitive load

Through such an investigation, instructional designers will be better informed to create interactions and e-learning courses that will achieve their intended outcomes.

Statement of the Problem

A range of instructional strategies targeting the management of intrinsic cognitive load, increasing germane cognitive load while reducing extraneous cognitive load and creating instructionally efficient interactions have emerged from the application of
cognitive load theory (Clark & Mayer, 2003; Clark et al., 2006; Sweller, 1988; Sweller, van Merriënboer, & Paas, 1998; Truman & Truman, 2006). There are also many suggested instructional strategies specific to the increase of cognitive engagement and the facilitation of cognitive processes (Clark, 2003; Gagné, 1985; Garrison & Cleveland-Innes, 2005; Hooper & Hannafin, 1991; Kennedy, 2004).

However, these studies have not focused on self-paced asynchronous e-learning courses within the corporate environment, and an instructional model does not exist which specifies instructional strategies for learner-to-content interactions that facilitate cognitive processes and applies cognitive load theory.

As evidenced by the research, if learners are not applying cognitive strategies, deep processing is unlikely to occur (Garrison & Cleveland-Innes, 2005). Learners need to go beyond surface learning to deeper levels of understanding in order for e-learning to be effective. Therefore, e-learning interactions should not only cognitively engage learners but also facilitate their cognitive processes (cognitive interactivity) and thereby enable more enjoyable, intrinsically motivating, and effective learning (Hooper & Hannafin, 1991; Kennedy, 2004).

The problem therefore is that although throughout the research instructional strategies are identified that enable the facilitation of cognitive processes, and others that are specific to the application of cognitive load theory, currently an instructional model does not exist that identifies instructional strategies as effective and efficient, specific to a self-paced asynchronous e-learning course within a corporate environment.
Purpose of the Study

The purpose of this study was to investigate the effectiveness and instructional efficiency of several interactions and an e-learning environment, which applied instructional strategies, designed to facilitate cognitive processes and applied cognitive load theory. The focus of this research was on the impact of cognitive interactivity within a corporate self-paced asynchronous e-learning course. Particularly, the research explored the affect of instructional strategies that enable interactions and the e-learning course as a whole to:

1. Manage intrinsic cognitive load
2. Decrease extraneous cognitive load
3. Increase germane cognitive load
4. Facilitate cognitive processes
5. Enable learners to achieve learning outcomes; and
6. Enable instructional designers to create instructionally efficient interactions and e-learning environments.

Research Hypotheses

Within a self-paced asynchronous e-learning course in a corporate environment, learner-content interactions designed to manage intrinsic cognitive load, facilitate learners’ cognitive processes, decrease extraneous cognitive load, and increase germane cognitive load will:

1. Enable learners to achieve learning outcomes
2. Enable learners to apply the principles learned within simulated workplace scenarios
3. Enable instructionally efficient interactions
4. Enable an instructionally efficient learning environment

Nature of the Study

As an exploratory quantitative study, the focus was on the cause and effect relationship between applied instructional strategies and the effectiveness and efficiency of the learning environment (Gall, Gall, & Borg, 2003). An e-learning course was created with learner-content interactions designed to facilitate cognitive processes, decrease extraneous cognitive load, and increase germane cognitive load. As an exploratory experimental study, the independent variables were not manipulated and reapplied to determine the effect. As stated by Gall et al. (2003), “These research designs do not permit strong conclusions about cause-and-effect, but are useful for initial exploratory investigations” (p. 295).

The key to this study is the application of interactions designed to facilitate learners’ cognitive processes and the application of cognitive load theory to create effective and instructionally efficient interactions and an effective and instructionally efficient e-learning environment. To date there have been several comparative studies specific to instructional efficiency through the application of cognitive load theory within lessons or single interactions and then compared to lessons or interactions that did not apply these instructional strategies. These studies also collected learning performance through an assessment following the interaction. This study collected learning performance scores during the actual interaction and combined several interactions that
facilitate cognitive processes and apply cognitive load theory to create a self-paced asynchronous e-learning course specifically developed for an identified business need.

The self-paced asynchronous corporate e-learning environment was selected in order to provide a purposeful audience with identified delivery modality and content experience. This environment also narrows down the possible interactions, allowing only for learner-content interactivity and provides a relatively homogenous audience. The goal of this study was to determine if the identified instructional strategies (a) enable learners to achieve learning outcomes, (b) enable learners to apply principles learned within simulated workplace scenarios, (c) create instructionally efficient interactions, and (d) an instructionally efficient e-learning environment.

Significance of the Study

According to the American Society for Training and Development’s “State of the Industry” report (Sugrue & Rivera, 2005)

Use of technology for delivering learning continued to increase, from 24% in 2003 to 27% in 2004 in benchmarking survey organizations, and from 35% to 38% in 2004 in benchmarking forum organizations. BEST (award winning) organizations delivered 32% of all their learning content using technology. Approximately 75% of technology-based learning was online in 2004, and about 75% of online learning was self-paced. (p. 4)

Nearly half of people who plan to participate in a postsecondary education program said they would rather attend one that is online or a mixture of online and on-campus instruction, according to a survey by Eduventures, a research and consulting firm for the education industry. (CLO, 2007, p. 1)

As Sims (2000a) stated, “despite attempts to provide a context for interactivity through taxonomies, levels and dimensions, there remains a level of mystery about its function and purpose” (p. 8). Even though researchers (Aldrich et al., 1998; Chang, 2005;
Gao & Lehman, 2003; Liaw, 1999; Kennedy, 2004; Petraglia, 1998; Moore, 1989; Schwier & Misanchuk, 1993; Sims, 1997, 2000a; Wagner, 1994, 1998) have focused in on the important role that interactivity plays within e-learning and they agree that interactivity is key to the success of e-learning they have all described, defined and categorized interactivity differently. Throughout the research on interactivity, many different terms have been used, including: interaction, instructional interaction, cognitive interactivity, interactivity, system interactivity, and functional interactivity. Although there is consensus that interactivity increases the effectiveness of e-learning, researchers cannot agree on how to define interactivity or on what elements of interactivity make it a necessary ingredient for effective e-learning.

According to Hooper and Hannafin, cognitive interactivity is the key to effective instructional interactions, not system or functional interactivity. As Hooper and Hannafin (1991) state, “the extent to which the learner engages in deep processing is of greater importance than the rate of responding” (p. 84). This is exactly why Kennedy (2004) is urging researchers to investigate the relationship between interactions and the cognitive strategies a learner employs in order to achieve the deep processing that then theoretically will increase a learner’s ability to achieve learning outcomes. These statements suggest that interactivity needs to cognitively engage and facilitate the cognitive processes of our learners in order to enable success in the course and back on the job.

However, Clark et al. (2006) found that with less experienced learners reduced cognitive engagement led to a more effective interaction. In their study they cite that worked and completion examples rather than problem-solving required less cognitive engagement and less time but were more effective in enabling less experienced learners
to achieve learning outcomes. This is a great example of increased germane cognitive load and the reduction of extraneous cognitive load in order to create instructionally efficient and effective interactions. Clark et al. (2006) attribute these findings to cognitive load theory. Problem-solving interactions for these inexperienced learners overloaded working memory, making it difficult for the learners to process the new information. Whereas the worked examples allowed these inexperienced learners to reflect, process the information and build the schema without having to utilize additional working memory to solve the problem. This type of interaction reduces extraneous cognitive load and increase germane cognitive load. However, the decision on whether to include worked examples, completion examples, or problem-solving examples is not clear-cut and can only be made by first determining your audiences experience with both the content and delivery modality and then it can be validated by the learners’ success and the application of the efficiency metric.

The research cited in Clark et al. (2006) includes several studies conducted with many different delivery modalities, most of which were quantitative pre and posttest experiments conducted to test one specific instructional strategy, specific to cognitive load theory. An example of a study sited, would be the application of dual coding through the use of audio and not text to describe complex graphics within a lesson. Each of the experiments cited by Clark et al. (2006) were testing one instructional strategy specific to the application of cognitive load theory for one interaction or lesson. The studies cited by Clark et al. 2006 only applied mental effort during learning within the mental efficiency metric (Paas & van Merriënboer, 1993). Where as this study will analyze the effectiveness and instructional efficiency of nine individual learner-content interactions
as well as the entire course, which was designed to facilitate learners cognitive processes and applied several CLT instructional strategies. This study will include measurements of mental effort during performance as well as during learning. According to Tuovinen and Paas (2004), “it would appear that the student achieving the performance with less effort had learned the content better, and thus it is desirable to take both learning and performance effort measures” (p. 136).

Definition of Terms

*Asynchronous online learning.* Web-based instruction that is typically found within higher education, is facilitated by an instructor, and utilizes software that allows for discussion threads.

*Cognitive interactivity.* Any interaction between learners, learner and content, or learner and instructor, which not only cognitively engages but also facilitates learners’ cognitive processes, including: (a) retrieving, (b) orienting, (c) presenting, and (d) encoding (Aldrich et al., 1998; Hooper & Hannafin, 1991).

*Deep learning.* An “approach to learning…[in which]…material is embraced and digested in the search for meaning” (Garrison & Cleveland-Innes, 2005, p. 137).

*Elaboration.* “Allows learners to combine known with to-be-learned lesson information” (Hannafin, 1989, p. 168).

*Encoding.* A process that makes it possible for learners to transfer the knowledge and skills acquired and practiced within the learning environment to real-life scenarios.

*Extraneous cognitive load.* “Work imposed on working memory that uses mental capacity but does not contribute to learning” (Clark et al., 2006, p. 346).
**Functional interactivity.** Any interaction between learners and content, which has a functional purpose (e.g., navigating through the course). Functional Interactivity is also sometimes referred to as systems interactivity.

**Germane cognitive load.** “Work imposed on working memory that uses mental capacity in ways that contribute to learning” (Clark et al., 2006, p. 346).

**Instructional interaction.** Type of interaction has the goal of instruction.

**Intrinsic cognitive load.** Type of mental effort directly affected by the learner’s experience and knowledge. It is because of this type of load that an interaction can be effective and instructionally efficient for one learner, ineffective and inefficient for a less experienced learner, due to increased intrinsic cognitive load.

**Learning management system (LMS).** Backend software that enables the collection of learner performance scores, time on task, and other relevant reporting data.

**Self-paced asynchronous e-learning.** Web-based training that is typically found within corporate settings, is not facilitated by an instructor, and is in the format of a tutorial.

**Sharable content object reference model (SCORM).** Enables the interoperability of e-learning no matter what the LMS.

**Surface learning.** An “approach to learning…[that]…employs the least amount of effort toward realizing the minimum required outcomes” (Garrison & Cleveland-Innes, 2005, p. 137).

**Systems interactivity.** Sometimes also referred to as functional interactivity, this is any interaction between learners and content that requires the learner to click, highlight, or key in information in order to continue the course.
Two-dimensional instructional efficiency. In this study, this was determined through a calculation of

\[ \text{InstructionalEfficiency} = z\text{LearningPerformance} - z\text{LearningMentalEffort} \div \sqrt{2} \]

This is a further adaptation of Paas and van Merriënboer’s (1993) two-dimensional approach and Tuovinen and Paas’s (2004) adaptation of the calculation which included the learning mental effort rather than the test effort but still used test performance rather than learning performance. In this study, we used learning performance and learning mental effort in the hope of enabling researchers to truly determine instructional efficiency during learning by collecting the performance score during learning and the learning mental effort score immediately following learning.

Three-dimensional instructional efficiency. In this study, this was determined through a calculation of

\[ \text{InstructionalEfficiency} = z\text{TestPerformance} - z\text{LearningMentalEffort} - z\text{TestEffort} \div \sqrt{3} \] (Tuovinen & Paas, 2004, p. 143)

This calculation enables researchers to add a third dimension to the instructional efficiency calculation, which according to Tuovinen and Paas (2004):

It would appear that the student achieving the performance with less effort had learned the content better, and thus it is desirable to take both learning and performance effort measures, into account when computing an instructional measure in conjunction with a performance measure. (p. 136)

Assumptions and Limitations

This research study will make the following assumptions:
1. All participants have the technical ability and bandwidth to receive streaming audio via their computer or laptop.

2. All participants have the basic technical skills necessary to access the course via the learning management system.

This research acknowledges the following limitations of this study:

1. Validity of the e-learning course as an instrument was limited to the approval by two e-learning experts and the subject matter experts.

2. The findings in this study could have other meanings based on interpretation.

3. The findings in this study apply to self-paced asynchronous e-learning where only content to learner interactivity is possible.

Organization of Study

This study includes five chapters. The first chapter introduced the study, discussed the background of the study, the problem statement, the nature of the study, the significance of the study, the research questions, and the assumptions and limitations of the study. The second chapter is the literature review where the research is discussed and analyzed specific to these relevant topics: (a) cognitive load theory, (b) instructional strategies and the cognitive processes they facilitate, (c) learning theory, (d) interface design, and (e) interactivity levels and dimensions. The third chapter is the methodology chapter where the specifics of the study are discussed, the significance of the study particular to the methodology is explained, and a detailed explanation of how the study will be conducted is also covered.
CHAPTER 2. LITERATURE REVIEW

Introduction

The goal of this chapter is to facilitate the selection of the research methods, identify and define the relevance of theoretical frameworks or constructs for each variable, identify the gaps in the current literature, and demonstrate how this particular study will contribute to the current knowledge base. This chapter will place the proposed study in context, through the provision of historical information and an analysis of the current literature. Both the provision of historical information and the analysis of the current literature will (a) clarify the gap, (b) demonstrate the contribution to the current knowledge base, and (c) substantiate the following research hypotheses: Learner-content interactions designed to manage intrinsic cognitive load, facilitate learners’ cognitive processes, decrease extraneous cognitive load, and increase germane cognitive load will:

1. Enable learners to achieve learning outcomes
2. Enable learners to apply the principles learned within simulated workplace scenarios
3. Enable instructionally efficient interactions
4. Enable an instructionally efficient learning environment

The historical information and literature analysis includes the following relevant topics: (a) cognitive load theory, (b) interface design, (c) interactivity constructs, and (d) cognitive processes, and instructional and learning theory.
Cognitive Load Theory

The proper facilitation of cognitive processes, through the implementation of instructional strategies proposed later in this chapter is not possible without the adherence to cognitive load theory (Sweller, 1988). Within cognitive load theory, there are three categories of load: (a) Intrinsic—the load created by the interaction between the elements of instruction and the learners’ experience and knowledge; (b) extraneous—load created by poorly designed instruction that takes the learners attention in a direction unrelated to the learning outcomes; and (c) germane—load generated by effectively designed instruction which facilitates learning (Paas et al., 2003).

The instructional strategies (discussed later) that will be implemented in the e-learning course as an instrument for this study, are dependent upon what the learner already knows, what their experience is with the delivery modality and content, as well as what it is that the instructional designer is attempting to teach. All of these variables contribute to the continuum of working memory, long-term memory, and retrieval. As Clark (2003) explains, cognitive load is “the amount of work imposed on working memory” (p. 46) which of course is different depending on the learner’s experience with the content area and delivery modality. This difference is referred to as intrinsic cognitive load. Which means some learners may already be experiencing significant cognitive load just by simply navigating a course. Therefore, some learners will experience cognitive overload sooner than others will experience it. Once this occurs working memory is unable to process and connect new information to existing information in long-term memory through retrieval. Cognitive overload has additional possible complications,
including: learner frustration and learner dropout prior to a course's completion. (Sweller, 1988)

The more experience a learner has with a concept or a skill, the easier they are able to retrieve information from long-term memory without involving their working memory, making it easier for them to incorporate the new information. Then there are those that are considered experts where automaticity is possible. Automaticity as explained by Clark (2003) is where a learner does not need to engage working memory at all to retrieve information related to a task (cognitive or behavioral) that has been performed many times. Less experienced learners might struggle with new concepts and skills because they need to use their working memory to process the new concepts or skills and to retrieve the existing knowledge. Of course, how much they need to involve their working memory is dependent on what their experience is with the content and the delivery modality.

This principle was evident within Chang’s (2005) study where the experienced online students performed better because they were able to concentrate on the content presented within the lessons and were not engaging working memory to interact within the online environment. Therefore, these learners had more working memory to dedicate to learning the new concepts. This is why it is crucial to conduct an audience analysis to determine the experience levels of learners specifically, delivery modality and content.

As stated by van Merriënboer and Sweller (2005), “effective instructional methods encourage learners to invest free processing resources to schema construction and automation, evoking germane cognitive load” (p. 152). Therefore, according to Clark et al. (2006), instructionally efficient learning environments—no matter the modality—
need to manage intrinsic load, decrease extraneous load, and increase germane cognitive load, through the implementation of specific instructional guidelines:

1. “Accelerate expertise with dual modalities” (p. 46).
   a. Explain graphics with audio
   b. Use diagrams to facilitate a deeper understanding.

2. Focus learners’ attention to facilitate achieving learning outcomes and prevent split attention.
   a. Use signals and cues.
   b. Integrate words and graphics.

3. Less is more.
   a. Convey information concisely.
   b. Summarize content through visuals explained by audio.
   c. Eliminate unnecessary information provided graphics, text, and diagrams.

4. Facilitate working memory through provided scaffolding.
   a. Provide job aids which comply with cognitive load theory.

5. Break down processes to chunks of instruction that gradually increase in difficulty.

6. Use both worked and completion examples to ease extraneous cognitive load.

7. Design instruction, which increases germane load and decreases extraneous load.
   a. Present content within different contexts.
   b. Facilitate far transfer.
   c. Facilitate self-explanations.

8. Manage intrinsic cognitive load.
a. Design for specific levels of content and modality expertise.

The studies cited (Clark et al., 2006) that have implemented cognitive load theory instructional guidelines were evaluated through the implementation of the efficiency metric (see Paas & van Merriënboer, 1993). Most of these studies were posttest only or pre and posttest control group studies. These studies also considered learning performance through the use of an assessment after the learning occurred. None of the studies cited compared complete courses, which had implemented several of the suggested instructional guidelines specific to cognitive load theory. Each experiment was usually done on one lesson or interaction specific to one of the instructional guidelines, for example, one interaction or lesson done as worked examples vs. problem-solving.

Instructional strategies specific to the (a) facilitation of cognitive processes, (b) the management of intrinsic load, (c) increasing germane cognitive load, and (d) decreasing extraneous cognitive load, are discussed in greater detail within the cognitive processes and instructional strategies section within this chapter.

Interface Design

According to Head (1999), “an interface is the visible piece of a system that a user sees or hears or touches” (p. 4); therefore, interface design is the design of these components. Although interface design is not a critical component to this research, it is worth mentioning because as Allen (2003) states when it comes to interface design, specifically a learner interface, it must be a facilitator not a distraction or complication to the learning. According to Allen (2003), the elements of an effective learner-interface design include (a) reducing cognitive load, (b) facilitating success, and (c) supporting
features. The use of the interface is referred to as usability. One of the founders of interface design principles, Donald Norman, was quoted in an *eLearn* magazine article (Feldstein, 2002) as saying when it comes to e-learning, “usability is not the major issue; learnability is” (p. 1). This means instructional designers and developers of e-learning must look beyond traditional interface design and usability an e-learning course must also consider the facilitation of the learning process. If learners do experience errors, and have to think about the interface in order to navigate appropriately, and are expending working memory and energy trying to negotiate the course. It is likely learners will not learn what they were supposed to learn, they may not complete the interaction, and they might leave the course.

Head (1999) broke down the concepts of *usability* and *learnability* into three distinct categories: (a) aesthetics: assist users visually by providing direction in the tasks necessary and by limiting cognitive load through the appropriate use of color and layout; (b) task support, and (c) usability. Based on these principles Head has created templates that can be used in order to create and/or evaluate interfaces that have been created to provide information to users (see Head, 1999, pp. 62–64).

**Interactivity Constructs**

A variety of researchers (e.g., Aldrich et al., 1998; Kennedy, 2004; Liaw, 1999; Moore, 1989; Petraglia, 1998; Schwier & Misanchuk, 1993; Sims, 1997, 2000a, 2006; Wagner, 1994, 1997, 1998) have defined the levels and dimensions of interaction and created taxonomies of interactivity.
Schwier (1993) created a taxonomy of interaction which he explains “grew out of the interactive videodisc literature, which used the term levels to describe hardware-dependent ways learners could operate equipment and software” (p. 3). Schwier’s interaction taxonomy describes three levels of interaction. The lowest level being reactive where a learner is reacting to a prompt within the e-learning environment, the second level is proactive where the learner has more control and is able to generate different responses from the e-learning environment, and mutual where the learner is submersed in the environment, like with a simulation or virtual reality scenario. He then goes on to describe possible roles (e.g., navigation), as well as the connections made to the interface through the actual physical contact made by a learner (1993). From an e-learning developer’s standpoint, Sims (1997) defined interactivity levels by their roles (e.g. hyperlinked navigation, linear navigation, and reflection).

Moore (1989) defined levels of interactivity by whom or what was interacting in order for learning to occur, these levels included learner-content, learner-instructor, and learner-learner interactivity. Then Hillman, Willis, and Gunawardena (1994) determined that Moore’s definition of interaction omitted learner-interface interaction, which they point out as a key interaction for all e-learning. Sims (2006) expands Moore’s (1989) levels of interactivity even further by introducing the inherent interaction between the instructional designer and learner. Schwier and Misanchuk (1993) expanded upon the levels of interactivity that were originally introduced specific to video learning (levels I, II, III and IV) and created a taxonomy of interaction. Within this taxonomy, they included (a) levels of interactivity: reactive, proactive, and mutual; (b) functions of
According to Elsenheimer (2003), interaction is one of the key elements of engagement within an e-learning course that increases completion rates and enables participants to achieve learning outcomes. He describes several levels; the lowest level of interaction as linear navigation going from page to page which requires no real thinking or engagement on the learners’ part. The highest level of interaction that Elsenheimer (2003) explains are questions forcing a learner to think.

However, the terms interactivity and interaction are controversial within the literature. Most of the research on interactivity use these terms interchangeably, however Wagner (1994) makes a distinction by linking interactivity with the delivery modality or technology and interaction as instructional. Therefore, according to Wagner, an instructional interaction does not necessarily require system interactivity. Aldrich et al. (1998) bring about the concept of cognitive interactivity, the idea of facilitating learners’ cognitive processes in order to improve engagement. Aldrich et al. (1998) believe although these taxonomies, dimensions, and definitions begin to define interactivity they lack a true understanding of interactivities affect on a learner because they do not consider the cognitive processes a learner is experiencing while interacting with another learner, content, or an instructor. Kennedy (2004) agrees, as he argues researchers are missing a key component to interactivity, the cognitive processes a user experiences that make the learning a success (p. 45). Therefore, after Kennedy completed his research he asks: “under what circumstances do interactive instructional events promote cognitive strategy use and is this reflected in more favourable outcomes” (2004, p. 53) As Garrison
& Cleveland-Innes (2005) so eloquently state; “Interaction by itself does not presume that one is engaged in a process of inquiry and cognitive presence exists” (p. 135). According to Truman and Truman (2006), although educational technology has evolved and now allows for the active involvement of our learners, it seems there has been little thought placed on how these technologies facilitate our learners’ cognitive processes. As Hooper and Hannafin (1991) state so eloquently, “perhaps the underlying problem with ‘technocentric’ perspectives is the attempt to optimize the capabilities of technology rather than learners” (p. 70).

Therefore, the question remains, how do instructional designers develop e-learning courses that enable cognitive strategies, which in turn allow learners to achieve learning outcomes (Garrison & Cleveland-Innes, 2005). When does interactivity facilitate a learner’s success in an e-learning course? Sims (2006) suggests “a set of heuristics that will maximize the likelihood of an online course achieving both the learning outcomes and providing an engaging learning experience” (p. 1) through the improvement and evaluation of interactivity. Glenn, Hoyt, and Jones (2003) discussed knowing how your audience learns being more important in an e-learning environment. However, in their research nothing was discussed on what they did to facilitate learners’ cognitive processes. As Northrup (2001) succinctly states: “interaction doesn’t just happen…. It must be designed intentionally into the Web-based course” (p. 5). However, this statement is only partially true. Interaction does sometimes happen without intention; it is instructional interaction that needs to be designed intentionally in order to create effective asynchronous e-learning courses. That is why there is a need for continued research into the area of cognitive interactions in order to determine what interactions facilitate
learners’ cognitive processes in a self-paced asynchronous e-learning course within a corporate environment.

Wagner (1994) points out that: “although there appears to be a growing acceptance of a causal relationship between system interactivity and instructional interaction, neither concept has been clearly or functionally defined” (p. 6). Wagner (1994) explains that due to the growing acceptance individuals involved with new learning technologies are expecting the technologies to be able to create effective instructional interactions. When in fact instructional designers and developers need to let the technologies take a back seat to learner characteristics, instructional theory, and learning theory. Once a decision has been made on the right instructional theory in context of a specific audience and content the instructional designer/developer can then determine the delivery modality and technologies as appropriate.

To demonstrate the complexity of instructional interactions, Wagner (1997) identified 12 types or modes for interaction: participation, communication, feedback, elaboration, learner control/self-regulation, motivation, negotiation, team building, discovery, exploration, clarification, and closure. However, Wagner cautions that although it is obvious that some if not all of these interactions are necessary for effective learning. “What is not so clear, at least not when viewing interaction as an independent construct, is the value that interaction brings to a learning endeavor when interaction is viewed out of the context of a specific learning endeavor” (Wagner, 1997, p. 5).

Sims (1997) takes a similar approach to instructional interaction. He terms it interactivity and identifies possible interactivity types from a developer’s perspective. Each interactivity type Sims (1997) identifies combines instructional interaction with the
system interactivity that will be necessary to support the execution of the instructional interaction. Sims (1997) identifies the following:

1. Object interactivity: when a learner selects elements using the mouse.
2. Linear interactivity: navigation to or from a page sequentially.
3. Support interactivity: allows a learner to access performance support.
4. Update interactivity: provides personalized feedback.
5. Construct interactivity: learner is able to create new items within the environment in order to meet specific learning objectives.
6. Reflective interactivity: learner is able to answer questions and then review expert and/or other learner answers.
7. Simulation interactivity: learner controlled pacing through a simulated environment, which allows a learner to closely experience what they may in a real-life scenario.
8. Hyperlinked interactivity: learner controlled navigation, which allows learners to access as little or as much as they feel, is necessary.
9. Non-immersive contextual interactivity: learner is not completely submersed into a virtual environment; however, all of the interactions replicate real-world tasks.
10. Immersive virtual interactivity: learner is immersed into a replicate of the environment they are expected to perform their daily tasks.

Aldrich et al. (1998) explain that although these taxonomies and categories of interactivity are effective in defining and describing what the possibilities are when it comes to interactivity in learning environments. At the same time, all of these researchers’ attempts in defining, describing, and categorizing interactivity omit a key element of learner interaction, which is the cognitive process a learner is experiencing, that is described by Aldrich et al. as cognitive interactivity, “the interaction between internal and external representations when performing cognitive tasks (e.g., learning)”
Kennedy (2004) agrees that researchers are missing a key component to interactivity, the cognitive processes a user experiences that make the learning a success (2004, p. 45). It is through these cognitive processes that a learner has either a surface level or deep understanding of the material instructional designers are attempting to teach. The instructional activities provided within our courseware can promote either rote memorization or a deeper conceptual understanding. Cognitive strategies like organization, integration, transfer, retrieval plans, enabling contexts, cognitive dissonance, metacognition, and cognitive practice all promote a deeper understanding. Kennedy (2004) believes that these cognitive strategies improve learning outcomes; “thus interactive learning designs and instructional events that actively promote cognitive strategy use should, theoretically, be reflected in greater recall of material and deeper conceptual understanding” (p. 53).

Petraglia states, “In contrast to learning through passive exposure to information, interactivity is often especially valued for its ability to engage the student in the material” (p. 57). In general, the research supports high-level interactions as the most effective for engaging learners, whether they are learner-content, learner-learner, or learner-instructor interactions. These high-level interactions need to “involve complex activities by the learners, such as engaging and reflecting, annotating, questioning, answering, pacing, elaborating, discussing, inquiring, problem-solving, linking, constructing, analyzing, evaluating, and synthesizing” (Liaw, 1999, p. 6). All of these high-level interactions require deeper processing by the learner therefore not only will these interactions engage but theoretically will allow for a deeper understanding of the materials (Garrison & Cleveland, 2005).
Gao and Lehman (2003) identified additional cognitive engagement does not always increase the effectiveness of an interaction. They found that although the reactive interactions (see Schwier, 1993), which provided immediate feedback, increased the effectiveness of the interactions, the proactive generative interactions (see Schwier, 1993) did not further increase the effectiveness of these interactions. They found that although students spent more time on these interactions, and they did score a bit higher on the posttest the results were not statistically significant. These findings did not support their hypothesis:

Students who receive learning material with a proactive interaction level will score higher than those who receive learning material with a reactive interaction level; and those who receive learning material with a reactive interaction level will score higher than those who receive learning material with a low interaction level on the achievement measure (Gao & Lehman, 2003, pp. 373–374).

Just as Sims (2000b) reported, “what the data revealed was a marked differentiation in allocation over a range of the examples, reinforcing the observation that the individual learner’s characteristics may be the essential component in achieving successful interactive encounters” (p. 6). Gao and Lehman’s (2003) findings could also be related to the characteristics of their learners. For example, the experience levels of their learners, specific to modality and content. Although their study attempted to define their audience’s experience with both WebCT and with the content, there was no indication of their exact experience levels or their mental effort while participating in this course. As a result, the proactive generative (see Schweir, 1993) interactions could have placed some learners in a scenario where they exceeded their cognitive load capacity,
which may explain why the exam scores and motivation findings did not support their hypothesis (Clark, 2003).

Gao and Lehman also indicated that although the scores were not significantly better on the posttest that it is possible that learners achieved significantly better far transfer (see Gagné, 1985). Therefore, they suggested future research on interactivity include a way in which to determine if deeper processing occurred allowing for learners to retain the new information for a longer period of time. In order to determine if deeper processing occurred learners could be surveyed or a posttest could be administered after some time had elapsed or in the case of a corporate scenario once, they are given a chance to apply their newly acquired knowledge.

It seems instructional designers within the corporate arena are also unsure of what instructional interaction or interactivity is and why it is beneficial. In Fisk’s (2005) article that highlighted e-learning courses that received top honors from their peers at an example emporium, under the topic heading “Lessons Learned” the instructional designers stated: “As we move towards using a higher level of interactivity, we need to create a balance between the student learning and playing games” (p. 5). It seems that there is a disconnect between the academic research of high-level interactions, and the corporate instructional designers that are applying higher-level interactions within their courseware.

There should not be a need to balance between learning and playing games as the games we design should incorporate instructional strategies that facilitate cognitive strategies and therefore promote learning. Unfortunately, it seems within the corporate arena an e-learning course’s effectiveness is determined on the interactivity wow factor,
not on whether learners achieved learning outcomes and were ultimately successful back on the job. The interactions we currently applaud might be cool and learners might like them. However, it seems neither the academic scholars nor the practitioners have a clear understanding of interactivity and its implications.

In general, the research states that interactivity is a necessary element of effective e-learning and higher levels of interactivity, which engage learners cognitively are the most effective. Although there has been a focus on interactivity it has been a heavy academic focus where the students are participating in asynchronous online learning, which unlike self-paced asynchronous e-learning, typically includes learner-instructor, learner-learner, and learner to content interaction. Recently Sims (2006) did make the distinction between e-learning typically found in academic environments versus corporate e-learning. The fact he brings to our attention is that some of his interactivity metrics are better applied to what he terms *self-paced* (SP), which is more of a corporate e-learning strategy. While others make sense for collaborative online (CO) environments, which is more prevalent within academic e-learning environments, while some work for both and he identifies these as appropriate (p. 1).

The question that remains in the realm of interactivity is, how instructional designers “create the cognitive presence consistent with deep meaning and understanding” (Garrison & Cleveland-Innes, 2005). It is not the amount of interactivity, or the number of interactions a learner encounters. According to Hooper and Hannafin, “Greater emphasis is placed on the learner as an active processor of information. Thus, the extent to which the learner engages in deep processing is of greater importance than the rate of responding” (1991, p. 84). This is exactly why Kennedy (2004) is urging
researchers to investigate the relationship between interactions and the cognitive strategies a learner employs in order to achieve the deep processing that then theoretically will increase a learner’s ability to achieve learning outcomes. Kennedy suggests the term *cognitive interactivity* and defines it as “a continuous, dynamic relationship between instructional events and students’ cognitive processes that are mediated by their behavioral processes” (2004, p. 58).

Cognitive Processes and Instructional Theory

As described by van Merriënboer and Sweller (2005) “cognitive load theory (CLT) uses interactions between information structures and knowledge of human cognition to determine instructional design” (p. 147). In order to design interactions that promote learning instructional designers need to understand the cognitive processes a learner is experiencing during the learning process. Hooper and Hannafin (1991) suggest not only to understand these processes but also to base instructional strategies on the cognitive processes our learners employ in order to learn. Kennedy (2004) also discusses cognitive processes but refers to them as cognitive strategies. “Cognitive strategies are the internal mental processes, operations and procedures that students engage in to acquire, integrate, organize, and retain new information” (p. 50). Kennedy defined the term cognitive interactivity as “a continuous, dynamic relationship between instructional events and students’ cognitive processes that are mediated by their behavioral processes” (2004, p. 58). Meaning how does the interaction with multimedia affect a learner’s cognitive processes and when do these processes increase the ability for the learner to be successful in the course? Kennedy (2004) suggests that researchers need to bring users’
cognitive processes while interacting with multimedia to the forefront of the research. He believes if researchers continue to do more research in the area of cognitive interactivity, instructional strategies will improve and be able to better promote cognitive interactivity and therefore increase the achievement of desired learning outcomes.

The cognitive phases that are analyzed throughout this section are as follows: (a) retrieving, (b) orienting, (c) presenting, and (d) encoding (pp. 71–88). Within each of these phases instructional strategies are discussed which facilitate learning during that cognitive phase. Many of these cognitive processes are dependent upon what the learner already knows, what their experience is and what an instructional designer is attempting to teach. All of these variables contribute to the continuum of working memory, long-term memory, and retrieval, which of course effects transfer of learning and involves cognitive load theory, which will also be discussed.

**Retrieving**

According to Clark (2003), “in the cognitive model, learning is about active construction of new knowledge by interacting with new information, and instruction is about promoting the psychological processes that mediate that construction” (p. 5). This construction of knowledge requires a learner to retrieve existing knowledge in order to integrate it with the new information (Clark, 2003). This is why retrieving is a crucial part of the process of learning and why Hooper and Hannafin (1991) describe several instructional strategies to facilitate this process including (a) organization, (b) integration, (c) transfer, and (d) retrieval plans (pp. 71–75).
Organizing for Improved Processing

Organization is an instructional strategy, which can improve retrieval (Hooper & Hannafin, 1991). According to Jonassen (1988) “Organizational strategies are helpful in structuring and restructuring one’s knowledge base, that is, seeing how ideas relate to other ideas” (p. 156). Strategies like mind mapping and strategies which categorize key concepts, remind learners of what they know and require them to analyze the relationships between the new and existing information as well as begin building new relationships for the new concepts. Organizational instructional strategy also includes grouping or modularization of material, which instructional designers can employ through the creation of modules or lessons that facilitate retrieval. Topic headings or page headings also enable a learner to organize the material strengthening their ability to encode and retrieve. Clark (2003) refers to these as “signals and cues” (p. 74) including: (a) transitions, (b) headings, (c) subheadings, (d) summaries, (e) topic introduction and (f) learning objectives. Signals point out what is important, give information organization, and provide structure for smaller chunks of information within topics that can be handled more efficiently by working memory.

Hannafin, Land, and Oliver’s (1999) open learning environments instructional theory suggests “conceptual scaffolding” (Reigeluth, 1999, p. 132) as an instructional strategy to facilitate retrieval through organization. Here the instructional designer directs the learner to the key concepts of a particular challenge through the presentation of learning objectives, or the creation of a structure within the course, which outlines the key concepts. An example could be asking learners to participate in a challenge within
the learning environment, which replicates a challenge that will be encountered on the job, composed of these key concepts.

Jonassen (1988) suggests guiding learners to the important concepts by highlighting them in a glossary or through headings, then having the key concepts linked or categorized through the identification of common properties or perhaps uncommon properties. This can be done through a job-aide type document, matrix, or concept mapping.

Gagné (1985) suggests providing learning objectives in order to provide cues for the learner on what is important and to create categories for the information the instructional designer is attempting to teach therefore improving retrieval. He also suggests the following strategies for reinforcing what is important and building organization or hierarchy within a learner’s long-term memory, and to improve retrieval and achieve learning outcomes when learning rules: (a) Asking questions that force the learner to recall concepts they have just learned, (b) asking questions that force the learner to demonstrate what they have just learned, (c) providing feedback to reinforce or remediate the new concepts learners just constructed, and (d) using the same verbiage that was used while they learned the new information in order to provide cues while they are applying it for the first time. All of these suggest more of a designer-controlled scenario where information is introduced and categorized in a particular manner within a particular context in order to facilitate the retrieval of information. However, Hooper and Hannafin (1991) also suggest that there is a place for hypertext or a more random access of information driven by the learner creating a more customizable path to learning. This type of strategy may be more appropriate for highly motivated learners. As Schwier and
Misanchuck (1993) suggest, “a highly motivated learner may benefit from open-ended strategies” (p. 157). Organization whether the learner has options or not, provides internal cues for the learners that will facilitate recall. The goal of organization as an instructional strategy, which facilitates the cognitive process of retrieving is to present information in a way that is more manageable, begin creating relationships between the new information and existing schema, begin creating relationships between the new information, and to let learners know what is important. These strategies enable learners to create and then rely on internal cues, throughout the course and after they complete the course when they need to apply their newly acquired knowledge.

*Integrating New Information Into Existing Schema*

When a learner encodes information for the first time, the encoding and later retrieval is strengthened if learners are required to bring existing knowledge into working memory and then integrate the new knowledge into this schema. As Gagné states “However encoding is done, its most important function is to make the learned information memorable as well as transferable to situations the learner will later encounter” (p. 171). That is exactly why the activation of existing knowledge and experience and the subsequent “integration” (Hooper & Hannafin, 1991, p. 73) of new information with existing knowledge is crucial to the learning process. The concept of integration is based on schema theory where “knowledge is stored in long-term memory in the form of schemas” (Sweller et al., 1998, p. 255). Schemas not only store information they reduce the load on working memory and organize information to make it easier to retrieve the information when necessary (Sweller et al., 1998). Integration is one step beyond recall, as information is now in context of existing knowledge within
long-term memory, not short-term memory where recall is engaged. As explained by Choi and Hannafin (1995), “Situated cognition emphasizes the importance of context in establishing meaningful linkages with learner experience and in promoting connections among knowledge, skill, and experience” (p. 4). When the learning is in context of the learners’ experiences and builds upon their current knowledge, it becomes more significant to the learner and therefore more easily retrievable because it is linked to that existing schema. Instructional strategies for integration must first activate relevant prior knowledge in order to facilitate the integration of new information into existing schema (Clark, 2003).

In order for instructional designers to implement integration as an instructional strategy, their success hinges upon their knowledge of the audience, including experience with content, how learners will apply the newly acquired knowledge, and their experience with the delivery modality. This knowledge enables the instructional designer to design and develop cognitive activities that build on learners’ knowledge and or experience.

Mayer’s (1999) designing for constructivist learning theory discusses the implementation of advance organizers, diagrams, worked examples, and elaborative questions as techniques to integrate new information into existing schema (Reigeluth, 1999, p. 155). Each of these strategies facilitates the activation of existing knowledge and the integration of the new information within the appropriate schema improving retrieval.

Advance organizers suggested by Mayer (1999) are those that activate prior knowledge through a relevant analogy. The relevance of the analogy needs to be generated by the concept that an instructional designer is attempting to teach. Gagné (1985) also suggests advance organizers in the form of a brief textual passage as a
strategy to provide meaningful context enabling learners to activate appropriate prior knowledge and then integrate the new information into the appropriate schema.

According to Clark et al. (2006), Gagné (1985), and Mayer (1999), diagrams not only assist with the integration of new information they also provide organization and cues for the key concepts an instructional designer is attempting to teach. However, according to Mayer’s theory in order to increase the effectiveness of the integration facilitation for diagrams, if an explanation is necessary then the explanations in text should be integrated into the diagram. Clark et al. (2006) agree based on their research and the research of Mayer, they discuss describing diagrams, or other visuals with audio or text and that if the description is with text that the text is integrated into the visual. This recommendation is based on the limited capacity of working memory and cognitive load theory.

Worked examples are another instructional strategy specific to the facilitation of integrating new information with existing knowledge in order to improve retrieval. According to van Merriënboer and Sweller (2005), worked examples “reduce extraneous cognitive load caused by weak-method problem-solving; focus learner’s attention on problem states and useful solution steps” (p. 151). The concept behind worked examples is to reduce extraneous cognitive load by presenting a systematic process of solving a problem that a learner can review and reflect upon. Both van Merriënboer and Sweller (2005) and Clark et al. (2006) also discuss completion examples. The concept of completion examples brings worked examples one step closer to problem-solving by continuing to decrease the cognitive load through stepping a learner through most of the
problem but then increasing germane cognitive load by requesting that the learner completes the problem on their own.

Another instructional strategy that facilitates integration is a conversational style of narration and storytelling within the context of real-life scenarios (Allen, 2003; Clark & Mayer, 2003). These instructional strategies also activate prior knowledge and facilitate the integration of new information into the appropriate schema. Both storytelling and a conversational style are cognitively engaging and they give the learner the context to build upon and relate back to when the learner attempts to apply the newly acquired knowledge once they are back on the job. According to Clark et al. (2006), conversational style can be used effectively by presenting information more personally by speaking directly to the learner through the use of the first and second person. According to Allen (2003), storytelling within the context of real-life scenarios places new information in context, creates a memorable structure, increases credibility, engages learners, allows learners to build on their current knowledge and experience, improves retrieval, and improves transfer of learning.

Once a connection has been made to the schema, through the activation of existing knowledge and the integration of the new information, Clark (2003) suggests, “elaborated practice” (p. 125) where learners are asked to retrieve this information several times in order to facilitate different interactions. The concept behind this type of practice is to allow the learner to apply the new concepts to different challenges, making it an even more effective retrieval and integration strategy.

Jonassen (1988) discusses designing an e-learning environment where the interactions within the environment facilitate the cognitive processes a learner
experiences while learning. He also suggests, “Adopting a functional context, performance-oriented strategy in instruction” (p. 146) in order to “enhance learning and transfer” (p. 146). Jonassen’s theory of “designing constructivist learning environments” (Reigeluth, 1999, p. 215) states that all tasks within the learning environment must engage learners by presenting tasks within real-world scenarios that are relevant to what the learners will do once they complete the course. The second key to successful practice within an e-learning environment is that the learner must be asked to manipulate elements and immediately see the results of the manipulation within the learning environment in order to increase engagement through ownership.

Although practice is not accomplished through all interactivity, interactivity within an e-learning environment is necessary for practice. As Schwier and Misanchuk (1993) state, “Practice is a larger construct which subsumes a much wider range of activity than just interaction” (p. 180). Schwier and Misanchuk recommend 10 principles for practice within an e-learning environment based on instructional theory.

1. Vary the practice exercises.

2. Increase the complexity and difficulty level of practice as a learner gains new knowledge and skills throughout the course.

3. Begin practice with hints, cues, and tips. Then as the learner progresses through the course begin fading this type of support.

4. Start with practice early and often and gradually increase the time in-between practice.

5. Where skills require automaticity start with practice requiring accuracy, then speed, and finally automaticity.

6. Although a summary where presented information may not be interactive, it is cognitively engaging and therefore promotes recall.
7. Feedback for all practice should be provided whether the correct or incorrect answer is supplied. The feedback should also provide guidance.

8. Integrate strategies that provide organization to the presented information, for example, “mnemonic devices, concept maps, epitomes, analogies, and outlines” (p. 183).

9. Require learners to not only apply new information presented but also to “discover and derive new relationships in information” (p. 183).

10. Practice follows the ARCS model of motivation (see Keller, 1983).

Van Merriënboer (1997) suggests “variability of practice,” which according to the author will “encourage learners to develop cognitive schemata, because it increases the chances that similar features can be identified and that relevant features can be distinguished from irrelevant ones” (p. 188). Another instructional strategy he recommends specific to practice is “contextual interference” (p. 188). The key to contextual interference as a strategy for practice is that the practice is random and cognitive load is increased. However, based on the studies, which show contextual interference to be an effective strategy for the practice of complex cognitive skills the load that is increased is germane load. In order to ensure germane cognitive load is increasing and extraneous cognitive load is kept to a minimum it is crucial to know the audience experience with the content and the delivery modality.

Near and Far Transfer

Integration strategies also must consider if the concept or skill that the learner is being taught requires near or far transfer. As Clark et al. (2006) point out, these are “not really two separate categories but represent a continuum” (pp. 220–221). According to Clark (2003), “The knowledge may be present in long-term memory as evidenced by a test following the training” (p. 27). However, a learner can experience “transfer failure”
(p. 27) and not be able to retrieve the new information when necessary. Gao and Lehman (2003) were discussing the reduction of transfer failure as a possible benefit of proactive generative interactions but could not substantiate this through the posttest they administered. When learners are asked to retrieve exact information it is referred to as near transfer, while if a learner is retrieving information that builds a case for a conclusion or requires adaptation of the skill or underlying concepts, far transfer is required, which will be visited later (Hooper & Hannafin, 1991).

Near transfer occurs when the learning environment can replicate the steps or processes involving the new information and is typically approached through instructional strategies such as drill and practice. If a learner has a chance to practice retrieving this information within the context of real-life scenarios within the learning environment, then the likelihood of being able to retrieve the information when faced with similar context outside of the classroom increases. However, far transfer is where it is impossible for a learning environment to replicate all of the possibilities and therefore requires a true understanding of underlying concepts to be able to apply those concepts no matter what situation is presented back on the job.

When someone can perform a task several times, it does not necessarily mean they understand the underlying principles. It is possible that they have performed the task enough to know what to do (behavior or skill), not necessarily why they are doing it. A great example of this is a deckhand that works on a tugboat on a daily basis tying up barges to bring into the harbor. Although he or she does this on a daily basis, it does not mean they understand the underlying concepts and maybe they do not need to understand these concepts. In order for an instructional designer to avoid transfer failure, they must
make the correct determination and apply the appropriate instructional strategies for either near or far transfer. For example, if a deckhand has to deal with many different barges and ships it would be necessary for him or her to understand the underlying principles, concepts and rules in order to apply them to the different possibilities (far transfer). Where as if a deckhand will only be dealing with a particular barge type they just need to know what they need to do (near transfer) not the underlying principles, rules or concepts. When an instructional designer gets into explaining the why and the underlying principles, rules, and concepts it becomes necessary to use more than behavioral instructional strategies and begin applying cognitive instructional strategies to achieve far transfer.

Another example of far transfer might be rules for managers to follow specific to legal issues like sexual harassment. Therefore, without telling a learner every possible scenario that might be construed as sexual harassment learners are given core values or concepts, which should be applied to all scenarios when attempting to determine if sexual harassment has occurred. This would demonstrate that learners understand the underlying concepts and not just the ability to perform. The same principle applies to sales people. Although it is impossible to present all the possible customers that may make a good fit for a particular product rules can be given as to how to qualify a customer for a particular product. Advanced organizers can be provided to begin setting up the core possible configurations where that product may fit and scenarios can be presented that represent a few possible customers that are very different but would benefit from that product. Scenarios can also become worked or completion examples (Clark et al., 2006; Sweller et
al., 1998) reducing extraneous cognitive load, strengthening germane cognitive load and allowing sales people to begin to sell within the e-learning course.

Creating Structure for Retrieval

Retrieval plan strategies can be prescriptive in nature and make sense for near transfer, the idea being to replicate exactly what a learner will see within the context of a real-world scenario so that they build retrieval specific to the process. This is for procedures or processes that do not change and can be replicated within a learning environment exactly the way they would be applied within a real-life scenario.

However, this strategy can also be relevant for learning more complex scenarios where the exact steps or procedures are unknown (far transfer) and an instructional designer can apply a more abstract strategy such as an advance organizer. Advance organizers for retrieval include concepts presented through a diagram, graphic, words, or an animation, that call up to working memory relevant prior knowledge to provide context for the new information that will be presented in that lesson or module (Clark, 2003).

Orienting

Orienting includes the use of making learners aware of learning objectives and advance organizers facilitating the retrieval of existing knowledge in long-term memory to short-term memory in order to integrate the new concepts that will be presented (Hooper & Hannafin, 1991).
Orienting Instructional Strategies

Hooper and Hannafin also discuss affective orienting activities, where the idea is to motivate learners through: (a) simulations, which allow learners to explore and experiment without the consequences of a real environment, (b) tutorials that provide a virtual instructor, and (c) games for drill and practice instruction where learners can turn tedious tasks into competitive energy (1991, p. 79). Chen, Toh, and Fauzy’s (2004) proposed “virtual reality-based learning environment” (p. 147) for Malaysia’s driver education program is a great example of a simulation, where learners would be able to explore possibilities within a safe environment without having to worry about the possible deadly consequences of their decisions. The reason these authors proposed this virtual reality was they felt this environment would give learners experience they could draw from if they did find themselves in a difficult situation while driving in the future. Obviously, this virtual environment would not make learners experts or allow them to practice the motor skills, but it certainly would allow them to practice making crucial decisions within a safe environment (Chen, Toh, & Fauzy, 2004).

Games are another possible orienting instructional strategy, which can be as simple as a drag and drop type of game, or as complex as a simulated environment where a learner competes against the system or other learners. However, Hooper and Hannafin (1991) warn about the possibility of too much stimulation as a distraction limiting the learners’ ability to achieve learning outcomes. This places instructional designers in a precarious position as these types of engaging activities, if done correctly, can provide (a) motivation, (b) cognitive engagement, and (c) improved retrieval leading to the achievement of learning outcomes and a satisfying learning experience. However, if done
incorrectly games can lead to extraneous cognitive load and therefore reduce the effectiveness.

Other instructional strategies for orienting include Hannafin et al.’s (1999) “enabling contexts” (Reigeluth, 1999, p. 124) within their open learning environments instructional theory. These contexts are described as “externally imposed,” (Reigeluth, 1999, p. 124) where learners are presented with performance challenges or problems that are in the context of relevant experiences, and the learner determines the appropriate solution(s). They also suggest “externally induced” (Reigeluth, 1999, p. 124) contexts, which include scenario-based challenges and case studies, where the learner identifies the problems to be resolved and determines the solutions; and “individually generated” contexts (Reigeluth, 1999, p. 124), where individual learner issues are addressed through specific challenges and these challenges direct the instructional strategy. All of these orienting instructional strategies would work well with van Merriënboer and Sweller (2005) worked or completion-example strategies in order to increase germane cognitive load and decrease extraneous cognitive load.

*Presenting*

This cognitive process includes the strategies “color” and “image acuity” (Hooper & Hannafin, 1991, pp. 80–82). Within this category Hooper and Hannafin (1991) discuss the broad possibilities available through new technologies and e-learning environments. Certainly, the concept of cognitive load can be addressed here too. As well as too much stimulation, or just not the right stimulation, these are all possible examples of technology being employed because it provides new ways of presenting information rather than because it provides learners with advantages in the attainment of learning
outcomes. Hooper and Hannafin (1991) also discuss the possible passive nature of some of these technologies, like video and animation, whereas “the use of implied, rather than supplied, images may force students to increase the amount of mental effort, which in turn results in more elaborations and deeper processing” (p. 80). However, what is not mentioned by Hooper and Hannafin (1991) is by forcing learners to supply images cognitive load is increased and therefore possibly over burdening their working memory making it more difficult or perhaps impossible to process the new information. This technique of implied images would be especially difficult for learners that are new to an online environment or novices with the content. Another option that would reduce cognitive load would be dual-encoding by leveraging multiple technologies and providing graphics or animations along with audio to describe these complex images.

Color and Its Impact

According to Hooper and Hannafin (1991), color is a way in which a designer can draw attention to particular points, or highlight key concepts. However, they also warn that the more this type of technique is used the effectiveness decreases. Therefore, they suggest that color is used “systematically to cue important concepts and to highlight important differences” (p. 81).

Image Fidelity and Its Impact

The next presentation strategy is image fidelity, and the key concept here is that it is only crucial if the details in the image represent key learning points (Hooper & Hannafin, 1991). For example the use of a photograph of the interior of a copier would facilitate a copier technician with a trouble shooting exercise better than a line drawing
where the components and wiring just cannot be replicated well enough for this type of a problem-solving exercise. Another example is in Chen, Toh, and Fauzy’s (2004) virtual reality course for driver education. This realistic replication of driving scenarios enables any student no matter their experience with e-learning environments the ability to apply knowledge gained (without overloading working memory) through the practice of cognitive skills, needed to achieve learning outcomes.

*Encoding*

This cognitive process includes the instructional strategies, (a) practice, (b) metacognition, and (c) cognitive dissonance (Hooper & Hannafin, 1991). The actual process of encoding involves a learner taking new information into working memory and transferring it to long-term memory in context with the information they had originally retrieved to appropriately store this new information.

*Cognitive Practice*

The first instructional strategy for encoding is cognitive practice (Hooper & Hannafin, 1991). Core to early job training through apprenticeships was the opportunity for learners to practice within real-life scenarios with an expert at their side. This type of practice was typically related to motor skill development. However, there is also cognitive practice, according to Gagné (1985). “For example, Clark (1960) found that mental practice of basketball foul shots was nearly as effective as physical practice in producing a moderate amount of skill” (p. 215). Therefore, practice is an essential part of both motor and cognitive skill improvement, which is necessary to be successful when applying newly acquired knowledge and/or skills.
Learners Monitoring Their Success

The next cognitive process for encoding is metacognition (Hooper & Hannafin 1991), which provides learners with internal prompts meant for them to check their progress. An instructional designer can implement an instructional strategy, which creates external prompts to do the same thing for learners that are unable or not skilled in this area. This type of instructional strategy would include frequent knowledge checks in the form of questions forcing learners to realize if they are getting it or not, and if they are not remediation and scaffolding to enable them to be successful. According to Clark (2003), successful learners employ this cognitive strategy on their own as they process new information, therefore, she does not recommend employing external cues for these learners. However, there is no recommendation on how an instructional designer would make this determination. It would seem that providing games where questions were asked would accomplish metacognition and foster motivation and confidence in learners that breeze through these interactions.

Counter Intuitive Strategy

The final instructional strategy in the realm of encoding is cognitive dissonance. This strategy is employed to counter possible lazy learning where a learner may disengage or not employ cognitive strategies because they feel they know the information (Hooper & Hannafin, 1991, p. 87). This strategy creates a scenario where information provided counters what the learner expects, forcing them to reengage in order to make sense of this new information. A good example of this would be in an e-learning course on imaging for experienced copier technicians. Any experienced copier technician knows how an image is created as this is core to being able to troubleshoot a device. However, if
a new product is being introduced which changes this process and training on the new product is being conducted, the course should begin with this particular area. This instructional strategy will catch the learners off guard and they are likely to pay attention throughout the entire course just in case there are other new features or functions that change the process, as they know it.

Summary

In summary, through the application of cognitive load theory many instructional strategies have been developed and tested. Instructional guidelines specific to many different modalities have also been tested and presented within several studies (Clark, 2003; Clark & Mayer; 2003; Clark et al., 2006; Sweller, van Merriënboer, & Paas, 1998; van Merriënboer & Sweller, 2005) specific to the (a) management of intrinsic cognitive load, (b) reduction of extraneous cognitive load, and (c) increase of germane cognitive load. The facilitation of cognitive processes has also been studied and instructional strategies suggested by (Clark & Mayer, 2003; Clark et al., 2006; Gagné, 1985; Garrison & Cleveland-Innes, 2005; Hooper & Hannafin, 1991; Kennedy, 2004; Schwier & Misanchuk, 1993). However, as demonstrated by this review, there has been little emphasis on a prescriptive instructional design model or process identified which allows instructional designers to design a course, which manages intrinsic cognitive load, reduces extraneous cognitive load, increases germane cognitive load, and facilitates cognitive processes.
CHAPTER 3. METHODOLOGY

Introduction

Critical to the further development of cognitive load theory is a rigorous testing program based on replicated and controlled experimental designs. Such rigor in experimental methods is too often missing in educational research but is needed to develop sound instructional theories capable of making a real difference to educational practice (van Merriënboer & Sweller, 2005, p. 173)

As an exploratory posttest only experimental study, this research employed quantitative methods to determine the effect of instructional strategies implemented within a self-paced asynchronous e-learning course.

The purpose of this study was to better understand the impact of learner-content interactions that are designed to facilitate learners’ cognitive processes, increase germane cognitive load, decrease extraneous cognitive load and manage intrinsic cognitive load. Using an e-learning course designed for corporate training, the impact of the instructional strategies used was measured through performance metrics and two instructional efficiency metrics (Tuovinen & Paas, 2004). Learner performance was measured through the collection of performance scores during each interaction and the posttest. Text entries for each workplace scenario were also collected and later manually scored. The instructional efficiency of each learner-content interaction, workplace scenario, and the learning environment was measured through efficiency metrics (Paas & van Merriënboer,
1993) which according to Paas et al. (2003) originally combined mental effort recorded by the mental effort survey (Paas, 1992, see Figure 1).

![Mental effort survey](image)

**Figure 1. Mental effort survey (Paas, 1992).**

The mental effort survey results and the performance scores for each scored learner-content interaction, each workplace scenario, and the posttest provide the data necessary to calculate the two-dimensional and three-dimensional efficiency rating. The studies cited in the literature review included the recording of mental effort immediately following instruction and the performance scores immediately following learning through an assessment. There were also studies that implemented the two-dimensional instructional efficiency metric by utilizing the test performance scores and test mental
effort. This study utilized the two-dimensional version, which includes the test performance score and the test mental effort; however, this calculation was only made with the performance and mental effort scores for the posttest to determine the two-dimensional instructional efficiency of the e-learning course (see Figure 2).

\[
 i_e = \frac{(Tp - Lm_e)}{\sqrt{2}} \quad \text{and} \quad i_e = \frac{(Tp - Tm_e)}{\sqrt{2}}
\]

- \( i_e \) = instructional efficiency
- \( Tp \) = test performance
- \( Lm_e \) = learning mental effort
- \( Tm_e \) = test mental effort

Figure 2. Two-dimensional instructional efficiency equation (Tuovinen & Paas, 2004).

This study utilized the two-dimensional instructional efficiency calculation, however the performance scores were collected during the learning interaction (\( Lp \)) and the learning mental effort (\( Lm_e \)) was collected immediately following the interaction (see Figure 3).

It also utilized the three-dimensional instructional efficiency metric devised by Tuovinen and Paas (2004). According to Tuovinen and Paas, “combining the three factors of learning effort, test effort, and test performance may incorporate the advantages of both approaches and so may provide a more useful measure for comparing instructional conditions” (p. 136).
\[ i_e = \frac{(Lp - Lm_e)}{\sqrt{2}} \]

\( i_e \) = instructional efficiency  
\( Lp \) = Learning performance  
\( Lm_e \) = learning mental effort

Figure 3. Two-dimensional instructional efficiency equation.

\[ i_e = \frac{(Tp - Lm_e - Tm_e)}{\sqrt{3}} \]

\( i_e \) = instructional efficiency  
\( Tp \) = test performance  
\( Lm_e \) = learning mental effort  
\( Tm_e \) = test mental effort

Figure 4. Three-dimensional instructional efficiency calculation.

**Research Design**

Throughout the research instructional strategies are identified that enable the facilitation of cognitive processes and others that are specific to the application of cognitive load theory. However, there is no one instructional model that identifies these instructional strategies as effective and instructionally efficient specific to a self-paced asynchronous e-learning course within a corporate environment.
The research hypotheses that will drive this study is as follows: Learner-content interactions designed to manage intrinsic cognitive load, facilitate learners’ cognitive processes, decrease extraneous cognitive load, and increase germane cognitive load will:

1. Enable learners to achieve learning outcomes
2. Enable learners to apply the principles learned within simulated workplace scenarios
3. Enable instructionally efficient interactions
4. Enable an instructionally efficient learning environment

Within this study the identified instructional strategies, which manage intrinsic cognitive load, decrease extraneous cognitive load, increase germane cognitive load, and facilitate cognitive processes; were implemented within a self-paced asynchronous e-learning course in a corporate environment.

The effectiveness of the learner-content interactions and the e-learning course as a whole was determined through:

1. Performance scores for each interaction.
2. Performance scores for three simulated workplace scenarios.
3. Performance scores for a final multiple-choice posttest.

The instructional efficiency was determined through the collection of mental effort scores for each of these interactions and the posttest which when combined with the performance scores provided the data necessary to implement the instructional efficiency metrics (Paas & van Merriënboer 1993; Tuovinen & Paas, 2004). According to Tuovinen and Paas (2004), this metric was originally designed to determine the mental efficiency of instruction through the comparison of a learner’s test performance with their
identified mental effort during their test performance. Tuovinen and Paas (2004) take the efficiency metric a step further by making it a “three-dimensional computational approach” (p. 134) to evaluate instructional efficiency. Although the past one- or two-dimensional approaches to instructionally efficiency were effective, Tuovinen and Paas believe “an approach combining the three factors of learning effort, test effort, and test performance may incorporate the advantages of both approaches and so may provide a more useful measure for comparing instructional conditions” (p. 136). Therefore this study employed both the two- and three-dimensional approach recommended by Tuovinen and Paas and takes it a step further by collecting learning performance during the interaction and evaluating each interaction as well as the effectiveness and instructional efficiency of the entire course through simulated workplace scenarios, and a multiple-choice posttest.

Based on the use of the instructional efficiency metric the collection and analysis of the following data was recorded:

1. Learners’ recorded mental effort (see Figure 1) after each interaction, after each workplace scenario, and after the posttest.

2. Learners’ combined mental effort for all learning interactions (including the three workplace scenarios) within the e-learning course.

3. Learners’ performance within each learning interaction.

4. Learners’ performance within each simulated workplace scenario.

5. Learners’ performance within the posttest.

Creswell (2003) describes quantitative research as “the reduction to a parsimonious set of variables, tightly controlled through design or statistical analysis, provides measures or observations for testing a theory” (p. 153). Within this posttest-only
experimental study, (a) performance scores for each learning interaction were collected by the LMS, (b) mental effort scores for each learning interaction and workplace scenario were collected by the LMS, (c) simulated workplace scenario data was collected by the LMS and later scored by the researcher and subject matter experts, and (d) posttest scores were collected by the LMS.

According to Clark et al. (2006), $z$ scores are used to “convert metrics that use different scales to a standard scale” (p. 333). In this study $z$ scores were calculated for the variables necessary to complete the two-dimensional and three-dimensional instructional efficiency metric calculations; learning performance, learning effort, test effort, and test performance. These $z$ scores were then inserted into the two- and three-dimensional instructional efficiency equations in order to determine how instructionally efficient, each learner-content interaction, and workplace scenario, were for each learner. Then the mean of these instructional efficiency calculations were used as the final efficiency ratings for each interaction and workplace scenario. Then the mean mental effort for all learning interactions and workplace scenarios for each learner were used along with the posttest performance scores to calculate the two- and three-dimensional instructional efficiency of the learning environment.

Sampling

This study was conducted with a relatively homogenous audience (technical sales people) that work for the same corporation and have similar experience with the product that they are selling and with the delivery modality.
The sampling method was one of convenience. Given the fact that an e-learning course needed to be developed specifically for this study, it was necessary to select a sample that was looking to implement training that would meet a real business need. A manufacturing corporation was selected due to its need for structured training on a relatively new product (Snake Bus, a power distribution system). The self-paced asynchronous e-learning course was designed for approximately 85 channel salespeople, and the LMS collected the necessary data for the study to determine if the instructional strategies implemented within each interaction and throughout the e-learning course would produce an effective and instructionally efficient course.

Variables

As an exploratory experiment, there were both independent and dependent variables. The independent variables in this study were the instructional strategies designed to address the four facets of cognitive load and the facilitation of cognitive processes.

Independent Variables

Strategies to Manage Intrinsic Cognitive Load

1. Interactions designed for specific levels of content and modality experience.
2. Each module included learner objectives, introductions, summaries, and transitions.
3. Manageable chunks were created through the use of modules.
Strategies to Decrease Extraneous Cognitive Load

1. Information was conveyed concisely.

2. Introductions and summaries included graphics explained by audio in context of the course and how the concepts will be applied once the learner is back on the job.

3. Unnecessary information was eliminated.

4. Worked examples were provided to eliminate poor problem-solving skills and decrease extraneous cognitive load.

5. Completion examples were provided to reduce extraneous load that may be created by forcing a learner to go through the entire process.

Strategies to Increase Germane Cognitive Load

1. Signals and cues were used to direct the learners’ attention to the critical concepts of the course.

2. Acronyms were used to create categories for content chunking information further in context of its application.

3. Words were integrated into graphics preventing split attention.

4. A learning agent was used to facilitate dual modality presentation of content through narration and images.

5. Completion examples allowed learners to focus in on the key concepts and skills necessary to be successful (see Appendix I).

Strategies to Facilitate Cognitive Processes

1. Enabled retrieval (organization)

2. Enabled retrieval for rules

3. Enabled retrieval (integration)

4. Enabled retrieval (near and far transfer)

5. Enabled retrieval (retrieval plan)
Oriented through games, simulations, and enabling contexts

Presented using dual-encoding techniques

Enabled encoding (cognitive practice)

Enabled encoding (metacognition)

Enabled encoding (self-explanations) (see Appendix E)

**Dependent Variables**

The eight dependent variables were:

1. Learner performance scores for each interaction
2. Learner performance scores for the workplace scenarios
3. Learner performance scores for the posttest
4. Learner mental effort scores for each interaction
5. Learner mental effort scores for the workplace scenarios
6. Learner mental effort scores for the posttest
7. The instructional efficiency of each interaction
8. The instructional efficiency of the e-learning environment

The measures used to determine the instructional efficiency of each interaction and the e-learning environment; (a) mental effort survey results for each learning interaction, (b) mental effort survey results for each workplace scenario, (c) the mental effort survey results for the posttest, (d) the performance scores for each interaction, (e) the performance scores for each workplace scenario, and (f) the performance scores for the posttest.
Research Instruments and Data Collection Devices

One main research instrument was employed in this study, the asynchronous e-learning course. Within this course, there was a mental effort survey, which collected mental effort scores for each interaction, the workplace scenarios, and the posttest. Within this course there were also several technologies used to collect learner performance and mental effort scores, which were then used to calculate instructional efficiency of each interaction, each workplace scenario, and for the course as a whole.

The e-learning course included nine learner-content interactions. Each interaction was designed using the instructional strategies identified earlier in this chapter and learners’ received scores during six of these learning interactions. A mental effort survey (see Paas, 1992) followed each interaction in order to collect learner data on their mental effort experienced during the interaction they just completed. These scores and survey responses were passed to the learning management system (LMS), and stored for each learner. This was all made possible through the application of sharable content object reference model (SCORM)-compliant courseware and interactions. Three of the nine interactions were workplace scenarios, which did not provide the learner with a score but collected free-form text entries within the scenario. These entries were then passed to the LMS to be scored later manually, and a mental effort survey followed each of the scenarios once again providing learners an opportunity to record their mental effort after each scenario.

E-Learning Design

Each interaction and the self-paced asynchronous e-learning course was designed for a specific audience with identified goals and learning objectives to (a) manage
intrinsic cognitive load, (b) reduce extraneous cognitive load, (c) increase germane
cognitive load, and (d) facilitate learners’ cognitive processes.

As Kennedy (2004) suggested, interactivity research should be concerned with (a)
the learning goals set by the instructional designer, (b) what types of instructional
interactions are necessary for the proposed learning goals, (c) what physical interactions
will be required by the learner, and (d) what cognitive strategies learners will have to
apply, to reach the proposed learning goal(s). Therefore, the e-learning course and each
learner-content interaction was designed with specific (a) learning goals (see Appendix
A), (b) audience and content analysis data (see Appendix B), (c) learning objectives (see
Appendix C), and (d) the instructional strategies that facilitate cognitive processes and
applied cognitive load theory, identified within the literature review. The first level of
Bloom’s (1956) Taxonomy was the tool used to write the learning objectives.

Deliverables created for the design of the course included the following: (a) project
definition document, (b) audience and content analysis document, (c) learning objectives
and outline document, and (d) storyboard (see Appendixes A, B, and C).

Cognitive Load Theory (CLT) Instructional Strategies

The interactions were designed through the consultation of three subject matter
experts provided by the corporation for content questions. Cognitive load theory was
applied as a framework for the design and development of the e-learning course to (a)
manage intrinsic cognitive load, (b) reduce extraneous cognitive load, and (c) increase
germane cognitive load Clark et al. (2006) as follows:

Managing intrinsic cognitive load. Interactions were designed for specific levels
of content and modality experience.
This course was designed based on a thorough content and audience analysis, which included the determination of content and modality experience (see Appendix A).

1. Manageable chunks were created through the use of modules.

2. Each module included learner objectives, introductions, summaries, and transitions.

Five modules were created to present the content in manageable chunks. Each module had an introduction; learner objectives, transitions and a summary (see Figure 5).

Figure 5. Module 4: Learning objectives.


*Decreasing extraneous cognitive load.*

1. Information was conveyed concisely.

2. Introductions and summaries included graphics explained by audio in context of each module and the course, as well as how the concepts will be applied once the learner is back on the job.

3. Unnecessary information was eliminated throughout the course.

Less is more (see Figure 6).

![Module introduction (dual modality) graphics and audio narration.](image)

Figure 6. Module introduction (dual modality) graphics and audio narration.

Worked examples were used to eliminate poor problem-solving skills, which increase extraneous cognitive load.
The course begins with a worked example where the learning agent interacts with customers and explains why they would benefit from Snake Bus. This interaction with the customer was explained by the learning agent through audio, and reinforced with images of the customer, their needs, and the benefits of the Snake Bus that will meet these needs.

Completion examples were used to reduce extraneous load that may be created by forcing a learner to go through the entire process.

Within the completion examples, the learners were given a chance to apply their knowledge through the presentation of three different possible incomplete workplace scenarios and they were asked to provide the close to these scenarios (see Figure 7).

Figure 7. Completion example (workplace scenarios).
*Increase germane cognitive load,* Signals and cues were used to direct the learners’ attention to the critical concepts of the course.

Throughout the e-learning course an acronym (Sleek Green RECAP) was used that represented all of the features, advantages, and benefits of Snake Bus. This acronym was applied within different contexts throughout the course (see Figure 8).

![Figure 8. Signals and cues.](image)

Words were integrated into graphics to prevent split attention (Clark, 2003, p. 76).

A diagram with imbedded text explained by audio was used to facilitate deeper understanding (see Figure 9).
A learning agent was used to facilitate dual modality presentation of content through narration and images, based on suggestions to “accelerate expertise with dual modalities” (Clark, 2003, p. 46), and use diagrams to facilitate a deeper understanding (p. 46).

Throughout the course, a learning agent described graphics. For example, the first learner-content interaction within the course begins with the learning agent introducing the learners to three possible Snake Bus customers. The needs of these customers are revealed and the benefits of Snake Bus are discussed. Graphics are used to represent the customer, the Snake Bus and the Snake Bus benefits (see Figure 10).
Figure 10. Increasing germane load through dual modalities (worked examples).

Completion examples were used, allowing learners to focus in on the key concepts and skills necessary to be successful (see Figure 4).

Acronyms were used to create categories for content chunking information further in context of its application (see Figure 5).

Dr. Ruth Clark, a cognitive load theory expert, evaluated the e-learning course. She confirmed that the interactions and the course as a whole applied cognitive load theory.
Instructional Strategies: Facilitation of Cognitive Processes

The e-learning course also applied the following instructional strategies, specific to the facilitation of learners’ cognitive processes, while remaining in the framework of cognitive load theory, based on the literature review:

Enabled Retrieval (Organization)

Manageable chunks (lessons, or module), as recommended by Clark (2003), provided “signals and cues” (p. 74) as to what was important including: (a) transitions, (b) headings, (c) subheadings, (d) summaries, (e) topic introduction, and (f) learning objectives.

Application. This course included five distinct modules and each of these modules had a topic introduction, learning objectives, transitions, and a module summary. For example, the Target Customers introduction page included the learning agent introducing the acronym *Sleek, Green, RECAP* and he describes how it is relevant to Snake Bus customers and the competition (see Figure 5). Visual clues are also presented consistently throughout this course, including (a) images of the same three customers, (b) images of the Snake Bus components, and (c) the Sleek, Green, RECAP images. To further chunk information, customers were placed into the following categories: (a) building owners, (b) engineers, (c) contractors, and (d) architects.

Enabled Retrieval for Rules (Organization)

1. Asked questions that enabled learners to recall concepts.
2. Allowed learners to demonstrate what they just learned.
3. Provided feedback to reinforce or remediate the new concepts learners just constructed.
4. Used similar verbiage to provide cues while learners are applying new information for the first time (Gagné, 1985, p. 127).

*Application.* Each module in the course included at least one interaction that required learners to make decisions or answer questions by recalling the new concepts covered in that module. Each of these interactions were also in context of a game which had a timing and scoring aspect, providing a sense of competition with the system and enabling learners to track their own progress. These interactions also provided immediate feedback. Feedback is provided for incorrect and correct responses (see Figure 11). Similar language and images are used throughout the course.

![Image of Snake Bus - Power Distribution](image)

*Figure 11.* Recalling new concepts with feedback.
**Enabled Retrieval (Integration)**

New information was placed in context of learners’ existing experience and knowledge to facilitate links and internal cues to existing schema. Narrative storytelling was provided in context of current knowledge through real-world scenarios that replicated actual challenges. A learning agent was used to deliver content. Current knowledge was brought into working memory and allowed the new information to be integrated into an existing schema increasing the likelihood of retrieval as learners moved through the course (Clark, 2003; Hooper & Hannafin, 1991; Jonassen, 1988; Kennedy, 2004).

**Application.** The learning agent used narrative storytelling throughout the course. Learners had experience with all of the customers presented in this course. However, the difference was the interactions within this course introduced the new power distribution product Snake Bus in context with the specific needs of these existing customers accentuating the features, benefits, and advantages of Snake Bus over the competition. The final interaction simulated three different workplace scenarios through a completion example, which replicated real-world challenges and reduces cognitive load (see Figure 7).

**Enabled Retrieval (Near and Far Transfer)**

Drill and practice was used for near transfer. Exact processes or procedures were replicated to ensure the success of the learner. Far transfer, on the other hand, requires an understanding of rules or concepts that need to be applied to several different possible contexts. In order to facilitate far transfer, learners need to practice applying rules, asking
questions to make connections to the process, and be provided with scaffolding and feedback throughout the lesson.

Application. The first three modules within this course used several drill and practice type activities where learners are being asked to recall concepts and apply them by answering questions or making decisions. The fourth module then provided an opportunity for the learners to apply these new concepts to three different possible workplace scenarios through the use of completion examples (see Figure 7). Scaffolding was provided through the use of images and the learning agent. Immediate feedback was provided throughout the course and for the simulated workplace scenarios feedback was provided to learners once they completed the course.

Enabled Retrieval (Retrieval Plan)

A retrieval plan is the facilitation of retrieval through a set plan that either completely replicated the exact process (near transfer) or was represented by an abstract advance organizer (far transfer) (Hooper & Hannafin, 1991).

Application. There is no way to replicate an exact sales scenario for all possible customers. However, by providing the acronym Sleek, Green, RECAP with supporting images as an advance organizer, retrieval was facilitated of the features, benefits, and advantages over the competition that Snake Bus provides (see Figure 8).

Orienting

Games, simulations, and enabling contexts enabled learners to be oriented to the new knowledge in many different ways, facilitating the encoding and later retrieval when
necessary in similar (near transfer) or different (far transfer) contexts within a real scenario (Hooper & Hannafin, 1991).

*Application.* Throughout the course, the concepts necessary to sell Snake Bus were approached in many different ways. First the entire picture is seen with three worked examples where the learning agent addressed three possible Snake Bus customers their needs, and the Snake Bus features, benefits, and its advantages over the competition specific to each customer’s needs. Several different games (two match games, Snake Bus quiz show game, the name-that-component game, and the sales process game) were used to engage learners through the application of newly taught concepts with feedback, scaffolding, in the context of the acronym *Sleek, Green, RECAP*, real-life scenarios, and customers were used to facilitate encoding and later retrieval. Then the final interactions, allowed learners to participate in three workplace scenarios, each setup as completion examples (see Figure 4).

*Presenting (Dual-Encoding)*

Dual encoding was achieved by providing information visually and through narration (Clark, 2003). Color and images were used to highlight key concepts (Hooper & Hannafin, 1991).

*Application.* Throughout the entire course, dual encoding is provided through the use of the learning agent describing graphics representing components, and customers in the context of learners’ current knowledge and real-world scenarios. Images are were also used to cue learners on key concepts including: (a) the Sleek, Green, RECAP acronym, (b) possible customers, (c) components, (d) features, (e) functions, (f) customer benefits, and (g) advantages over the competition (see Figures 8, 9, and 10).
**Enabled Encoding (Cognitive Practice)**

Cognitive practice was applied to allow learners to apply rules or underlying concepts while practicing making crucial decisions within the learning environment (Gagné, 1985; Hooper & Hannafin, 1991).

**Application.** Throughout the course the games, two match games (see Figure 12), Snake Bus quiz show game (see Figure 11), the name-that-component game (see Figure 10), and the sales process game, as well as the three workplace scenarios (see Figure 8) allowed learners to apply the underlying concepts and practice making crucial decisions within the learning environment.

---

**Figure 12.** Applying new concepts: Game format, audio narration, feedback.
**Enabled Encoding (Metacognition)**

Metacognition was applied to enable the learner to check their progress through activities where they were challenged by questions or the application of the newly acquired knowledge (Gagné, 1985).

**Application.** Throughout this course four games, including: (a) two match games (see Figure 12); (b) Snake Bus quiz show game (see Figure 11), the name-that-component game (see Figure 13); and (c) the sales process game (see Figure 14). These games enabled learners to check their progress by challenging them with questions, decisions, and the application of newly acquired knowledge and providing them with performance scores during learning and immediate feedback.

![Figure 13. Applying new concepts: Game format with scaffolding and feedback.](image-url)
Enabled Encoding (Self-Explanations)

Enable learners to reflect and form self-explanations. “Learning involves the integration of new information into existing knowledge. Generating explanations to oneself (self-explaining) facilitates that integration process” (Chi, Leeuw, Chiu, & Lavancher, 1994).

Application. The learning agent models self-explanations (Figure 7) and participants were given several opportunities to generate self-explanations. An example of this is within all three of the workplace scenarios (see Figure 4).
Throughout the design and development process subject matter experts (SMEs) reviewed, edited, and approved all design documents, including the following: (a) project definition document (learning goals), (b) learning objectives and outline document, and (c) storyboard (see Appendixes B, and C). Once the e-learning course was complete, two e-learning experts and three SMEs evaluated the course. The evaluation by the experts was based on the literature review findings, including (a) interface design, (b) interactivity constructs, and (c) instructional strategies and guidelines specific to the application of cognitive load theory. One expert concentrated on the interface design and interactivity constructs, and the other expert concentrated on the appropriate application of cognitive load theory. The evaluation by the SMEs also included (a) usability, (b) content, and (c) context.

**Learning Management System (LMS)**

The learning management system (LMS) is the back-end software that was used to collect the data from the self-paced e-learning course, necessary to complete this study. The LMS’s main function as an instrument for this study was the collection, storage, and tracking of the following data:

1. Scores for each learning interaction for each learner.
2. The mental effort score reported by the learner after the completion of each interaction and the posttest.
3. The free-form text responses from the learners for three different simulated workplace scenarios.
4. The score on the posttest for each learner.

In order for the collection of this data to be possible, each interaction and the course as a whole had to be SCORM-compliant.
When researchers are looking to record learners’ mental effort, the mental effort survey (Paas, 1992) (see Figure 1) is the most reliable choice. According to Paas et al. (2003), “The scale’s reliability and sensitivity (Paas et al., 1994) and moreover its ease of use have made this scale, and variants of it, the most widespread measure of working memory load within CLT research” (p. 68). Once mental effort information is recorded through the mental effort survey (Paas, 1992), the efficiency metric (see Paas & van Merriënboer, 1993) allows researchers to gauge instructional efficiency through a computation that takes into consideration both the mental effort and performance of learners. Paas et al. state “the combination of measures of mental effort and performance can reveal important information about cognitive load, which is not necessarily reflected by performance and mental effort measures alone” (p. 67).

**Mental Effort Survey**

This survey has been found to have reliability based on its internal consistency within studies that have used the labels and scale originally developed by Paas in 1992 (Paas et al., 2003). This study will implement the 9-point mental effort rating scale and labels developed originally by Paas (1992) (see Figure 1).

**Efficiency Metric**

Performance measurements alone cannot capture “the cognitive costs associated with a certain performance level…. Instead, the combination of measures of mental effort and performance can reveal important information about cognitive load, which is not necessarily reflected by performance and mental effort measures alone” (Paas et al.,
Therefore, it is important for studies that are applying cognitive load theory to utilize the efficiency metric. The efficiency metric measures the efficiency of the instruction by combining the learners self-reported mental effort scores from the mental effort survey along with the performance numbers, which allowed the researcher to determine the efficiency of each interaction. High mental effort during instruction and low performance is referred to as “low-instructional efficiency” (p. 67), and low mental effort during instruction and high performance is referred to as “high-instructional efficiency” (p. 67). However, according to Tuovinen and Paas (2004), learners that perform well with less effort during performance have experienced better transfer of learning, therefore it makes sense to measure effort during learning and performance through the three-dimensional instructional efficiency metric (p. 136). That is why this study collected learning performance during each interaction, after the completion of the workplace scenarios, and after the completion of the posttest. Then mental effort data was collected immediately following each learning interaction, workplace scenario, and posttest by employing the mental effort survey (Paas, 1992). Then these measurements of mental effort and performance were used in the two- and three-dimensional instructional efficiency metrics to determine the instructional efficiency of each interaction as well as the instructional efficiency of the entire e-learning course. However, since previous research utilizing instructional efficiency metrics was done as comparison studies there is no benchmark that indicates whether an instructional efficiency rating is instructionally efficient, just that it is more or less efficient than other interactions. Within this study, comparisons will be made to the other interactions within this course, negative
instructional efficiency ratings will be considered not instructionally efficient and positive instructional efficiency ratings will be considered instructionally efficient.

Data Analysis

Introduction

The focus of the analysis was driven by the research hypotheses: Learner-content interactions designed to manage intrinsic cognitive load, facilitate learners’ cognitive processes, decrease extraneous cognitive load, and increase germane cognitive load will:

1. Enable learners to achieve learning outcomes
2. Enable learners to apply the principles learned within simulated workplace scenarios
3. Enable instructionally efficient interactions
4. Enable an instructionally efficient learning environment

Performance

Learners’ ability to achieve learning outcomes was measured through scores collected by the LMS for each interaction and on the posttest. The learning performance scores were collected during the actual interaction. The simulated workplace scenarios did not capture a score but free-form text entries were captured which learners entered into a text box. Therefore, performance scores were provided by the researcher and subject matter experts through a determination of the accuracy of the statements provided by the learners. These statements were graded based on (a) the learning objectives, (b) customer information, (c) product features, advantages, and benefits, and (d) competitor details provided to the learners during the e-learning course.
Instructional Efficiency

The instructional efficiency of the learning environment was measured through the efficiency metric (Paas & van Merriënboer 1993). The efficiency metric included the variables mental effort and performance. According to Tuovinen and Paas (2004), the mental effort must be measured during instruction as well as performance. The mental effort of learners was calculated through the implementation of the mental effort survey (see Paas, 1992) and learners’ performance was determined through scores on each interaction as well as scores for workplace scenarios and the posttest, which determined overall performance.

Since there is no direct method for mapping units of performance on units of mental effort, the measures are converted to standardized (z scores) formed by subtracting the grand mean from each score and dividing the result by the standard deviation. (Tuovinen & Paas, 2004, pp. 141–142)

The instructional efficiency of each interaction was measured by the three-dimensional efficiency metric recommended by Tuovinen and Paas (2004). The two-dimensional instructional efficiency of each interaction was also determined. A comparison was made between the instructional efficiency of each interaction utilizing both the two-dimensional instructional efficiency metric and the three-dimensional instructional efficiency metric. The three-dimensional instructional efficiency metric was applied based on Tuovinen and Paas’s findings that this metric leads to more consistent instructional efficiency ratings and possibly denotes a more accurate rating of the total instructional process (2004, p. 149). Finally, the overall instructional efficiency of the e-learning environment was calculated by implementing both instructional efficiency metrics, the two-dimensional instructional efficiency metric by utilizing the mean mental effort scores for each learning interaction and workplace scenario throughout the course.
and the mean performance scores for the posttest. The three-dimensional instructional efficiency metric by utilizing the mean mental effort scores for each learning interaction and workplace scenario throughout the course, the test effort scores for the posttest, and the performance scores for the posttest.

Confidentiality

Participants were advised that data collection and analysis was done in the strictest of confidence and all data was coded anonymously to ensure participants could not be identified through either the collection or analysis of the data. The research did not proceed until the researcher was given appropriate approval from the researcher’s committee, the School of Education at Capella University, and the Institutional Review Board (IRB).

Summary

The design and development of a self-paced asynchronous e-learning course for a corporation with specific training needs was the main instrument for this study. This instrument along with the back-end support of an LMS enabled the researcher to collect performance data during each learning interaction in order to determine if the instructional strategies applied were effective. This instrument along with the back-end support of an LMS, and a mental effort survey, which immediately followed each learning interaction enabled the researcher to collect mental effort data for each learning interaction and the posttest. These research instruments combined to provide the necessary data to calculate the instructional efficiency for each learning interaction and
the posttest through the application of both the two-dimensional instructional efficiency metric and the three-dimensional instructional efficiency metric. The combination of these created and existing research instruments allowed the researcher to determine the effectiveness and the instructional efficiency of each interaction, the underlying instructional strategies, and the course as a whole.
CHAPTER 4. DATA COLLECTION AND ANALYSIS

Introduction

As stated in the research problem, several researchers have identified instructional strategies that enable the facilitation of cognitive processes (Clark, 2003; Gagné, 1985; Garrison & Cleveland-Innes, 2005; Hooper & Hannafin 1991; Kennedy, 2004) whereas others have focused on instructional strategies that apply cognitive load theory (Clark & Mayer, 2003; Clark et al., 2006; Sweller, 1988; Sweller & van Merriënboer 1999; Truman & Truman, 2006). There is, however, no one instructional model that identifies these instructional strategies as effective and efficient specific to self-paced asynchronous e-learning courses within a corporate environment.

The identified instructional strategies (see Appendixes E and F) that (a) manage intrinsic cognitive load, (b) decrease extraneous cognitive load, (c) increase germane cognitive load, and (d) facilitate cognitive processes were implemented in a self-paced asynchronous e-learning course within a corporate environment. The effectiveness of these instructional strategies was determined by collecting the performance scores for five learner-content interactions, three workplace scenarios, and a posttest. The instructional efficiency of these interactions was calculated by using the performance scores along with the mental effort survey responses, which were entered by the learner after they completed each interaction, workplace scenario, and the posttest through the use of two distinct instructional efficiency metrics as discussed in detail in chapter 3.
These metrics were designed to determine the efficiency of instruction through the comparison of a learner’s performance with their identified mental effort while learning and the mental effort while being tested. In order to determine the instructional efficiency of each interaction and the entire e-learning course, the collection and analysis of the following dependent variables was made.

1. Learners’ performance scores within each learning interaction
2. Learners’ recorded mental effort, after each learning interaction, and after the posttest
3. Learners’ performance within the simulated workplace scenarios
4. Learners’ test performance on the posttest

This chapter presents the results from this study, how they relate to the stated problem, and to the hypotheses: Learner-content interactions designed to manage intrinsic cognitive load, facilitate learners’ cognitive processes, decrease extraneous cognitive load, and increase germane cognitive load will:

1. Enable learners to achieve learning outcomes
2. Enable learners to apply the principles learned within simulated workplace scenarios
3. Enable instructionally efficient interactions
4. Enable an instructionally efficient learning environment

Results

Several instructional strategies were applied throughout the entire e-learning course. These instructional strategies were implemented to facilitate cognitive processes and they applied cognitive load theory (see Appendixes E and F). Data was not captured for every page of the e-learning course. Performance and mental effort scores were only 87
collected and analyzed for five learning interactions, three workplace scenarios, and the posttest.

The results for these five learning interactions, three workplace scenarios, and the posttest; include performance scores, mental effort scores, and instructional efficiency ratings. Not all learning interactions or mental effort surveys were completed by all learners.

The first scored learner-content interaction was match game 1 where learners were asked to drag and drop customer needs to the appropriate customer. Then once they matched the needs with the benefits and the customers, they were asked to match the benefits to the needs and the customers. This interaction reinforces building owner and contractor needs and the specific Snake Bus benefits that meet those needs in context of the Sleek, Green, RECAP acronym, which provides signals and cues to the key concepts of this course. This interaction also applied the dual modality instructional strategy and it allowed learners to apply the underlying concepts and practice making crucial decisions within the learning environment while being provided feedback and scaffolding (see Figure 15).
Thirty-two learners completed this learning interaction and 39 of these learners completed the corresponding mental effort survey. The mean performance score was 80% and the mean mental effort score was 5.5, which corresponds to a learning effort of neither low nor high mental effort. The two-dimensional instructional efficiency was .0350 and the three-dimensional instructional efficiency was .2176.

These results supported the hypothesis statement, the application of specific instructional strategies within this interaction and throughout this e-learning course, that
facilitated cognitive processes and applied cognitive load theory would enable learners to achieve learning outcomes and enable instructionally efficient interactions.

Learners achieved learning outcomes with a mean performance score of 80%. Since a negative instructional efficiency rating indicates a poor instructional efficiency, the two-dimensional instructional efficiency rating of .0350 indicates an instructionally efficient interaction utilizing the performance and mental effort scores during learning.

The three-dimensional instructional efficiency rating of .2176, which utilizes the posttest performance, mental effort during the interaction, and the mental effort during the posttest, also indicated that this interaction is instructionally efficient. Indicating that the learners that completed this interaction also performed well on the posttest and the mental effort required to complete the interaction and the posttest was not significant. The statistical analysis is provided in Table 1.

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The second scored learner-content interaction was another match game in module 2, which reinforces architect and engineer needs and the specific Snake Bus benefits that meet those needs in context of the *Sleek, Green, RECAP* acronym, which provides signals and cues to the key concepts of this course. This learner interaction also applied the dual modalities instructional strategy with the learning agent and allowed learners to make decisions and apply newly acquired concepts within a safe environment with feedback and scaffolding (see Figure 16).

Figure 16. Match game 2.
Thirty-five learners completed this learning interaction and 34 completed the corresponding mental effort survey. The mean performance score was 83% and the mean mental effort score was 5.4, which corresponds to the learning effort equivalent to *neither low nor high mental effort*. The two-dimensional instructional efficiency rating was -.0416 and the three-dimensional rating was .5175.

The results of this learner-content interaction support the hypothesis statement, the application of specific instructional strategies within this interaction and throughout this e-learning course, that facilitated cognitive processes and applied cognitive load theory would enable learners to achieve learning outcomes for this interaction. However, with a negative two-dimensional instructional efficiency rating the results for this interaction rejects the hypothesis statement; the instructional strategies will enable instructionally efficient interactions.

Learners achieved learning outcomes with a mean performance score of 83%. Since a negative instructional efficiency rating indicates a poor instructional efficiency, the two-dimensional results of -.0416 indicate that this interaction was not instructionally efficient.

The three-dimensional instructional efficiency rating of .5175, which utilizes the posttest performance score, mental effort during learning interaction, and mental effort during the posttest, indicated that this interaction was instructionally efficient. Indicating that the learners that completed this interaction scored well on the posttest and that the mental effort required for learning and the posttest was not significant. The statistical analysis for this interaction is provided in Table 2.
The third learner-content interaction that was scored was module 2’s Jeopardy-like quiz game, which had four categories (a) building owners, (b) engineers, (c) contractors, and (d) architects. Each category had three questions relevant to the customer category. This interaction reinforces the lessons learned specific to customer needs and the corresponding Snake Bus benefits covered in the match games and customer interactions throughout module 1 and 2. The instructional strategies include the use of signals and cues by using customers as the categories, chunking of content into categories, and placing questions in context of real-life scenarios. Questions were also used to allow learners to apply newly acquired concepts to real-life possible scenarios and immediate feedback was provided for both incorrect and correct answers (see Figure 17).
Forty-one learners completed this interaction and 36 of those learners completed the corresponding mental effort survey. The mean performance score was 77% and the mean mental effort score was 5.2, which corresponds to the mental effort equivalent to neither high nor low mental effort. The two-dimensional instructional efficiency rating was .1032 and the three-dimensional rating was .3735.

The results for this learner-content interaction support the hypothesis statement, the application of specific instructional strategies within this interaction and throughout this e-learning course that facilitated cognitive processes and applied cognitive load
theory would enable learners to achieve learning outcomes and enable instructionally efficient interactions.

This interaction enabled learners to achieve learning outcomes with a mean performance score of 77%. The two-dimensional instructional efficiency rating of .1032, which utilizes the performance score and mental effort during learning, indicates that this interaction was instructionally efficient.

The three-dimensional instructional efficiency rating of .3735, which utilizes the posttest performance score, mental effort during learning, and mental effort during the posttest, indicated that it was an instructionally efficient interaction. This instructional efficiency rating indicates that the learners that completed this interaction scored well on the posttest and that the mental effort required for learning and the posttest was not significant. The complete statistical analysis is provided in Table 3.

Table 3. Descriptive Statistics/Snake Bus Quiz Show Game

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</table>
The fourth interaction that was scored was the name-that-component game, where a statement or question in context of how the feature will be used is presented to the learner and they are asked to determine which component provides the feature or function. Text in close proximity to graphics to prevent split attention was used, and learners were provided with scaffolding and immediate feedback (see Figure 18).

![Figure 18. Name-that-component game.](Image)

Thirty-eight learners completed this learning interaction and 36 completed the corresponding mental effort survey. The mean performance score was 86% and the mean
mental effort score was 5.2, which corresponds to the learning effort equivalent to neither low nor high mental effort. The two-dimensional instructional efficiency rating was .0303 and the three-dimensional rating was .3735.

The results for this learner-content interaction supported the hypothesis statement, the application of specific instructional strategies within this interaction and throughout the e-learning course that facilitated cognitive processes and applied cognitive load theory would enable learners to achieve learning outcomes and enable instructionally efficient interactions.

This interaction enabled learners to achieve learning outcomes with a mean performance score of 86%. The two-dimensional instructional efficiency rating of .0303, which utilizes the performance score and mental effort during learning, for this learning interaction indicates that it was an instructionally efficient interaction.

The three-dimensional instructional efficiency rating of .3735, which utilizes the posttest performance score, mental effort during learning, and mental effort during the posttest, indicates that this interaction was instructionally efficient. This instructional efficiency rating indicates that the learners that completed this interaction scored well on the posttest and that the mental effort required for learning and the posttest was not significant. The complete statistical analysis is provided in Table 4.
Table 4. Descriptive Statistics/Component Game

<table>
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<td>3.74</td>
<td>.3735</td>
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</tbody>
</table>

The next scored learner-content interaction was the Sales Process interaction, which provides the learners with the steps and tasks, involved with the sales process through audio narration in context of learners’ experience provided by the learning agent and a graphic, which represents the sales process. The sales process interaction decreases extraneous cognitive load by presenting a text-integrated graphic (Clark, 2003). Then, a statement is posed or question is asked and the learner must select the appropriate step or task within the Snake Bus sales process. Immediate feedback was also provided for either incorrect or correct answers.
Seventeen learners completed this learning interaction and 36 completed the corresponding mental effort survey. The mean performance score was 86% and the mean mental effort score was 4.9, which when rounded to 5 corresponds to the learning effort equivalent to *neither low nor high mental effort*. The two-dimensional instructional efficiency rating was .0477 and the three-dimensional rating was .3259.

The results for this interaction support the hypothesis statement, the application of specific instructional strategies within this interaction and throughout this e-learning course that facilitated cognitive processes and applied cognitive load theory would enable learners to achieve learning outcomes and enable instructionally efficient interactions.
This interaction allowed learners to achieve learning outcomes with a mean performance score of 86%. The two-dimensional instructional efficiency rating of .0477, which utilizes the performance and the mental effort during learning, indicates that this interaction was instructionally efficient.

The three-dimensional instructional efficiency rating of .3259, which utilizes the posttest performance score, mental effort during learning, and mental effort during the posttest, confirmed the instructional efficiency of this interaction. This instructional efficiency rating indicates that the learners that completed this interaction scored well on the posttest and that the mental effort required for learning and the posttest was not significant. The complete statistical analysis is provided in Table 5.

<table>
<thead>
<tr>
<th>Table 5. Descriptive Statistics/Sales Process</th>
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<td>.3259</td>
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</tr>
</tbody>
</table>

The next three interactions that were scored were the workplace scenarios. These scenarios were in the form of completion examples where learners entered the key
features, advantages, and benefits of Snake Bus specific to each customer provided in each scenario. Learners made these entries as free-form text, the LMS collected these entries and the entries were then manually scored by an SME and the researcher. The scenarios were also designed to facilitate far transfer through the use of three different customers and therefore varied context.

There are three of these simulated workplace scenarios, which utilize a completion example as the instructional strategy. The first is with an architect as a customer (see Figure 20).

Figure 20. Architect scenario.
Twenty-seven learners completed this learning interaction and 30 learners completed the corresponding mental effort survey. The mean performance score was 83% and the mean mental effort score was 5.8, which when rounded to 6 corresponds to the learning effort equivalent to *rather high mental effort*. The two-dimensional instructional efficiency rating was -.0806 and the three-dimensional rating was .1825.

The results for this interaction support the hypothesis statement, the application of specific instructional strategies within this interaction and throughout the e-learning course that facilitated cognitive processes and applied cognitive load theory would enable learners to achieve learning outcomes. However, with a negative two-dimensional instructional efficiency rating, the results for this interaction reject the hypothesis statement; the instructional strategies applied within this interaction would enable an instructionally efficient interaction.

This interaction met learning outcomes and enabled learners to apply principles learned within simulated workplace scenarios with a mean performance score of 83%. However, with a two-dimensional instructional efficiency rating of -.0806, which utilizes the performance score and mental effort during learning, the interaction was not found to be instructionally efficient.

The three-dimensional instructional efficiency rating of .1825, which utilizes the posttest performance, mental effort during learning, and mental effort during the posttest, indicates that this interaction is instructionally efficient. This instructional efficiency rating indicates that the learners that completed this interaction scored well on the posttest and that the mental effort required for learning and the posttest was not significant. These results also indicate that this interaction was instructionally efficient.
according to the three-dimensional calculation. This supports the hypothesis statement, the application of the instructional strategies that facilitate cognitive processes, apply cognitive load theory within this interaction, and throughout the e-learning course have enabled an instructionally efficient interaction. The complete statistical analysis is provided in Table 6.

Table 6. Descriptive Statistics/Architect Scenario

<table>
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</table>

The next completion example utilized an engineer as a customer (see Figure 21).
Twenty-three learners completed this learning interaction and 25 learners completed the corresponding mental effort survey. The mean performance score was 78% and the mean mental effort score was 5.88, which when rounded to 6 corresponds to the learning effort equivalent to rather high mental effort. The two-dimensional instructional efficiency rating was -.0399 and the three-dimensional Instructional rating was .1200.

The results for this interaction support the hypothesis statement, the application of specific instructional strategies within this interaction and throughout the e-learning course that facilitated cognitive processes and applied cognitive load theory would enable
learners to achieve learning outcomes. These results also support the hypothesis statement that the instructional strategies would enable learners to apply principles learned to simulated workplace scenarios. However, with a negative instructional efficiency rating the results for this interaction reject the hypothesis statement that the instructional strategies applied to this interaction would enable an instructionally efficient interaction.

This interaction met learning outcomes and enabled learners to apply principles learned to a simulated workplace scenario, with a mean performance score of 78%. This interaction’s two-dimensional instructional efficiency rating of -.0399, which utilizes the performance and mental effort scores during learning, indicates that it was not an instructionally efficient interaction.

The three-dimensional instructional efficiency rating of .1200, which utilizes the posttest performance score, mental effort during learning, and the mental effort during the posttest, indicates that this interaction was instructionally efficient. This instructional efficiency rating indicates that the learners that completed this interaction scored well on the posttest and that the mental effort required for learning and the posttest was not significant. These results also indicate that this interaction was instructionally efficient according to the three-dimensional calculation. This supports the hypothesis statement that the application of the instructional strategies that facilitate cognitive processes and apply cognitive load theory within this interaction and throughout the e-learning course have enabled an instructionally efficient interaction. The complete statistical analysis is provided in Table 7.
<table>
<thead>
<tr>
<th></th>
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</table>

The final completion example utilized a building owner as a customer (see Figure 22).
Figure 22. Building owner scenario.

Twenty-four learners completed this learning interaction and 25 learners completed the corresponding mental effort survey. The mean performance score was 84% and the mean mental effort score was 5.8, which when rounded to 6 corresponds to the learning effort equivalent to rather high mental effort. The two-dimensional Instructional rating was -.0126 and the three-dimensional rating was .0444.

The results for this interaction support the hypothesis statement that the application of specific instructional strategies within this interaction and throughout the e-learning course that facilitated cognitive processes and applied cognitive load theory would enable learners to achieve learning outcomes. These results also support the
hypothesis statement that these instructional strategies would enable learners to apply principles learned to simulated workplace scenarios. However, with a negative instructional efficiency rating the results for this interaction reject the hypothesis statement that the instructional strategies applied to this interaction would enable an instructionally efficient interaction.

This interaction met learning outcomes with a mean performance score of 84%. The two-dimensional instructional efficiency rating of -.0126 that utilizes the performance and mental effort scores while learning indicated that this interaction was not instructionally efficient.

The three-dimensional instructional efficiency rating of .0444, which utilizes the posttest performance scores, mental effort during learning, and mental effort during the posttest, indicates that this interaction is instructionally efficient. This instructional efficiency rating indicates that the learners that completed this interaction scored well on the posttest and that the mental effort required for learning and the posttest was not significant. These results support the hypothesis statement that the application of the instructional strategies that facilitate cognitive processes and apply cognitive load theory within this interaction and throughout the e-learning course have enabled an instructionally efficient interaction. The complete statistical analysis is provided in Table 8.
Table 8. Descriptive Statistics/Building Owner Scenario

<table>
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</table>

The posttest consisted of 15 multiple-choice questions (see Figure 23) that addressed the goal of the course as a whole and the learners achieved an average score of 91%.
Figure 23. Posttest consisting of 15 multiple-choice questions.

Twenty-eight learners completed this test and 29 learners completed the corresponding mental effort survey. The mean performance score was 91%. The mean total mental effort score was 5.2, which when rounded to 5 corresponds to the learning effort equivalent to *neither low nor high mental effort*. The two-dimensional instructional efficiency rating was .0981 and the three-dimensional instructional efficiency rating was .1712.

These results support the hypothesis statement that the application of specific instructional strategies throughout this e-learning course that facilitated cognitive
processes and applied cognitive load theory would enable learners to achieve learning outcomes.

The posttest mean performance score of 91% indicates that learners achieved the learning outcomes designed for the course as a whole. The total instructional efficiency for the e-learning course calculated through the two-dimensional instructional efficiency metric was .0981, which utilizes the performance score for the posttest and the learning mental effort for all interactions within the course, indicates that the entire course was instructionally efficient. This result supports the hypothesis statement that the application of instructional strategies, which facilitate cognitive processes and apply cognitive load theory throughout the course, would enable an instructionally efficient e-learning environment.

The three-dimensional instructional efficiency rating of .1712, which utilizes the posttest performance score, total learning mental effort, and the posttest mental effort, also indicates that the e-learning course as a whole was instructionally efficient. These results support the hypothesis statement that the instructional strategies would enable an instructionally efficient e-learning environment. The complete statistical analysis is provided in Table 9.
Table 9. Descriptive Statistics/Posttest

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Summary of Results

This chapter has reported the results and findings of this study specific to the hypothesis. The variables involved within this study include the scored learning interactions, posttest and the corresponding data for each learner (a) performance scores during learning and the posttest, (b) mental effort during learning and the posttest, and (c) instructional efficiency, which are summarized in Figures 24, 25, and 26.

Figure 21 provides the performance scores for each learning interaction and the posttest score for the course. As the concepts were applied through the match games, which focused on content from the first module specific to only two customers per match game learners did well. However, their scores decreased during the Snake Bus quiz show game, which presented concepts from all the previous learning interactions and asked...
them to apply these newly acquired concepts across multiple modules specific to four possible customers. Following the Snake Bus quiz show game where the mean performance score was 77%, learners scored better on the next two individual learning interactions, with a mean performance score of 86% for both of these interactions. These interactions concentrated on new concepts specific to components and then the sales process after listening to the introduction provided by the learning agent using the instructional strategy of dual modalities and placing these new concepts in context of existing knowledge. Their scores dipped again once they began putting all of the course concepts together for the first scenario. Based on the performance scores for the simulated workplace scenarios—architect scenario 83%, engineer scenario 78%, and building owner scenario 84%—learners struggled with the engineer scenario when compared to the building owner and architect scenarios. Based on the content provided this is not surprising there were clear benefits for the building owners and architects, but the benefits of this new product for engineers were not as well defined. Once they reached the final posttest, which was a culmination of all of the new concepts, applied in a multiple-choice question and answer format they performed well, outscoring all of the previous interactions. The interactions and the posttest as they appear in the course are listed in Figure 24, along with their corresponding performance scores.
Based on the results of the two-dimensional instructional efficiency metric, four of the learning interactions were instructionally efficient and four were not. The e-learning course as a whole was also found to be instructionally efficient. However, the three workplace scenarios and the second match game were found not to be instructionally efficient (see Figure 25). These results both support and reject the hypothesis statement that the instructional strategies applied within each interaction and throughout the e-learning course would enable instructionally efficient interactions.
According to the three-dimensional instructional efficiency metric, all of the interactions were instructionally efficient. This metric included the incorporation of the posttest performance score, mental effort during learning, and mental effort during the posttest. The three-dimensional instructional efficiency metric was applied based on the recommendation of Tuovinen and Paas (2004) who suggest the introduction of the three-dimensional instructional efficiency metric provides a more accurate and stabilizing way to review the instructional efficiency of an interaction, through the application of learning effort, test effort, and test performance (see Figure 26).
Summary

The results within this study supported the hypothesis statement that the applying instructional strategies that facilitate cognitive processes and apply cognitive load theory would enable learners to achieve learning outcomes and enable an instructionally efficient e-learning course. The results also support the hypothesis statement, through the application of these instructional strategies learners would be able to apply the principles learned within simulated workplace scenarios.

However, the results for each interaction specific to the two-dimensional instructional efficiency rating were not as clear-cut. The hypothesis statement, these instructional strategies would enable instructionally efficient interactions was rejected for four of the interactions within this e-learning course which produced negative two-dimensional instructional efficiency ratings indicating that each of these interactions were not instructionally efficient. However, these same interactions produced positive three-
dimensional instructional efficiency ratings indicating that these interactions in fact were or could be deemed instructionally efficient, according to this metric. This finding supports the claims made by Tuovinen and Paas (2004), who indicate that because the three-dimensional approach includes the test performance, test effort and learning effort it provides a more accurate view of the instructional efficiency for the entire instruction process. In the next chapter, the results and conclusions of these findings will be discussed along with recommended future research.
CHAPTER 5. RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

The purpose of this study was to explore the impact of instructional strategies that facilitated cognitive processes and applied cognitive load theory on the ability of learners to achieve learning outcomes and the instructional efficiency of the learning environment.

This study set out to test the following hypothesis. Learner-content interactions designed to manage intrinsic cognitive load, decrease extraneous cognitive load, increase germane cognitive, and facilitate learners’ cognitive processes will:

1. Enable learners to achieve learning outcomes
2. Enable learners to apply the principles learned within simulated workplace scenarios
3. Enable instructionally efficient interactions
4. Enable an instructionally efficient learning environment

Conclusions

Enable Learners to Achieve Learning Outcomes and Instructional Efficiency Match Games

The match games reinforce customer needs and the specific Snake Bus benefits that meet those needs in context of the Sleek, Green, RECAP acronym, which provides signals and cues (Clark, 2003) to the key concepts of this course. These learner interactions also applied the dual modalities (Clark et al., 2006) instructional strategy
with the learning agent and allowed learners to make decisions and apply newly acquired concepts within a safe environment with feedback and scaffolding (Gagné, 1985).

The first match game was effective with a performance score of 80%, which was a little lower than the average performance score for all learning interactions of 82%. However, it was still an effective interaction and enabled learners to achieve learning outcomes. The second match game was also effective with learners achieving a mean score of 83%, which is slightly higher than the mean performance score for all learning interactions. Therefore, the learners achieved learning outcomes within both of these interactions.

The first match game had positive two-dimensional and three-dimensional instructional efficiency ratings. However, the three-dimensional instructional rating was the lowest of all the scored learner-content interactions; the three completion examples (workplace scenarios) had lower three-dimensional ratings. Proving that the context of a game that learners were unfamiliar with increased extraneous cognitive load and therefore created a low three-dimensional instructional efficiency rating for the first match game, but when learners interacted with the game the second time their instructional efficiency ratings doubled. The second match game had the highest three-dimensional instructional efficiency rating proving that extraneous cognitive load was reduced through the familiarity of the game now that the learners had already completed the first match game. However, the two-dimensional instructional efficiency rating for the second match game was negative which can be explained by Tuovinen and Paas’s (2004) theory that the three-dimensional instructional efficiency rating is more reliable and accurate due to the fact that it includes all of the variables during the learning process.
(i.e., testing performance, learning effort, and test effort). The two-dimensional instructional efficiency rating only includes the learning performance score, and the learning mental effort. The negative two-dimensional instructional efficiency rating may also be explained by the fact that a worked example was used prior to the first match game where the learning agent modeled the desired behavior, and outlined the specific features, functions, and benefits of this new product specific to 3 different possible customers. Therefore, even though these two games were identical instructionally, which reduced extraneous cognitive load during the second match game, learners experienced an increase in germane cognitive load because they did not have the benefit of a worked example immediately preceding the second match game.

**Snake Bus Quiz Show Game**

The mean performance score of 77% for the Snake Bus quiz show game was the lowest mean performance score for all of the learning interactions; this score was also below the combined mean learning performance score, which was 82%. This particular interaction chunked content into categories, presented scenario-based questions, and referenced the acronym *Sleek, Green, RECAP*, all of which are recommended strategies from the research, including Clark et al. (2006); Gagne (1985); Hooper and Hannafin (1991); and Jonassen (1988) (see Tables 10 and 11). However, it was also presented in the context of a game, which according to Clark et al. (2006) increases extraneous cognitive load because it does not replicate real-life scenarios. The increased extraneous cognitive load would then theoretically lower the performance scores, increase the mental effort scores and therefore decrease the instructional efficiency of this interaction. However, although the performance scores within this interaction are the lowest of all the
interactions, the mental effort score of 5.2 was also low equivalent to *neither low nor high mental effort*. Learners were also still able to achieve learning outcomes, demonstrated by their learning performance within this interaction, their performance within the scenarios and their posttest scores. Therefore, extraneous load during this interaction did not cause learners to perform poorly.

Prior research did not collect learning performance data within the learning interaction; they collected performance scores within an assessment following the learning interaction(s). One could argue that the Snake Bus quiz game show functioned as an assessment covering the content covered within the two match games. The Snake Bus quiz show game was at the end of the second module following the two match games. It was the first place in the e-learning course where learners’ knowledge was checked specific to the content covered during the two match games. Based on the instructionally efficiency ratings for the first match game the extraneous load experienced by learners during this interaction contributed to the learners’ poor performance scores for the Snake Bus quiz show game.

The match games were also presented in a game format. However, unlike the Snake Bus quiz show game’s familiar game-show context these games were original designs and therefore completely new to the learners. However, once the learners had completed the first match game, the performance scores for the second match game increased and the mental effort scores decreased. The first match game had the lowest three-dimensional instructional efficiency rating of all the interactions except the workplace scenarios. Where the second match game had the highest three-dimensional instructional efficiency rating for all interactions, the two match games were identical.
except for the content. Proving that the familiarity of the game the second time through decreased learners’ extraneous cognitive load.

*Component Game*

This particular interaction utilized graphics and questions or statements in context of how the feature would benefit a customer, represented through relevant images and verbiage (Gagne, 1985; Hooper & Hannafin, 1991). However, it was also in a game format, which has been documented in the past by researchers like Clark (2003) as adding extraneous load to learning and not an instructionally efficient way of presenting learning within a self-paced e-learning course. The three-dimensional instructional efficiency results for this interaction contradict this finding with a .3437 instructional efficiency rating which was the second highest within the course. This data suggests that the instructional strategies applied within the game enabled learners to perform better and reduced extraneous cognitive load and increased germane cognitive load, therefore enabling an instructionally efficient interaction. With a performance score of 86%, this interaction was also effective in enabling learners to achieve learning outcomes for this interaction.

*Sales Process*

This particular interaction utilized graphics, questions or statements, and immediate feedback enabling learners to check their progress through activities where they are challenged by forcing learners to make decisions through the application of newly acquired concepts (Gagné, 1985). This interaction also incorporated text within a diagram to reduce split attention and to facilitate a deeper understanding (Clark, 2003).
However, it was also in a game format, which has been documented in the past by researchers like Clark (2003) as adding extraneous load to learning and not an instructionally efficient way of presenting learning within a self-paced e-learning course. This interaction had three-dimensional instructional efficiency results of .3259 and the lowest mental effort scores of 4.9, which contradict this research through the production of an instructionally efficient interaction. The mean performance score of 86% also indicates that this interaction enabled learners to achieve learning outcomes. Therefore, this interaction was both instructionally efficient and effective.

**Applying Principles Learned Within Simulated Workplace Scenarios**

The workplace scenarios follow the instructional strategies of the cognitive load researchers specific to a completion example and utilize graphics and audio narration providing dual modality to facilitate the cognitive process of encoding (Clark et al., 2006; Hooper & Hannafin, 1991; Sweller et al., 1998). These interactions also placed new information in context of learners’ existing experience and knowledge to facilitate links and internal cues to existing schema and therefore enable the cognitive process of retrieval through integration. Narrative storytelling was also used in context of current knowledge through real-world scenarios that replicate actual challenges (Clark, 2003; Hooper & Hannafin, 1991; Jonassen, 1988; Kennedy, 2004). These interactions also enabled encoding through self-explanations by allowing learners to reflect and complete the scenarios in a free-form text format (Chi et al., 1994).

The three-dimensional instructional efficiency rating for each scenario was positive with the architect scenario having the highest instructional efficiency rating of .1825. However, all three workplace scenarios had the lowest instructional efficiency
ratings when compared to all of the other learning interactions (see Figure 23). They also had the highest learning mental effort scores averaging 5.8, indicating that learners felt these interactions required rather high mental effort. This result contradicts the research, which states that the instructional strategies implemented should have reduced the cognitive load. However, the performance scores averaged 82% indicating that extraneous load was low. Therefore, the conclusion can be made that although learners felt that these fill-in-the-blank simulated scenarios in the form of completion examples were difficult, the difficulty was relevant to germane cognitive load. The other variable that could have played a part in these results is that these completion examples were part of a course where learners experienced several interactions prior to these that did not require as much mental effort because they were in the form of games that provided scaffolding or multiple-choice questions with feedback. However, the workplace scenarios required the learners to answer utilizing their own words once they were provided with the scenario and some information about the customer, making it easy for learners to state that these interactions required more mental effort.

The performance scores support the hypothesis statement, by implementing instructional strategies that facilitate cognitive processes and apply cognitive load theory learners will be able to apply the principles learned within simulated workplace scenarios.

Effectiveness and Instructional Efficiency of the E-Learning Course

The mean performance score for the posttest was 91%, indicating that learners achieved learning outcomes for the entire course. The calculation of the instructional efficiency of the e-learning course was based on the three-dimensional instructional
efficiency metric and included the performance on the posttest, the learning mental effort for all interactions, and the mental effort during the posttest. The instructional efficiency was efficient but with a mean mental effort of 5.8, which when rounded to 6 is equivalent to *rather high mental effort* for the posttest; the mental effort ratings were higher than every interaction except for one workplace scenario (completion example). Again, this mental effort was related to germane load due to the performance scores, making the e-learning course instructionally efficient and effective. Supporting the hypothesis statement, by applying instructional strategies that facilitate cognitive processes and apply cognitive load theory the learning environment will be instructionally efficient and learners will achieve learning outcomes.

*Technologies*

In order to create each interaction and the e-learning course as a whole several different technologies were necessary. These technologies included:

1. A learning management system (LMS) to capture the learners’ performance and mental effort scores.

2. Interactive learning agent technology (TelSim) as a coach throughout the course.

3. Audio (TextSpeech Pro) through the use of the learning agent, to reduce extraneous cognitive load.

4. Multimedia software (Flash and Lectora) to deliver complex graphics and the learning agent to deliver interactions that facilitated cognitive processes, while applying cognitive load theory.

Although technology was not the focus of this study, it became a challenge when working with an LMS to collect the performance and mental effort data necessary to conduct the study. Two LMS companies were put to the test to enable the collection of
this type of data and after months of working with these companies, making
determinations on what needed to be done and through what technology, followed by
weeks of testing, the collection of the data was enabled and the study was launched. Due
to the fact that the data needed to be collected while learners were learning, rather than
immediately following through an assessment, the code for each interaction had to be
tweaked to allow for the collection of performance data during each interaction. Although
Lectora was used for the creation of the course navigation and template, it was not used
to create each of the learner-content interactions. These interactions were developed in
Flash and then the Flash files were embedded into the course. Then SCORM-specific
code had to be added to each learner-content interaction by a programmer familiar with
the learning management system (LMS) code and SCORM. The mental effort surveys
also had to be custom created and coded to collect the data immediately following each
learner-content interaction. The version of Lectora used would only allow for the creation
of surveys at the end of each module or at the end of a course, not at the end of each
interaction. Therefore, each survey had to be custom created in flash and the SCORM
code had to be manually added to each of the surveys. It seems although SCORM is
meant to create interoperability there is still much work to be done when it comes to the
limitations of the WYSIWIG programs that are able to create SCORM-compliant content.
However, in the end SCORM and an LMS were the technologies that enabled the
collection of the performance and mental effort data necessary to complete the study.

*Learning Agent*

The technology that had the greatest impact on the ability to implement the
instructional strategies cited in the research effectively was the interactive learning agent
provided by TelSim Software. Without the use of this technology, the implementation of the following instructional strategies could not have been done as effectively.

*Managing intrinsic cognitive load.* Within each module’s introduction, learning objective page, and summary, the learning agent enabled conversational style of narration for each of these pages.

*Decreasing extraneous cognitive load.* Dual-modality instructional strategy was enabled through the use of graphics explained by the learning agent in context of each module, the course, and how knowledge and skills will be applied once the learner is back on the job. The learning agent provided a worked example where he modeled the wanted behavior by interacting with three different possible customers. Then within the workplace scenarios, the instructional strategy of a completion example was applied where the learning agent set up the scenarios and provided the necessary cues and signals along with graphics in context of what the learners had already learned.

*Increasing germane cognitive load.* The learning agent was able to amplify signals and cues to the key concepts within the course through conversational dialogue and through pointing out the key concepts.

*Facilitating cognitive processes.* The learning agent enabled retrieval through organization by providing introductions, summaries, transitions, and signals and cues. The learning agent enabled retrieval through integration by placing new information in context of learners’ existing experience and knowledge to facilitate links and internal cues to existing schema through narrative storytelling in context of real-world scenarios.
Results

Achieving Learning Outcomes

Learner-Content Interactions

As shown in Figure 21, each learning interaction enabled learners to achieve learning outcomes with a mean performance score of 82% for all learning interactions, and a mean performance score of 91% on the posttest. Based on these performance scores it is clear that the interactions enabled learners to achieve learning outcomes within each interaction and the course as a whole. These results support the statement in the hypothesis that the instructional strategies applied enabled learners to achieve learning outcomes. Prior to this e-learning course learners could not identify possible customers and describe the appropriate features, functions, advantages and benefits of the product, or describe the tasks involved with the sales process, which were all topics of the scored learner-content interactions. Achievement of these learning outcomes indicates that through the use of the identified instructional strategies (see Appendix D and E) throughout the e-learning course and within each of the scored interactions learners’ cognitive processes were facilitated, extraneous cognitive load was minimized and germane cognitive load was kept at an appropriate level for these learners. Instructional designers that wish to create effective interactions and effective e-learning courses should not only apply these instructional strategies within each learner-content interaction but throughout the entire e-learning course.
Workplace Scenarios (Completion Examples)

Each workplace scenario enabled learners to achieve learning outcomes and apply the principles learned within a simulated workplace scenario. Learners provided specific detail on the features, advantages, and benefits of the Snake Bus for each customer, for each of the completion examples (workplace scenarios) provided in the final module of the e-learning course. The performance within these workplace scenarios supports two statements within the hypothesis, that the instructional strategies applied enabled learners to achieve learning outcomes and apply the principles learned within simulated workplace scenarios.

These real-life scenarios utilized the instructional strategy suggested by cognitive load theory of completion examples where the scenario was setup by the learning agent and the learners completed it by listing the features, advantages, and benefits specific to the customer’s needs for each of the scenarios. These results make it possible to conclude that the learners were provided the appropriate instructional strategies throughout the e-learning course and within the workplace scenarios. Making it possible for the learners to achieve learning outcomes for each workplace scenario and apply the principles learned within a simulated workplace scenario and therefore supporting the hypothesis.

Instructional Efficiency

The instructional efficiency results for each interaction and the e-learning course as a whole are not as clear, when comparing the two-dimensional and three-dimensional instructional efficiency results as seen in Figure 22 and Figure 23 respectively. Tuovinen and Paas (2004) were accurate when stating the three-dimensional instructional efficiency metric seems to:
Iron out many of the random fluctuations in the learning and test effort measures obtained at different times, rather than producing spurious results based on chance when effort measures are sought only during limited components of the learning and test process. (p. 149)

The three-dimensional instructional efficiency calculation allows for more of a consistent look at the entire course and each interaction’s instructional efficiency by utilizing the three variables of (a) test performance, (b) learning mental effort, and (c) test mental effort (Tuovinen & Paas, 2004). The fact that all of the interactions and the e-learning course as a whole produced instructionally efficient ratings using the three-dimensional instructional efficiency metric corresponds with the fact that this metric enables a clearer look at instructional environments through the facilitation of germane cognitive load (Tuovinen & Paas, 2004). This was accomplished within this learning environment through instructional strategies meant to manage intrinsic cognitive load, increase germane cognitive load, decrease extraneous cognitive load, and facilitate cognitive processes relevant to the learning outcomes.

Recommendations

**Instructional Efficiency Metric**

To determine instructional efficiency this study utilized both the two-dimensional and three-dimensional instructional efficiency metrics for each learner-content interaction and the e-learning course as whole. The results substantiated the statement made by Tuovinen and Paas (2004) that because the three-dimensional instructional efficiency metric combines learning effort, test effort, and test performance “it appears to smooth out the individual process differences and provide a more valid and possibly more
reliable measure than either of the two-dimensional alternatives” (p. 148). However, the three-dimensional instructional efficiency metric applied was not identical to how it was applied to studies in the past. This study applied the three-dimensional instructional efficiency through the use of the learning mental effort, posttest mental effort, and posttest performance data. The three-dimensional instructional efficiency cited in the Tuovinen and Paas 2004 study utilized the learning mental effort, and test mental effort and performance from an assessment, which immediately followed the learning interaction.

Additional research is necessary to determine what the best application is of either the two-dimensional or three-dimensional instructional efficiency metric and when should we be collecting the data for each metric. Additional research is also necessary specific to how these calculations should be made. Clark et al. (2006) perform the two-dimensional calculation as the average in $z$ scores for learning performance—average in $z$ scores for learning mental effort ÷ the square root of 2. This study calculated the two-dimensional instructional efficiency rating as Tuovinen and Paas (2004) did by taking each learner’s $z$ score for performance during learning – $z$ score for mental effort during learning ÷ the square root of 2. Previous research studies also collected learning performance data immediately following the learning activity through an assessment, where this study collected learning performance data as the learner completed the interaction.

There are many questions that remain unanswered as to the effectiveness of the new approach to performance data collection and the application of the two-dimensional or three-dimensional instructional efficiency metric. Did collecting the performance data
during learning skew the learners’ mental effort rating because they already knew how they performed? Did the fact that they completed multiple learner-content interactions within a course skew their mental effort ratings because they were comparing each interaction? For example, the mental effort ratings for each completion example were the highest of all the mental effort ratings for all of the learner-content interactions. Was this because they required more germane cognitive load then any of the other interactions and when learners compared the mental effort required to complete these scenarios to the interactions previously they naturally scored them higher? Does the three-dimensional instructional efficiency metric still maintain its reliability by applying it with posttest data rather than performance data on assessments immediately following each learning interaction?

The drawback of all of these metrics no matter when the data is collected, is that although they all measure cognitive load they do not differentiate between intrinsic, germane, or extraneous cognitive load. Therefore, future research that is able to create an instrument which is capable of isolating intrinsic, extraneous, or germane cognitive load would be an invaluable tool for future researchers interested in determining the instructional efficiency of learner-content interactions or e-learning environments.

*Managing Intrinsic Cognitive Load*

According to cognitive load theory (Sweller, 1988), working memory for all learners has limitations that are dependent on the learner’s existing knowledge and experience. The continuum of working memory resources leading up to automaticity affects the acceptable levels of extraneous and germane cognitive load and can play a large role in the ability of learners to achieve learning outcomes and improve on-job
performance. According to Clark et al. (2006), for learners that have not achieved automaticity, “the instructional environment must substitute for limited schemas of novices by segmenting, sequencing, and presenting content in ways that will avoid overload” (p. 39). The instructional environment created by this research did exactly that by facilitating cognitive processes and applying cognitive load theory (Sweller, 1988) through the application of instructional strategies that were identified throughout the research as effective.

In order to determine the actual impact of learner experience on instructional efficiency and performance, future research should collect detailed upfront data for each learner specific to their experience with the content and modality. Then a comparison should be made of the instructional efficiency results and mental effort scores for each of these learners. Performance scores should be captured during the learning process and the three-dimensional instructional efficiency metric should be applied. A possible research question would focus on whether the instructional efficiency results rise with the experience of the learner when presented with the same interactions that are designed to facilitate cognitive processes and apply cognitive load theory (Sweller, 1988). According to cognitive load theory (Sweller, 1988), the more experienced learners will have decreased extraneous cognitive load no matter the type of interaction. In theory, this would decrease their overall mental effort and enable them to score higher because they are able to dedicate more mental effort towards germane cognitive load. In theory, this would also enable higher instructional efficiency results.

Additional research could also include a follow-up with the same learners that completed the e-learning course to determine if the learners are able to maintain and
apply the knowledge within the workplace. A possible research strategy could include learners taking simulated workplace scenarios again once they have been without any additional instruction for a specific amount of time. Then a comparison could be made between these results and the results from the initial performance scores achieved within the e-learning course simulated scenarios.

Summary

This study set out to determine if the researcher could support the following hypothesis. Learner-content interactions designed to manage intrinsic cognitive load, decrease extraneous cognitive load, increase germane cognitive load, and facilitate learners’ cognitive processes will:

1. Enable learners to achieve learning outcomes
2. Enable learners to apply the principles learned within simulated workplace scenarios
3. Enable instructionally efficient interactions
4. Enable an instructionally efficient learning environment

Although it was clear that the instructional strategies applied within each interaction and throughout the course, enabled learners to achieve learning outcomes for each interaction and the e-learning course, and enabled the learners to apply the principles learned within the simulated workplace scenarios. The instructional efficiency of each interaction and the course as a whole was not as clear.

The key difference with this study, when compared to previous studies, was that the instructional efficiency metric was not being applied within a comparative study, including both poorly designed interactions and interactions that applied cognitive load.
theory and facilitated cognitive processes. Therefore, the benefits of the two- and three-dimensional instructional efficiency metrics were not as clear. This study also collected learning performance detail within the interaction itself rather than immediately following the interaction through an assessment, which reflects true learning performance not test performance. However, this timing affected the mental effort scores and consequently the instructional efficiency ratings as indicated within the conclusion section of this document.

Because it was an exploratory study and there was no benchmark that could be used specific to instructional efficiency. The researcher established a positive instructional efficiency rating as instructionally efficient and a negative instructional efficiency rating as not efficient. The exploratory study format of multiple interactions within one e-learning course designed to facilitate cognitive processes and apply cognitive load theory. Also revealed a possible issue with how learners’ recorded mental effort scores, which directly influences instructional efficiency, it seems as learners went through the course they began to compare the difficulty of one interaction to another and therefore gave interactions higher ratings because they seemed more difficult or easier than the prior interaction. For example, anyone would state that answering a multiple-choice question is easier than answering an essay question. This is similar to the comparison that could be made to the workplace scenarios when compared to any of the other interactions within the course. Therefore possibly contributing to the workplace scenarios resulting in the highest mean mental effort ratings and the lowest instructionally efficiency ratings. However, it is clear that the load incurred by learners within these
scenarios was germane as they performed well during each of these interactions with an average score of 82%.

There were both expected and unexpected findings and results throughout this study. The most surprising findings were the gaps that still exist in the technology available to develop SCORM-conformant e-learning, which in turn enables the collection of the data necessary to conduct studies like these. At the same time, the advancement of these standards is what allowed this researcher to collect performance data as learning was occurring rather than after the learning interaction in the form of an assessment. The advancements of this standard also enabled this researcher to collect free-form text entries for the workplace scenarios (completion examples) and score them later with the help of subject matter experts. Both of these tasks were made possible through the creation of flash interactions with the appropriate SCORM code for a particular LMS. The gaps were identified with the WYSIWIG technology that is supposed to enable designers to create SCORM-conformant e-learning. Although the this technology enabled the researcher to create the e-learning course and the SCORM-based navigation, an advancement over creating a navigation template manually, to capture all of the data including the survey results, the surveys and all of the scored interactions had to be created in flash. Then SCORM code had to be added to each of these interactions to enable the collection of the data necessary for the research. This SCORM code was not a generic line of code but rather specific to the LMS that was implemented.

The expected findings and results were those that supported the hypothesis statement, the application of the identified instructional strategies that facilitate cognitive processes and apply cognitive load theory would enable learners to achieve learning
outcomes and would produce an instructional efficient learning environment. The third result that supports the hypothesis but was not expected was that learners were able to apply their newly acquired knowledge to simulated workplace scenarios. Future studies should bring this result a step further to answer the following question: Do the application of instructional strategies that facilitate learners’ cognitive processes and apply cognitive load theory enable learners to apply newly acquired knowledge once they are back in the workplace?

Further unexpected results were the two-dimensional instructional efficiency ratings that were negative for all three workplace scenarios and one of the scored learner-content interactions (match game 2). This result can be explained by Tuovinen and Paas’s (2004) theory: because the two-dimensional instructional efficiency metric does not capture all the portions of the learning process, it is not as accurate of a calculation as the three-dimensional instructional efficiency metric. This metric captures mental effort data during learning, mental effort data during testing and performance scores during testing. This is supported by the findings in this study. The three-dimensional instructional efficiency ratings for the five learner-content interactions that were scored, the three workplace scenarios, and the e-learning course as a whole were all higher than the two-dimensional instructional efficiency ratings.

Given the results and conclusions of this study instructional designers looking to design and develop an asynchronous e-learning course that is both instructionally efficient and effective should be applying the instructional strategies identified in Tables 10 and 11.
These strategies provide instructional designers with a toolset that explains the instructional strategies, their impact, and provides examples of how the instructional strategies can be applied enabling designers to create e-learning courses that are instructionally efficient and effective.

A critical path to success in the creation of future e-learning will be the application of instructional strategies and their supporting technologies to enable effective and instructionally efficient e-learning environments. It is time that the industry begins utilizing learning technologies to support research-based instructional strategies, which enable learners to achieve learning outcomes, and move away from the application of learning technologies for the fleeting *wow* factor.
<table>
<thead>
<tr>
<th>Cognitive Load Theory (CLT)</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Managing intrinsic cognitive load</td>
<td>Complete a content and audience analysis to determine learner experience with modality and content. Use modules, introductions, summaries, transition statements and learner objectives to key learners to important concepts for the course and each module. Chunk content as it will be chunked once learners return to the workplace.</td>
</tr>
<tr>
<td>Decreasing extraneous cognitive load</td>
<td>Convey information concisely with graphics and audio narration in context of each module, the course, and how the concepts will be applied within the work environment. Use a learning agent to model the behavior you want learners to replicate by the end of the course. This should be done through worked examples that provide a complete picture of the process and/or behavior learners will need to achieve learning outcomes. Use completion examples as learners progress through the content and if appropriate move to problem-solving by the end of the course.</td>
</tr>
<tr>
<td>Increasing germane cognitive load</td>
<td>Use signals and cues throughout the course for key concepts. For example an acronym along with graphics that is also later used once learners are back in the field. Integrate words into diagrams or graphics to prevent split attention throughout the course. Explain complex graphics or processes through narration, preferably a learning agent.</td>
</tr>
</tbody>
</table>
Table 11. Strategies for Effective, Efficient E-Learning through the Facilitation of Cognitive Processes

<table>
<thead>
<tr>
<th>Facilitating Cognitive Processes</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enabling retrieval (organization)</td>
<td>Provide questions to force learners to recall key concepts. Utilize scenario-based questions to force learners to apply key concepts within real-world scenarios that replicate their work environment. Provide immediate feedback throughout the course to reinforce or remediate the same key concepts. Use similar verbiage during learning, for the questions, and application, as well as the feedback. Utilize headings, subheadings, summaries, introductions and learner objectives to structure the content in a way that replicates the application throughout the course and later back in the workplace. This will enable retrieval throughout the course and once back on the job.</td>
</tr>
<tr>
<td>Enabling retrieval (integration)</td>
<td>Use real-life examples of current customers or current scenarios to place information in context of learners’ existing knowledge throughout the course. Then introduce the new product or concepts in context of these existing customers or scenarios. If possible, use a learning agent that provides narrative storytelling in context of current knowledge throughout the course, including, in the introductions, worked examples, completion examples, problem-solving tasks, and summaries.</td>
</tr>
<tr>
<td>Enabling retrieval (near and far transfer)</td>
<td>For near transfer utilize drill and practice type exercises where learners get to practice the same process or application of the processes several times in several different ways. For far transfer applications use workplace scenarios applied to several different possible customers or contexts. Allowing learners to draw upon the newly acquired knowledge and apply it in many different ways.</td>
</tr>
<tr>
<td>Enabling retrieval (retrieval plan)</td>
<td>Some processes will require learners to apply the same exact process, which should be replicated in the learning environment exactly the way they will apply it. While others will require concepts applied in many different contexts, which require abstract organizers, and/or acronyms represented by graphics in order to allow learners to remember the key concepts and than be able to apply them within multiple contexts.</td>
</tr>
</tbody>
</table>
Table 11. Strategies for Effective, Efficient E-Learning through the Facilitation of Cognitive Processes *(continued)*

<table>
<thead>
<tr>
<th>Facilitating Cognitive Processes</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orienting</td>
<td>Orient the learners to the key concepts and their application in many different ways, enabling learners to practice applying concepts within different contexts.</td>
</tr>
<tr>
<td>Presenting (dual encoding)</td>
<td>Highlight key concepts and their application within real-world examples, by using images and audio narration within introductions, summaries, worked examples, completion examples, and problem-solving tasks.</td>
</tr>
<tr>
<td>Enabling encoding (cognitive practice)</td>
<td>Allow learners to apply the underlying concepts and practice making crucial decisions within the learning environment.</td>
</tr>
<tr>
<td>Enabling encoding (metacognition)</td>
<td>Allow learners to check their progress as they apply their newly acquired knowledge and skills.</td>
</tr>
<tr>
<td>Enabling encoding (self-explanations)</td>
<td>Allow the learning agent to model self-explanations through completion examples and then allow learners to generate self-explanations through completion examples and problem-solving. These self-explanations need to be provided within free-form text entries not through the selection of supplied possible answers.</td>
</tr>
</tbody>
</table>
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APPENDIX A
PROJECT DEFINITION WORKSHEET

Scope: Create a small e-learning module- approximately 5 total interactions possibly 20 pages of content including posttest.

Milestones and Due Dates: Kickoff Meeting (12/08/06) Project Definition Worksheet (12/14/06) Scenarios- FAQ (ASAP) Learning Objectives (1/30/06) Outline (1/30/06) Storyboard (3/01/06) e-learning Development (3/25/06)

Purpose of this Worksheet:
The Project Definition Worksheet is designed to collect the information necessary to begin a project.

**Project Definition Questions**

**Goal (End Result)**
What is it you want to accomplish?
Provide independent sales reps with the knowledge and ability to acknowledge Snake Bus opportunities from existing and new customers.

**Objectives**
Why are you doing this?
To provide the independent sales reps with information on what customers are the right fit for Snake Bus and when they should involve Roger or Scott.
To demystify the basics of electricity allowing sales reps to feel comfortable selling Snake Bus.
Provide workplace scenarios for the independent sales reps to emulate.
Provide workplace scenarios for the independent sales reps to practice.
To improve product knowledge in context of possible workplace scenarios.

**Business Case**
What is the business case?
Sell more Snake Bus

**Project Definition Questions (cont.)**

**ROI**
What is the ROI?
A greater number of independent sales reps call Roger and Scott with Snake Bus opportunities.

**Audience**
Who is your audience?
Independent Sales Reps- 65- (Data Com and Electrical Engineer)
Who is directly and indirectly impacted?
Independent Sales Reps, Customer, Roger, and Scott
Assumption(s)
What are our assumptions about the project and audience?
Knowledge of electricity not up to par, do not know enough about the product, do not know who to target to sell the product.

Expectation(s)
What will we produce, deliver, or show as our results?
More Independent sales reps contacting Roger and Scott with identified Snake Bus sales.

How will we know we have been successful?
Independent sales reps call Roger and Scott more often to get them involved to close deals on Snake Bus.

How will we measure our success?
The percentage of independent sales reps approaching Roger and Scott with the right audience for Snake Bus. (Correct Target Market)

Project Definition Questions (cont.)
Program Phases
Project Definition Document, Scenarios, Learning Objectives, Outline, Storyboard, e-learning
Course
Schedule
Total design and development should span starting January 8th - February 23rd.

Challenges
What are some challenges we may encounter?
Taking the time to take the e-learning course, not certain what the advantages of taking e-learning course maybe.
What can we do to avoid them?
Market it. Use incentives

Subject Matter Experts
Roger & Scott

Resource Team
What are their roles/responsibilities?

<table>
<thead>
<tr>
<th>Team Member</th>
<th>Role</th>
<th>Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roger and Scott</td>
<td>SME</td>
<td>Scenarios and FAQs, Learning Objectives approval, Outline approval, Storyboard approval, Interface Approval, and e-learning course approval.</td>
</tr>
<tr>
<td>Molly</td>
<td>SME</td>
<td>Website Link, Learning Objectives approval, Outline approval, Storyboard approval, Interface Approval, and e-learning course approval.</td>
</tr>
<tr>
<td>Gina Richter GO-Learning Inc.</td>
<td>Instructional Designer</td>
<td>Kickoff Meeting, Learning Objectives, Outline, Storyboard, and delivery of final e-learning course.</td>
</tr>
<tr>
<td>Audience Analysis Questions</td>
<td>Answer</td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>1. What type of training for Snake Bus have sales reps received in the past? Instructor-Led, e-learning, etc.</td>
<td>Scott &amp; Roger deliver training with product and literature and move through each individual 2 to 3 hours at time for 2 days or so. Relaxed atmosphere with rep and then tag team with rep and go to a customer site. 60 to 70% (ego?) would rather have Scott just sell it. Then the other 30-40% actually tag team and sell the product with Scott.</td>
<td></td>
</tr>
<tr>
<td>2. If they have not seen e-learning for product training, have they seen it for any other training?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Answer:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>We don’t know if they have seen any e-learning.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Should we do a glossary of terms for the e-learning course?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Answer: Yes- if electricity is covered. Need to know it – Concepts of basic electricity.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Have the sales reps provided feedback on training in the past? How was this done, and what were the results?</td>
<td>Answer: Have asked for more training on products, like training that was done.</td>
<td></td>
</tr>
<tr>
<td>5. Are there any success stories that can be shared relating to some of the features/functionality of Snake Bus?</td>
<td>Answer: Yes. Roger and Scott will supply 5 scenarios.</td>
<td></td>
</tr>
<tr>
<td>Answer:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Is there a helpdesk or any support line for product questions, etc. which can be mined?</td>
<td>Answer: Not flexible. Rigid 8 ft. piece of medal understanding the whips which adds the flexibility. 25 ft tap rule.</td>
<td></td>
</tr>
<tr>
<td>Answer:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Is there a list of FAQs about Snake Bus?</td>
<td>Answer: Requested FAQ for Snake Bus.</td>
<td></td>
</tr>
</tbody>
</table>
8. What is the average experience level of the sales reps specific to this industry?

**Answer:**
60 percent are from distribution, 30% from contracting, 10% other.

9. What other types of support (i.e. manuals, helpdesk, supervisor, etc.) have the sales reps received specific to Snake Bus?

**Answer:**
Training manual new approach because of the new technology- electricity 101 (sales training) than snake bus “training” manual that can be left on engineers’ desks.

### Content Analysis Questions

1. What do you feel are the key features and functions of Snake Bus that every sales rep must know?

**Answer:** Brochure.

2. What features/functions of Snake Bus reduce training for your customer or make it easier or cost effective to install?

**Answer:** no need for skilled laborer for implementation, predictable results, reduction of engineering time, return on investment for building owner.

3. What types of features/functions can be added to Snake Bus in order to provide the best possible solution for a customer?

**Answer:** front end installation reduces costs, labor, and then backside add, moves, and changes are done faster without down time. Long-term investment. Day one and moves are less cost, tax benefits, taking your power source with you when you move. Reduces waste through plug and play. Reusable, reclaimable,

4. What are 3 or 4 possible workplace scenarios where Snake Bus should be provided along with some of its peripherals in order to provide a total solution?

**Answer:** Molly getting them for me.

5. What challenges (if any) will a sales rep face when selling the Snake Bus?

**Answer:** too data center oriented, need to refocus on general office space, not enough information on electrical concepts which reduced confidence in selling the product, not focusing in on engineer and architect focus, searching for possible customers,

6. What do you as a sales rep see as the primary goal for Snake Bus training?

**Answer:**
7. What do you see as the possible upsell and/or cross-sell possibilities when selling this product?

**Answer:** get in early with snake bus which will introduce them to the project early which then enables them to cross-sell and or upsell to canyon, and snake tray. Solution Sell.

**Right customer Snake Bus, gets you in for ....then the snake canyon, cable, connectors, and enclosures. With this model because of Snake Bus… you can sell many more products. TOTAL SOLUTION SELL**

8. What are the key features and functions of the Snake Bus that allow sales people to solution sell vs. product sell?

**Answer:**

9. Who is the target customer for this product?

**Answer:** Electrical Engineers, Architects, Building Owners.
Module 1: Introduction
Welcome to the Selling Snake Bus e-learning Course.

- **Course Performance Objective:** At the end of this self-paced e-learning course Sales Reps will be able to recognize Snake Bus opportunities and present potential customers with the features and benefits that apply to their particular needs.
  - **NOTE:** All modules will have review questions at the end of the module and retention type activities/games within the module that will reinforce what has been presented.
  - **NOTE:** When new terms are introduced, they will have a link, which can be clicked to launch the definition. These definitions will also be contained in a downloadable and printable PDF.
  - **NOTE:** This is where animations will play introducing the Snake Bus through quick “teaser” type scenarios, which will be accompanied by audio and graphics.

- **Narrator:** This is one bus your customers will not want to miss; it is not yellow, but it has been certified “green”. Snake Bus is a power distribution system that is adaptable, powerful, fast, convenient, and efficient.
  - **Building Owner:** I always use Pipe & Wire for my power distribution needs in all my commercial buildings and it has worked well for me. Why should I switch to Snake Bus?
    - **Narrator:** Great question. Snake Bus will reduce your setup costs up to 37% over traditional pipe & wire and reconfiguration is easier, cheaper and quicker. Making leasing your building an easy decision.
  - **Architect:** Most of my clients are now looking to reap the benefits of building green. Including, saving energy and money, how can Snake Bus help?
    - **Narrator:** It is a green product and helps with green certification (there really is not a point system for certification where we can attached a specific points to our products)
  - **Engineer:** With traditional pipe & wire configurations are not easily changed once they have been laid. Not only is it costly but it also takes a lot of time and man hours. How does Snake Bus compare?
    - **Narrator:** Snake Bus uses true Plug-n-Play components which eliminate traditional methods of hard wiring equipment. Instantly creating an adaptable modular power distribution system.
  - **NOTE:** This is where learners are introduced to the course and how to navigate through the course.

- **Course Overview Page**
  - **Objectives:**
    - **Identify how much time they will need to complete this course.**
Identify how to navigate the course.
Identify what will be covered throughout this course.

Subjects:
- 20 minute course which provides an overview of the target audience for Snake Bus; Snake Bus features, functions and benefits, and how it can provide a cost effective power distribution solution for Building Owners, Engineers, Architects, and Contractors.
  - By the end of this course you will be able to:
    - Identify why it is important to complete this e-learning course and why you may want to return to this course.
    - Identify the target audience for Snake Bus
    - Describe how building owners, engineers, architects, and contractors will benefit from several Snake Bus key features and functions.
  ➤ This course will also provide you with a downloadable product reference card, which will help you at the point of sale or prior to going to a customer’s site.

**Module 2: Target Customers**

**Performance Objective:** At the end of this module, you will be able to explain what makes Snake Bus the optimal power distribution solution for Building Owners, Engineers, Contractors, and Architects.

**Learning Objectives- At the end of this module Sales reps will be able to:**
- Identify the needs of building owners, engineers, contractors, and architects.
- Identify how building owners, engineers, contractors and architects will benefit from purchasing Snake Bus.

**Topics:**
➤ **NOTE:** I would like to use an acronym for the headings Scott had in his document (with a few changes) which I will be using throughout the course. This is the acronym I came up with.
- The ANSWER: SLEEK, GREEN - RECAP
  SLEEK, GREEN, RAPID, EFFICIENT, CONVENIENT, ADAPTABLE, AND POWERFUL
- **Building Owners Want**
  - Reduced Building Costs
  - Ease of Lease Process
  - Ease of transitioning incoming and exiting tenants
  - Reduced Maintenance Costs
    - Snake Bus Provides:
      - **EFFICIENT:**
- Reduces setup costs up to 37% over traditional pipe & wire.
- Due to green factors let’s go over this

- **ADAPTABLE:**
  - Through its plug and play features, Snake Bus can be reconfigured in hours with no wasted materials, and no skilled labor necessary.

- **POWERFUL:**
  - Offers three times the amount of power that is available with generic modular systems.

- **Architects Want**
  - Flexibility that allows for easy & inexpensive changes
  - Raised Floors
  - Green Certification
    - Snake Bus Provides:
      - **CONVENIENT:**
        - A simplified part system makes installation and retrofits quick and easy.
        - 4 & 8 ft. tracks instantly snap together enabling you to configure any size power distribution system.
        - Reconfigurable whips can be plugged into the bus anywhere on the track and can be powering as many devices as necessary.

- **GREEN:**
  - With its low profile, Snake Bus works efficiently within the shallowest of raised floors, maximizing airflow.
  - Contributes to green certification, including:
    - Energy efficient
    - Recycled materials
    - Regional materials
    - Compliments an access floor
    - Materials reusability
    - Decrease construction waste management
      - When used with Raised Floors
        - Increased ventilation
        - Thermal comfort
        - Controllability of systems
        - Daylight views

- **Engineers Want**
  - A Quick design
  - A Happy Customer (Building Owner)
    - Snake Bus Provides:
      - **RAPID:**
Plug & Play components eliminate traditional methods of hard wiring equipment.

These Plug & Play components also enable additions, moves, and changes to be completed in minutes rather than days.

**EFFICIENT:**
- Allows for multiple power configurations from the same track.
  - Assemble each whip as a dedicated single, two- or three-pole circuit
- Capable of providing 30AMPS of uninterrupted power.
- Each device can then be easily relocated anywhere on the Snake Bus power grid by simply un-plugging the whip and re-positioning it.

**Contractors Want**
- Ease of Installation
- Predictable Results
- Reduced Costs
  - Labor
  - Materials
- Flexibility that allows for easy & inexpensive changes

**ADAPTABLE:** Leading to cost savings
- Installations, moves, and changes are easily completed with the Snake Whips (tap-offs) that deliver power to individual devices anywhere along the track with a 10-second connection.
- Each device can then be easily relocated anywhere on the Snake Bus power grid by simply un-plugging the whip and re-positioning it.

**CONVENIENT:**
- A simplified part system makes installation and retrofits quick and easy.
- 4 & 8 ft. tracks instantly snap together enabling you to configure any size power distribution system.
- Reconfigurable whips can be plugged into the bus anywhere on the track and can be powering as many devices as necessary.

**EFFICIENT:**
- Allows for multiple power configurations from the same track.
  - Assemble each whip as a dedicated single, two- or three-pole circuit
- Capable of providing 30AMPS of uninterrupted power.
Each device can then be easily relocated anywhere on the Snake Bus power grid by simply un-plugging the whip and re-positioning it.

- **FAST:**
  - When compared to traditional pipe and wire, Snake Bus can save 100s of man-hours required for setup.
  - The ability to save these man-hours results in Snake Bus setup days ahead of schedule, when compared to traditional pipe & wire.
  - Adds, moves and changes are also completed in minutes rather than days.

- Possibly reflective type questions that may spur self-explanations (Clark et al., 2006, p. 232)
  - Why did you select this customer?
  - How will the Snake Bus benefit this customer?
  - Why is the Snake Bus a better solution for this customer?
- Email Roger or Scott to find out what they would have said. Compare their answers to an expert. (Roger & Scott)

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**Module 3: Features, Functions, & Benefits**

**Performance Objective:** At the end of this module, you will be able to explain Snake Bus features, functions, and benefits that provide Building Owners, Engineers, Architects, and Contractors with the optimal power distribution solution.

**Learning Objectives- At the end of this module Sales reps will be able to:**

- Identify and describe the features, functions, and benefits of Snake Bus and its peripherals.
- Determine which features and functions make Snake Bus the right Power Distribution option for 3 different possible customers.
- Participate in the sale of Snake Bus to a possible customer.

**Subjects:**

- **NOTE:** In this module, we will ask sales reps to identify features, functions, and benefits through a drag and drop exercise. This exercise will lead to creating a features, functions, and benefits quick reference card that can be printed from the course.
- **NOTE:** Then they will have a chance to participate in workplace scenarios where they get to match features, functions, and benefits with customer needs.
- **NOTE:** Finally, they will get to review the reasons why Snake Bus is the Cable Management Solution for the following customers: Building Owners, Engineers, Architects, and Contractors.

- **Snake Bus**
  - Power Track Sections
  - Feed Modules
• Interlinks
  • Snake Whips (Tap Offs)
  • Modular Furniture Interface
  • Raised Floor Boxes
  • Accessory Boxes
• The Scenarios will emphasize the following: Customers Save Time, Money, and Resources (Human & Materials):
  • FAST, GREEN, SLEEK, POWERFUL, EFFICIENT, ADAPTABLE, AND CONVENIENT

Module 4: Wrap-Up & Resources

Subjects:
Here we will conclude by re-emphasizing the key features, functions and benefits within the context of workplace scenarios. Then we will provide them with the following downloadable and printable documents:

• Feature, Function & Benefits Quick Reference (developed in course from an activity)
• The Fast Track to Power – Snake Bus
• 707 Series Snake Bus Installation & Electricity 101 (Scott’s Document)
• Any other documents you would like to add
## APPENDIX D
### COGNITIVE LOAD THEORY: INSTRUCTIONAL STRATEGIES

<table>
<thead>
<tr>
<th>Applying CLT</th>
<th>Instructional Strategies</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Managing intrinsic cognitive load</td>
<td>Design interaction for content and modality experience.</td>
<td>Create chunks of content through the use of modules.</td>
</tr>
</tbody>
</table>

| Decreasing extraneous cognitive load | Convey information concisely. | Include graphics in intros and summaries explained by audio in context of each module, course, and how the concepts will be applied once the learner is back on the job. | Eliminate unnecessary information. | Worked and completion examples were used in order to eliminate poor problem-solving skills. | Information was conveyed concisely with graphics and narration in context of each module, the course and how the concepts will be applied. Worked examples were used in module one where the learning agent modeled customer interactions. Completion examples were used in the final module through the three workplace scenarios. |

| Increasing germane cognitive load | Use “signals and cues” to direct learners’ attention to the critical concepts of the course (Clark, 2003). | Integrate words within graphics preventing split attention (Clark, 2003). | Facilitate dual modality presentation of content through the narration of images. | Use diagrams to facilitate deeper understanding (Clark et al., 2006). | Signals and cues were used through the application of the SLEEK GREEEN RECAP acronym. Words were integrated into diagrams to prevent split attention throughout the course. All graphics were explained using the learning agent. |
## APPENDIX E
### COGNITIVE PROCESSES: INSTRUCTIONAL STRATEGIES

<table>
<thead>
<tr>
<th>Facilitating Cognitive Processes</th>
<th>Instructional Strategies</th>
<th>Application</th>
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</thead>
<tbody>
<tr>
<td>Enabling retrieval (organization)</td>
<td>Create manageable chunks (modules). Provide “signals and cues” (Clark, 2003, p. 74) as to what was important, through transitions, headings, sub-headings, summaries, introductions, and learner objectives.</td>
<td>Ask questions that enable learners to recall concepts, allow learners to demonstrate what they have just learned. Provide feedback to reinforce or remediate the new concepts learners just constructed, and use similar verbiage to provide cues while learners are applying new information for the first time (Gagné, 1985). Questions and feedback were provided within the SB Quiz interaction, Sales Process interaction, and Component Game interaction. Headings, sub-headings, summaries, intros and learning objectives were provided throughout the course.</td>
</tr>
<tr>
<td>Enabling retrieval (integration)</td>
<td>Provide narrative storytelling in context of learners’ existing experience and knowledge through real-world scenarios that replicate real-world challenges to facilitate links and internal cues to existing schema.</td>
<td>Use a learning agent to deliver content. Bring current knowledge into working memory and allow the new information to be integrated into an existing schema, increasing the likelihood of retrieval as learners move through the course and when necessary once they complete the course (Jonassen, 1988; Hooper &amp; Hannafin, 1991; Clark, 2003; Kennedy, 2004). Current customers were used to place information in context of learners’ existing knowledge throughout the course. The learning agent used narrative storytelling in context of current knowledge in both the worked and completion examples, as well as the intros, and summaries.</td>
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</tbody>
</table>

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<table>
<thead>
<tr>
<th>Facilitating Cognitive Processes</th>
<th>Instructional Strategies</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enabling retrieval (near and far transfer)</td>
<td>Drill and practice for near transfer, replicates exact process or procedure that the learner will need to be successful.</td>
<td>Far transfer requires an understanding of rules, or concepts that need to be applied to several different possible challenges.</td>
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<td></td>
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<td>To facilitate far transfer practice applying rules, asking questions to make connections to the process, provide scaffolding, and feedback throughout the module.</td>
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<td>Sales process presented through the diagram of the steps necessary for each sale utilized drill and practice. Workplace scenarios required far transfer and the application of concepts applied to several different possible customers. Prior to that challenge learners were provided with questions, feedback and scaffolding on specific concepts that needed to be applied.</td>
</tr>
<tr>
<td>Enabling retrieval (retrieval plan)</td>
<td>Set plan which completely replicates the exact process for near transfer (Hooper &amp; Hannafin 1991). Abstract organizers for far transfer (Hooper &amp; Hannafin, 1991).</td>
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<td></td>
<td>Sales process diagram represented an exact process. Where the SLEEK GREEN RECAP represented an abstract organizer for far transfer.</td>
</tr>
<tr>
<td>Facilitating Cognitive Processes</td>
<td>Instructional Strategies</td>
<td>Application</td>
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<tr>
<td>Orienting</td>
<td>Games and Simulations enable a learner to be oriented to the new knowledge in many different ways facilitating the encoding and later retrieval when necessary in similar contexts for near transfer or different contexts for far transfer within a real scenario (Hooper &amp; Hannafin, 1991).</td>
<td>Match games, SB quiz show game, component game, sales process interaction, and workplace scenarios.</td>
</tr>
<tr>
<td>Presenting (dual encoding)</td>
<td>Apply dual encoding by providing information visually and through narration (Clark, 2003).</td>
<td>Use color and images to highlight key concepts (Hooper &amp; Hannafin, 1991). All intros, summaries, worked examples, and completion examples. Component game, sales process game, intros, and summaries also used images to highlight key concepts.</td>
</tr>
<tr>
<td>Enabling encoding (cognitive practice)</td>
<td>Apply cognitive practice, allow learners to apply rules or underlying concepts and practice making crucial decisions within the learning environment (Hooper &amp; Hannafin, 1991, Gagné).</td>
<td>All of the interactions throughout the course allow learners to apply the underlying concepts and practice making crucial decisions within the learning environment.</td>
</tr>
<tr>
<td>Facilitating Cognitive Processes</td>
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<td>Application</td>
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<tr>
<td>Enabling encoding (metacognition)</td>
<td>Enable learners to check their progress through activities where they are challenged by questions or possibly the application of skills, or maybe the application of the newly acquired knowledge and skills (Gagné, 1985).</td>
<td>All of the interactions challenge the learners with questions and allow learners to check their progress as they apply their newly acquired knowledge and skills.</td>
</tr>
<tr>
<td>Enabling encoding (self-explanations)</td>
<td>Enable learners to reflect and form self-explanations.</td>
<td>The learning agent models self-explanations through the completion examples and then learners are given an opportunity to generate self-explanations through the completion examples (workplace scenarios).</td>
</tr>
</tbody>
</table>