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EXPLORING DIFFERENT INSTRUCTIONAL DESIGNS OF A SCREEN-CAPTURED VIDEO LESSON: A MIXED METHODS STUDY OF TRANSFER OF LEARNNG.

A Dissertation
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy
Curriculum and Instruction

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by
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August 2009

Accepted by:
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Robert M. Horton
Chris L. Peters

ABSTRACT

Digital instruction, whether in the form of training delivered on CD/DVD-ROMs or online courses delivered via the Internet is being used in all levels of education. It can, after all, increase student achievement if designed properly (Moersch, 1999). Many established instructional technologies (e.g. Microsoft PowerPoint®) have been researched to determine effective and ineffective instructional designs. However, newer technologies such as screen-captured videos, have not.

Because the research of newer, multimedia instructional technology is “in its infancy” (Mayer, 2001, p.194), a timely challenge for instructional technologists is to determine how to design and research these technologies. Theoretical frameworks on which to base these designs include Cognitive Load Theory (CLT) and the Cognitive Theory of Multimedia Learning (CTML). Each is based on Baddeley’s (1992) working memory model that says that our ability to think and process is constrained by working memory limitations.

According to CLT, when learning new information, working memory can be overloaded by ineffectively designed instruction. One effective instructional design technique that can alleviate cognitive overload is the integration of scaffolds that serve as a bridge between what students know and what they have not yet learned.

Similar to CLT, CTML also focuses on how to reduce cognitive load, only within a multimedia-based learning environment. An outcome of CTML is the segmenting effect, in which long periods of instruction are broken down into smaller sections in order to allow for better learning.

Using these techniques, the researcher designed a mixed-methods study, which combined a 2x2 factorial-designed experiment with follow-up, qualitative interviews. Learning effects were tested with 108 participants at a Southeastern university who were given one of four different versions of screen-captured video lessons.

Through the implementation of instructional techniques (scaffolding and segmentation) designed to decrease extraneous load, the researcher hoped but failed to promote long-term learning. Whereas an immediate test of learning transfer suggested that the effectiveness of the four instructional designs varied, the delayed measure of transfer indicated that those initial differences were fleeting. Several possibilities could explain this effect, including information overload and lack of motivation.

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CHAPTER 1

INTRODUCTION

Digital Education

Digital instruction, whether in the form of training CD/DVD-ROMs or online courses delivered via the Internet, has become a mainstay within education for social, financial and educational reasons. One reason is societal demand. Business and industry have demanded that American schools educate students in technological skills. In a survey of companies' posted job descriptions, for instance, 82% of hiring employers ranked technological fluency as the most desirable skill (Thornburg, 2001). A second reason is that between the *Technology for Education Act of 1994* and the *No Child Left Behind (NCLB) act of 2001*, more than $40 billion has been spent on technology for education (Dickard, 2003). A third reason for the prevalence of technology in schools is that effective technological integration can lead to increases in student achievement (Moersch, 1999).

The extent to which technology is being integrated into education is impressive. As an illustration of this digital revolution, consider a high school in Tucson, Arizona, and how its staff implemented a project that caused a fundamental change in the way the students were taught.

In 2005, Empire High School was one of the first public schools to go almost entirely digital (McHale, 2008). All of the high school's students were issued software-loaded laptops, which they were expected to bring to and use within classrooms supplied with wireless Internet signals, projectors and interactive whiteboards. Further, the school decided to forgo all printed textbooks. Instead, students downloaded digital texts and other multimedia resources for each course, as well as the software that would enable them to take notes within these resources. When one considers the slow pace at which change usually occurs in American education, these are extreme measures— perhaps even revolutionary.

The kinds of changes evinced by Empire High School have prompted some to declare the primary role textbooks play as content sources as fading, eventually becoming a thing of the past, altogether (McLester, 2008). In fact, in addition to high schools, there are school districts and entire states that currently are trying to increase opportunities for online delivery of content. For example, the state of South Carolina has created the *South Carolina Virtual School*, which aims to, as State Superintendent of Education Jim Rex (2009) explains, “keep students engaged in school and better prepare them for the careers they are interested in by tailoring high school coursework to each student's specific interests.”

The occurrence and growth of online learning within the state of South Carolina is representative of the larger U.S. population, as illustrated by a recent study by the Sloan Consortium. The study reported that more than one million K-12 students were engaged in virtual coursework, an astounding 50% increase from the previous year (Allen & Seaman, 2008). But K-12 schools are not the sole participants in this revolution; higher education has long been a leader in digital education.

Take, for instance, a recent survey study of over 2,500 colleges and universities that found online course enrollments had grown by an average of 21.5% annually over the five years prior to the study (Allen & Seaman, 2007). Further, almost 3.5 million students, or nearly 20% of all students enrolled in the schools in that study, took at least one online course during the fall, 2006 term. Finally, 35% of the institutions surveyed offered academic programs in which *all* courses were delivered over the Internet. These statistics perhaps represent higher education, in general.

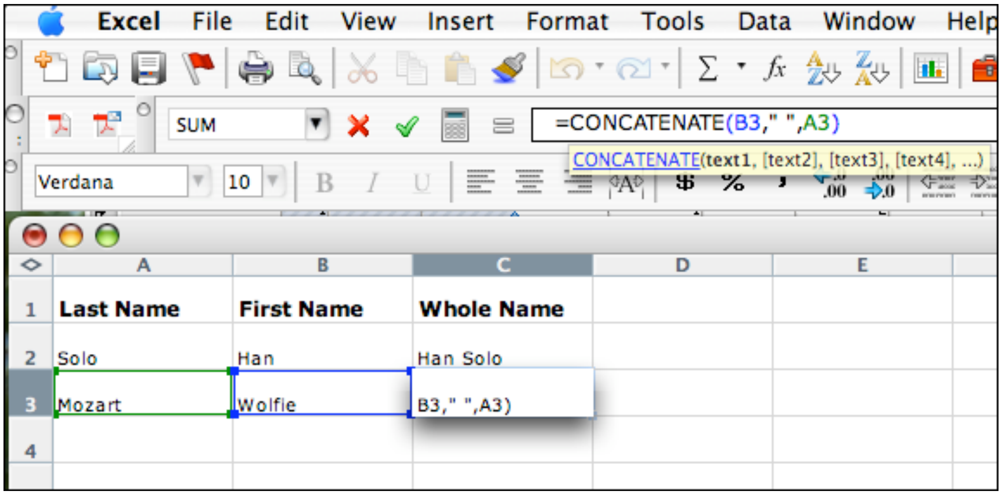
More specifically, teacher education programs show a similar, increasing trend in the offering of online courses and digital instruction (Blank & Hernandez, 2008; Harrell & Harris, 2006; Kleiner, Thomas, Lewis & National Center for Education Statistics, 2007; Martin & Smith, 2006; Skylar, Higgins, Boone & Jones, 2005). For example, in a 2006 national survey of Title IV, degree-granting, four-year, postsecondary institutions with teacher education programs, 95% of the programs reported using multimedia-based digital content (video or audio) for instructional purposes (Kleiner et al., 2007).

Clearly, the use of digital technologies—be they delivered over the Internet, or in video, audio, or other multimedia form—is ubiquitous in higher education, as well as K-12 education. It does not necessarily follow, however, that such technologies are being used effectively. Ideally, educational research should provide support for the efficacy of certain uses of technology. And it has. Extensive research has tested differing uses of common educational technologies, such as PowerPoint presentations, Web sites, animation, and text-based documents (Apperson, Laws & Scepansky, 2006; Chou & Liu, 2005; Mayer & Moreno, 2003; Susskind, 2005). Distinguishing between effective and ineffective instructional designs, this research has provided evidence and theoretical frameworks on which teachers can base lessons. There is, then, at least research-supported potential for such technologies to be used effectively. This is not the case for certain newer technologies, however.

The extant research addressing newer, commonly used multimedia-based technologies (e.g., wikis, screen-captured video) as a form of digital or online instruction is sparse, resulting in a dearth of instructional prescriptions. Consequently, the use of these technological devices in education is prevalent without having been proven educationally beneficial (see e.g., Liaupsin, 2002; Navarro & Shoemaker, 2000; Skylar et al., 2005).

Screen Capture Technology: Images and Video

Instruction containing screen-captured content is one such entity that is being used as an instructional tool despite having virtually no research support. *Screen-captured images* are commonly used in computer training materials because they provide learners with static diagrams of information relevant to learning. As an example, preservice teachers might be taught how to use Microsoft Excel® in order to create a digital gradebook. The development of a gradebook requires many skills (e.g., concatenating data, parsing data, calculating weighted grades), and students could learn these necessary skills by reading a step-by-step text-based guide. However, the guide may be supplemented and even improved upon with the adjunct screen captured-images, giving learners a clearer representation of the information being conveyed (see Figure 1).



=CONCATENATE(B3," ",A3)

	A	B	C	D	E
1	**Last Name**	**First Name**	**Whole Name**		
2	Solo	Han	Han Solo		
3	Mozart	Wolfie	B3," ",A3)		
4					

Figure 1.1. Screen-captured image demonstrating how to use the concatenation function within MS Excel.

The modest amount of research on instruction that utilizes screen-captured images has been positive. Studies have documented increases in self-efficacy of learners who were learning how to use software programs through instruction that utilized such images, as well as decreases in performance time (Urata, 2004; van der Meij, 1996).

As opposed to static, screen-captured images, *screen-captured videos* are dynamic recordings of content originally displayed on a computer screen that then can be presented to learners as videos. They commonly are used as instructional or training materials to provide learners with elaborate visual representations that demonstrate learning goals, such as the procedures used in a computer program (Clark & Kou, 2008; Evans & Champion, 2007; Mark, 2004). The advent of easy-to-use and relatively inexpensive software, such as Techsmith Camtasia® and Adobe Captivate®, has increased the prevalence of video-based screen captures for instructional and training purposes in several fields, including business (Mark, 2004), engineering (McGrann, 2005), medicine (Clark & Kou, 2008), and instructional technology (Peters & Visser, 2003).

Unlike screen-captured images, empirical research on the effective use of screen-captured videos is nonexistent. In fact, a recent search of educational and psychological research databases yielded some anecdotal evidence, opinions, and guides; however, no empirically-based studies were found within a search of the following online databases: Academic Search Premier; Applied Science & Technology Abstracts; Communication & Mass Media Complete; Computer Science Index; Computer Source; ERIC; Health Technology Assessments; Human Resources Abstracts; Library, Information Science & Technology Abstracts; MAS Ultra - School Edition; Primary Search; PsycARTICLES; and PsycINFO. This lack of search results suggests that a gap in the multimedia education literature needs to be addressed, a pertinent question being: *How can multimedia-based technologies such as screen-captured videos be used effectively in instruction?*

Considerations for Multimedia Research Design

According to Richard Mayer (2001), an educational psychologist with research expertise in multimedia learning, several criteria need to be met in order to design and research effective multimedia-based instruction. For example, a presentation ought to be aesthetically pleasing and technologically sophisticated. Screen-captured video can be tailored to meet each criterion—the technological sophistication of screen-capture video software, if used correctly, can produce videos that present exact computer screen representations that play smoothly and with crystal-clear narration.

Another integral criterion when developing an effective presentation is the actual content that is being delivered. Mayer (2001) states quite simply, “You want to make sure it presents the information that you intend to convey” (p.193). Once the relevant content is being presented in an appealing manner, a final criterion is needed before multimedia instruction can be researched: the design consideration regarding how people learn (Mayer, 2001).

The study of human learning has a long, rich history. Learning theory related to multimedia, however, is “in its infancy” (Mayer, 2001, p.194). Nonetheless, some important foundational considerations have been established. One is that comparisons among multimedia-based instruction, text-based instruction, and traditional, classroom instruction are not possible because the effects of the delivery medium cannot be separated from those of the instructional method (Clark, 1994; Mayer, 2001). For instance, we cannot effectively compare screen-captured video instruction with text-based instruction. Each medium has its own particular instructional method; therefore, any resulting “differences may be attributable to instructional method rather than medium” (Mayer, 2001, p. 70).

In fact, regarding multimedia-based instruction, “instead of asking which medium makes the best deliveries, we might ask which instructional techniques help guide the learner’s cognitive processing of the presented material” (Mayer, 2001, p.71). Just as there are instructional design guidelines for texts, which can help students effectively learn content, so too exist techniques that can maximize the potential for learning from multimedia-based instruction. Multimedia-based instructional design guides have been set forth by two cognitive learning theories: Cognitive Load Theory (Sweller, van Merriënboer, & Paas, 1998) and Mayer's (2001) Cognitive Theory of Multimedia Learning. Each theory contributed to the development of both the screen-captured videos and the experimental design used in this dissertation study, as did a related pilot study, which is discussed next.

Pilot Study

In order to create a multimedia presentation that would be effective and researchable for this dissertation study, a pilot study was used to formulate the design and materials. From the outset, roughly one year prior to the dissertation study, the researcher formally conducted a pilot study, beginning with the development of the experimental design, the creation of all materials, and obtaining IRB approval.

The initial step in the process was to identify course content relevant to pre-service teachers in an instructional technology class that could be delivered through screen-capture video. The researcher decided that a spreadsheet-based gradebook in Microsoft Excel® would be suitable. In order to ensure that content was relevant to the course, all of the discrete, target skills were identified by the primary researcher and another instructional technologist responsible for teaching the course. As the skills were identified, so too were alpha versions of scripts for narration in the videos.

The video creation process began with the selection of Techsmith Camtasia®, a sophisticated screen-capture software program used to create the screen-captured, instructional videos. This particular software was chosen because of its accessibility and the researcher's familiarity with it. Although the researcher was an experienced user of

Camtasia®, the video creation process was complex and time-consuming.

The developer first created the materials to be used in the recording process; images, text files, html files and multiple Excel® spreadsheets were needed before the recording process could begin. Relatively polished scripts also were essential prior to recording because absent them, the number of 'takes' needed to create a video dramatically increases. Recording tests were used before actual recording to help the narrator "warm up" and to test audio levels. Even with these precautionary measures, many 'takes' were needed due to verbal flubs and miscommunications (even with a script), technical glitches, and a host of other reasons. The narration was informal and conversational, as if the researcher were talking to students in a class.

Once a video was recorded, the real tedium began: editing the movie by removing distracting phenomena picked up by the microphone. These included narrator stutters, yawns, sniffles, telephone rings, clock chimes, and cat meows. Mispronunciations were edited out and correct pronunciations were re-recorded and inserted. Occasionally, video segments were spliced together and audio levels were balanced. Once the editing process was over, the movies were then concatenated in order to create a single movie. In Chapter 3 of this dissertation, you will see that this negated the need for the researcher to press play, pause, and stop during the experimental intervention.

In addition to the screen-captured videos, the researcher, under the guidance of an educational psychologist, created a demographic survey, a prior knowledge assessment, practice worksheets, and immediate and delayed measures designed to assess student learning. All of these materials, to be discussed in greater length in Chapter 3 of this paper, were printed and used in the pilot study, which was implemented six months prior to the dissertation study.

Although data were collected during the pilot study, it was not fully analyzed due to intervention mishaps (timing and pacing issues and computer lab malfunctions). Despite the lack of results, the researcher gained valuable knowledge and experience that led to the success of the dissertation study. For example, the instructors spent too much time discussing class-related issues that were irrelevant to the study, leaving insufficient time to conduct the entire experiment. Therefore, during the dissertation study, the researcher announced prior to the intervention that because of time constraints, there would be no class discussion during the study. Another example occurred during the prior knowledge assessment. In the pilot study, participants were given 60 seconds to answer each of the 12 questions, which the researcher observed was more than an ample amount of time needed by the participants. As a result, the time allotment was reduced to 45 seconds for the dissertation study, thereby again, saving time. The researcher acknowledges the possibility that this change may have had an unintended effect on the outcome.

Other examples of how the pilot study helped to inform the dissertation study were found through a class discussion held after the intervention. Students reported being distracted by a slight, yet audible hissing sound present in some of the videos due to an air-conditioner vent. Videos recorded for the dissertation intervention contained no such hiss. Additionally, students reported unfamiliarity with certain words used in the videos. Therefore, words such as “parse” and “concatenate” that were used in the pilot study were changed to “separate” and “combine,” respectively, for the dissertation study.

The purpose of this study was to explore the effects of differing instructional designs of a screen-captured video lesson on college students’ transfer of skills related to the use of a computer program. In the initial, quantitative phase of study, a 2 x 2 factorial experiment was conducted to test the learning and transfer effects associated with differing instructional components of a screen-captured video lesson. In the qualitative follow-up phase of investigation, interview data and subsequent qualitative analyses provided themes that help explain the effects established by the experiment.

In the remaining chapters of this dissertation, I first highlight relevant learning theory and related research that can be used to conceptualize screen-captured video for research purposes (Chapter 2). Second, I create a set of hypotheses for screen-captured video instruction based on that literature and elaborate on an appropriate mixed methods research study intended to test experimentally those hypotheses and to explore qualitatively subsequent experimental results (Chapter 3). Finally, I report on the results of the study (Chapter 4) and discuss their theoretical, educational, and practical implications and limitations (Chapter 5).

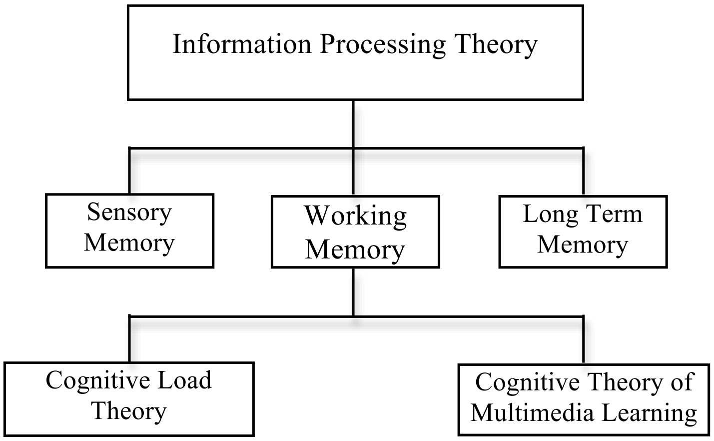
CHAPTER 2

REVIEW OF LITERATURE

Related Literature for Theoretical Framework

Although minimal research exists that specifically pertains to the effective design and presentation of screen-captured video, particular theories and subsequent areas of related research can be used to postulate effective designs of screen-captured video instruction. Specifically, this relevant research addresses Information Processing Theory (IPT), which proposes a cognitive architecture to explain how information is processed, organized, and learned. More specific information processing subtheories--Cognitive Load Theory (Sweller et al., 1998) and Cognitive Theory of Multimedia Learning (Mayer, 2001)—each apply IPT's central tenets toward instructional design and therefore are also relevant. See Figure 2.1 for a spatial display of these cognitive theories.

Throughout the remainder of this chapter, I first will elaborate on IPT, describing the essential elements of the theory, which includes three critical memory subsystems. Of specific import to the present study is the construct *working memory*, the fundamental memory component upon which Cognitive Load Theory (CLT) and Cognitive Theory of Multimedia Learning (CTML) are based. These theories, which posit that instructional design should be based upon the limitations of human cognitive architecture and the manner in which learners process information (Tabbers, Martens & van Merriënboer, 2004), are reviewed second and third, respectively. Each theory will be discussed in detail, with particular focus on each theory's central tenets, supporting research, limitations, and relevance to this particular study.



Explains	The limitations of working memory can hamper learning if not controlled for.	The limitations of working memory can hamper learning if not controlled for.
Predicts	Instruction is most effective when it accounts for the limitations of the working memory.	Multimedia instruction is most effective when it fruitfully combines sights and sounds.

Figure 2.1. Spatial diagram of the related literature for theoretical framework used in this dissertation.

Information-Processing Theory

Information-Processing Theory is a cognitive learning theory that suggests learning is dependent upon the manipulation and organization of schema (which include prior knowledge and experiences) and new information. According to this theory, students learn by first attending to some information and then purposefully and strategically thinking about it (O'Donnell, Reeve, Smith, 2007). Although several variations of IPT have been postulated, Aaron Baddeley (1992) formulated the IPT model most widely cited within CLT and CTML literature due to its emphasis on working memory. His model distinguishes three memory subsystems related to learning: sensory memory, working memory, and long-term memory.

Sensory Memory

The sensory memory subsystem briefly stores a perpetual stream of environmental information entering the senses (Baddeley, 1992). In a classroom setting, for example, a student's sensory memory might take in and briefly hold a teacher's voice, a ticking clock, and a bright glare on a window. Sensory memory is a passive system with a very short duration – up to ½ second for visual material, 2-4 seconds for auditory material (Ormrod, 2005). For an example of sensory memory's brevity, consider the light from a quickly moving sparkler, which will remain in one's sensory memory long enough for it to appear as a quickly disappearing trail. In terms of passivity, we do not control the trail of light we see following a sparkler; it simply appears to be there. Information stored in sensory memory quickly decays, unless a person pays attention to it, at which point the information moves from sensory memory to working memory, where processing begins.

Working Memory

Once attended to by the learner, information can move from the sensory memory subsystem to the working memory subsystem. The processing that occurs within the working memory is an active and conscious event unlike the passivity of the sensory memory. Whereas sensory memory might passively hold the light trailing behind a sparkler, working memory might hold an active, corresponding thought, such as, "I wonder if I can finish writing my name before the trailing light disappears."

Once the learner pays attention to the material being presented, the information moves from the sensory memory and is processed within the working memory via the phonological loop system and the visuospatial sketchpad (Baddeley, 1992). The phonological loop governs the manipulation and maintenance of audio-based information whereas the visuospatial sketchpad does the same for visual or spatial information (Baddeley, 1992). In his CTML, Mayer also distinguishes between how information is processed within the working memory; however, he relabeled the terms. The verbal channel is equivalent to what Baddeley called the phonological loop system and the visual channel is the visuospatial sketchpad (Mayer, 2001). Regardless of the terminology being used, theories that focus on working memory agree that in order for people to learn, they must actively process information, be it audio-based or visual-based information.

Due to learners' active participation in processing information, working memory is known as the subsystem in which thinking and learning occur, which makes it a major consideration for instruction (Baddeley, 1992). For learning to be meaningful, instructional designers must consider the ways in which information can be processed within the working memory. These considerations include an understanding of (1) the limited duration in which the working memory can hold information, (2) the limited amount of storage and processing space within the working memory, (3) the ways in which verbal and visual channels are able to work together, and (4) the manner in which working memory interacts with long-term memory.

The first two considerations, *the limited duration in which the working memory can hold information,* and *the limited amount of processing and storage space within the working memory,* are essential to Baddeley's theory of working memory, CLT and CTML. The duration in which information remains in working memory without conscious processing is typically 20-30 seconds (Peterson & Peterson, 1959). To comprehend the brevity of the working memory, imagine that you are asked to remember an unfamiliar 7-digit telephone number. You might employ a repetition strategy in order to remember it. Without this rehearsal, or once it stops, you likely would have 20-30 seconds before the correct number fades from the working memory. The limited duration of the working memory provides a challenge to any teacher, trainer, or instructional designer who is trying to keep the audience engaged or on task, which is why effective instruction often utilizes signals designed to capture attention (or focus one's thoughts).

Although the limited duration of the working memory poses a significant challenge to instructional designers, working memory's limited amount of storage and processing space is quite possibly an even more critical issue. The average person's working memory capacity is about seven elements of information when *storing* information (Miller, 1956) and not more than two to three elements when *processing* information (van Gog, Ericsson, Rikers & Paas, 2005). For instance, most people can temporarily store a seven-digit telephone number in their working memory. However, they cannot learn seven vocabulary words and corresponding definitions simultaneously; they must select one word and definition (representing two elements) and then use the remaining working memory space to process and learn the word.

Understanding the limited amount of storage and processing capabilities of working memory is critical when presenting information to learners. This is, perhaps, the central tenet to CLT and CTML; and researchers have established guidelines—many of which will be discussed later—that account for and help manage these limitations. One working memory principle that has helped shape many of these guidelines is that the visual and the verbal channels can process information either independently or in conjunction with one another. The latter has been researched and documented many times and frequently appears in the literature as dual-coding, dual-modality, dual-channel, or multimodal processing (Igo, Kiewra, & Bruning, 2004; Igo, Kiewra, Zumbrunn, & Kirschbaum, 2007). This concept will be examined more closely later in this paper, but, in brief, the implication of multimodal processing is that working memory capacity can be improved upon by using both channels simultaneously rather than just one channel alone (Mayer, 2001; Sweller et al., 1998). Whether it is through dual-coding or other techniques, instructional designers have the ability to manage the capacity of working memory and potentially improve processing and learning.

Although learning, as Sweller (2006, p.355) defines it, is "a change in long-term memory", the majority of the learning process (ie. changing the long-term memory) occurs within the working memory. For instance, while attempting to learn the Chinese word *jung*, which means middle, a student might access prior knowledge (June is the middle month) and move that knowledge into working memory, where she might think "*jung* is spelled like June, and June is the *middle* month." This type of constructive thinking occurs within working memory, but the new knowledge is encoded into long-term memory.

Long-term Memory

Unlike the working and sensory memory subsystems, long-term memory (LTM) is a virtually limitless repository of information with virtually no decay (Mayer & Moreno, 2003). Like sensory memory, LTM is passive; one does not have to actively try to remember information that is stored in LTM, but rather information is passively stored in units of organized ideas, called schemata, until it needs to be activated and used. These schemata are initially constructed (learning the month June) and then made more complex (attaching June to *jung*) within the confines of the aforementioned working memory, which poses a challenge to instructional designers due to its limitations.

CLT and CTML are two related, instructional design theories. Each attempts to explain how the limitations of working memory can frustrate instruction, and each offers a path toward maximizing schema acquisition through effective instructional design. The next section of this literature review describes each theory, elaborates on their basic tenets, critiques their limitations, and relates them to research on screen capture video instruction.

Cognitive Load Theory

CLT is an instructional design theory that postulates that instruction is effective when it purposefully accounts for the limitations of students' working memory and thus allows for constructive thinking and schema building (Sweller et al., 1998). According to CLT, when learning new information, the burden placed on the working memory can be affected by each or any combination of the following: the inherent difficulty of the material (intrinsic cognitive load); an unnecessary burden placed on working memory by instructional materials (extraneous cognitive load); or, the mental effort the learner extends towards learning (germane cognitive load) (Sweller et al., 1998).

Intrinsic Cognitive Load

Intrinsic cognitive load refers to the burden placed on working memory by the inherent difficulty of some task, to-be-learned information, or problem state. For instance, the multiplication problem 17 x 8 has a relatively low intrinsic load, and as a result, many people can solve it in their heads (or, within working memory). However, the problem 796 x 687 imposes a higher intrinsic load, and fewer people can solve this problem within the bounds of working memory without external aid or a clever strategy.

The difficulty of the information being addressed depends on the number of informational elements that are interacting, or being processed, simultaneously. This is called element interactivity (Sweller et al., 1998). The multiplication problems above, for instance, have differing amounts of element interactivity. The former problem has considerably fewer interactions than the latter problem, thereby making it more manageable within the confines of the working memory. For example, a skilled problem solver might complete the calculation (17 x 8) within working memory by thinking, “8 times 10 equals 80” (one element), “8 times 7 equals 56” (another element), and, “80 plus 56 equals 136” (two elements interacting). Ultimately, the capacity of working memory is never breached. Consider, however, the number of elements that would interact in the more complex problem (796 x 687).

Many researchers have argued (see e.g., Chandler & Sweller, 1991; Paas et al., 2003; Pollock, Chandler, & Sweller, 2002) that a task has a fixed amount of element interactivity that is innate to a particular task. Further, the level of interactivity "cannot be manipulated by instructional design without changing the nature of the task or compromising understanding" (Ayres, 2006, p.288). However, one should not assume that because a given task has a fixed amount of element interactivity, the task has the same level of difficulty for different learners. For instance, in the second and more complex example of multiplication discussed previously (796 x 687), the average person would have a difficult time solving it in his head. However, someone who possesses a clever mathematical strategy (learner expertise) might be able to solve the problem within the working memory. In other words, according to van Merriënboer & Sweller (2005):

> "a large number of interacting elements for one person might be a single element for another more experienced person who has a schema that incorporates the elements. Thus, element interactivity can be determined only by counting the number of interacting elements that people deal with at a particular level of expertise." (p. 150)

To summarize, controlling for learner expertise, materials considered easy to learn and problems considered easy to solve have low element interactivity. As the level of element interaction increases, however, more information must simultaneously be processed within the constrained working memory, making it difficult to understand. As can be seen in the multiplication example, the amount of intrinsic load placed on working memory is contingent upon the relationship between the inherent nature of the information being addressed and a learner's level of expertise regarding that information (van Merriënboer & Ayres, 2005). Therefore, instructional designers, although unable to manipulate the inherent difficulty of material being presented, should take into account the level of expertise of the intended audience in order to most effectively present the material or problem states.

Extraneous Cognitive Load

Instructional designers are unable to reduce the intrinsic load of the to-be-learned material; however, they do have direct control over the management of another type of cognitive load, called extraneous load. Extraneous cognitive load can be defined as unnecessary working memory load imposed by the ineffective presentation of instructional materials (Sweller et al., 1998). For example, a professor demonstrating spreadsheet functionalities might impose extraneous load on her students by using unrelated and unnecessary technical jargon. The students, upon hearing these extraneous words, may think, "*What does that word mean?*" Thinking about this question typically requires and utilizes valuable working memory space thereby imposing an extraneous cognitive burden and preventing effective schema construction.

More examples of extraneous load often can be found within multimedia-based instruction. For instance, slideshows created within MS PowerPoint$^{®}$, a commonly used method of instructional delivery, often subject learners to both animated and sound effects (think of a zoooooom sound every time a letter flies in from off screen). Attention might be paid to these animations and, for a brief time, a student's working memory might be spent processing thoughts, such as, "*Those sound effects are annoying,*" rather than focusing on the content being delivered.

Another example of ineffective delivery of information that can cause an extraneous cognitive load occurs when a presenter reads a PowerPoint slide that contains a large amount of text. An individual trying to simultaneously read the text and listen to the presenter may not be able to construct or manipulate schema, which is necessary for long-term learning, because the capacity of the working memory has been exhausted.

The majority of CLT research has focused on how extraneous cognitive load affects learners and how it can be reduced through properly designed instruction. CLT research has identified numerous strategies, many of which will be discussed later in this paper, that can guide designers who are attempting to create effective instruction. Interestingly, numerous studies of extraneous load have found that some instruction, even if it places an extraneous load on the working memory, can still result in learning. Van Merriënboer and Sweller (2005) explained it this way:

> "The explanation is that for materials with low element interactivity, there is no need to decrease extraneous cognitive load because there are sufficient cognitive resources available for learning. For materials with high element interactivity, the decrease of extraneous cognitive load is necessary to free up processing resources that can be devoted subsequently to learning." (p. 156)

Nonetheless, "a major assumption of cognitive load theory is that instruction should be structured to reduce unnecessary extraneous working memory load" (Pollock, Chandler, & Sweller, 2002, p.62). With less extraneous load burdening the working memory, its limited capacity is maximized thereby allowing learners a better opportunity to construct schema. Although much of the earlier CLT research focuses on reducing extraneous load, more recent research posits that effective instructional design should also promote cognitive processing and deep elaboration (Bannert, 2002). Presumably, by reducing extraneous load, more working memory is available for the kind of processing that is directly relevant to the information being presented (Bannert, 2002). For instance, if a student does not have to waste cognitive resources thinking about irrelevant information, such as wondering about the meaning of lofty vocabulary words being presented in the instruction, more cognitive resources could be dedicated to processing information germane to the material being presented.

Germane Cognitive Load

Germane cognitive load refers to the working memory space consumed by conscious mental effort exerted by a learner during schema construction (Sweller et al., 1998). This exertion often utilizes many of the limited working memory resources, but, as opposed to extraneous load, it is a desirable and necessary type of cognitive load that can lead to meaningful learning (Sweller et al., 1998). Germane load can result in deep learning when an individual uses his working memory to attach new information to knowledge that has been previously stored in long-term memory. Thus, germane load should be encouraged whenever possible.

The promotion of germane load should be a prime goal of instructional design; it is necessary for people to learn. However, the provision of opportunities that induce germane load is not as straightforward as it might seem. Intrinsic, extraneous, and germane cognitive load are additive; that is, their combined "total load cannot exceed the working memory resources available if learning is to occur" (Paas, Renkl, & Sweller, 2003, p.2). And, because instructional designers cannot reduce intrinsic load, a given portion of working memory resources must be allocated towards dealing with intrinsic load. The remaining resources can then be dedicated towards dealing with extraneous load, germane load, or both, thus illustrating the magnitude of the need to reduce extraneous load.

There are several ways in which germane load can be encouraged through effective instructional design: (1) the provision of learning scaffolds, (2) questions, or prompts that require the learner to activate previously learned schema, or (3) opportunities to practice or process the material. Instructional materials that promote germane load can result in schema construction and, therefore, better learning (Clarke, Ayres & Sweller, 2005).

Thus, the central tenet of CLT is to reduce extraneous cognitive load and to increase the cognitive load that is germane to learning newly presented information. However, this must be done within the limits of the working memory capacity in order to prevent cognitive overload (van Merriënboer & Ayres, 2005). The remainder of this chapter discusses ways in which CLT and CTML address preventing cognitive overload through researched instructional design techniques.

Instructional Design Considerations in Cognitive Load Theory

In the mid-1980s, John Sweller, an Australian educational psychologist, formulated Cognitive Load Theory during a period in which many cognitive researchers were examining differences in how experts and novices approached problem solving in various content areas (see Chase & Simon, 1973a; Chase & Simon, 1973b; Jeffries, Turner, Polson, & Atwood, 1981; Larkin, McDermott, Simon, & Simon, 1980a; Larkin, McDermott, Simon, & Simon, 1980b; Sweller & Cooper, 1985). The existing research purported that a significant difference exists between the approaches used by the two types of learners. Owen and Sweller (1985) offer the following explanation:

> "On seeing a problem, an expert can use a schema or knowledge structure to classify the problem accurately according to a solution mode and to generate the required equations. A forward-working strategy is consequently used. Novices, not having the required schemata, must use means-ends analysis to solve the problems." (p.273)

Furthermore, Sweller suggests that problems conventional to many classroom settings and textbooks (eg. *If a motorcycle starts from rest and accelerates uniformly in a straight line travelling 212 meters over a 22 second period, what speed will it reach?*) often elicit a means-ends analysis from students. This type of analysis can be an effective problem strategy but regularly results in minimal learning because it does not directly promote conceptual understanding (Renkl & Atkinson, 2003).

Consider the learner who is employing this backwards approach to problem solving. She must determine the current problem state, the desired problem state, the difference between the current and desired problem states, the subgoals of the current problem state and the relevant operators that are needed to achieve the desired problem state. A learner who is simultaneously considering the above factors and trying to construct or organize their schema (ie. learn) will often have difficulty. Sweller (1988), in his first Cognitive Load article, suggests a rationale for this difficulty stating that the "cognitive processes required by the two activities overlap insufficiently, and that conventional problem solving in the form of means-ends analysis requires a relatively large amount of cognitive processing capacity which is consequently unavailable for schema acquisition" (p.257).

In other words, there is a heavy cognitive load placed on the working memory when using a means-end analysis. Oftentimes, this load surpasses the working memory's capacity, leaving little opportunity to construct knowledge. Therefore, according to CLT, conventional problems may not be the most effective form of instruction. Instead, CLT researchers argue, alternative problem formats should be considered.

Alternative problem formats

Worked examples, goal-modified, and goal-free problems are all examples of alternative problems that attempt to reduce the goal specificity of conventional problems. The worked example is an alternative problem that demonstrates to the learner exactly how to manipulate the provided information in order to solve a given problem (Kalyuga & Sweller, 2005). Textbooks often offer worked examples to help students complete the conventional problems that follow. In CLT, however, "the example phase is lengthened so that a number of examples are presented before learners are expected to engage in problem solving" (Renkl & Atkinson, 2003, p.15). Research has shown that worked examples can improve knowledge acquisition across various domains and learners (see Paas, 1992; Paas & van Merriënboer, 1994; van Gerven, Paas, van Merriënboer, & Schmidt, 2002).

According to CLT researchers, examples are a critical component in learning problem solving skills; without them, "learners do not appropriately understand formulae and, therefore, they are not able to apply them" (Stark, Mandl, Gruber & Renkl, 2002, p.40). Asking students to solve problems without examples is an example of how instruction can impose an extraneous load that may prevent effective utilization of their entire working memory.

In addition to worked examples, there are other types of alternative problem formats that attempt to reduce cognitive load. An example of a problem with reduced goal specificity might look like this: *A motorcycle starts from rest and accelerates uniformly in a straight line traveling 212 meters over a 22 second period. Identify and calculate the value of as many of the unknown variables as you can.* Presumably, by reducing the specificity of the goal, the need to work backwards is eliminated, which, in turn, alleviates the cognitive load and affords the learner with greater opportunity to construct schema.

Owen and Sweller (1985) conducted a series of experiments that studied the effects of alternative problem formats. In these experiments, trigonometric ratios were used as the subject matter when testing student differences in performance, learning and transfer. In each of the three experiments conducted, a control group was given conventional trigonometric problems, in which a particular goal was desired (eg. find the length of BD using the triangle shown below). Students in the experimental group, however, were given unconventional, goal-free problems asking them to “find the length of all unknown sides” of the triangle depicted in Figure 2.2 below.

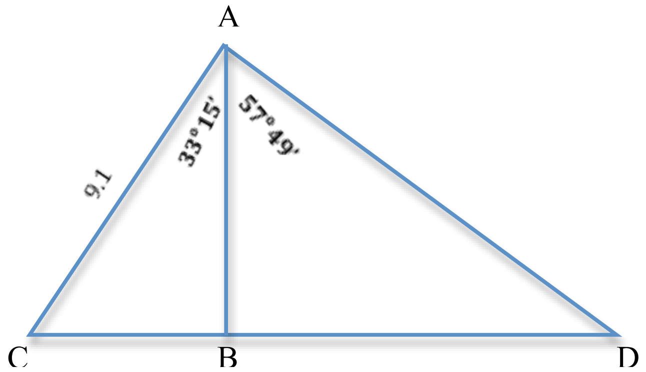


Figure 2.2. Example of using goal-free problems in Trigonometry.

In the first experiment, 10th grade students (*n*=20) who had learned trigonometry the previous year, were given a pre-test which assessed their general knowledge of trigonometric ratios and their problem-solving strategies. A brief period of instruction designed to promote schema acquisition followed the pre-test. In this instruction, students were provided worked examples in which they could see completely worked-out solutions to problems. Students were given worked examples with either a high level (conventional problems) or a low level (goal-free) of goal specificity - dependent upon their condition. Lastly, a post-test identical to the pre-test was administered to the students. Performance was tested and results demonstrated that students in the experimental group, those receiving goal-free problems, had a significantly smaller error rate on the post measure than those in the control group.

Experiments 2 and 3 used a similar experimental design; however, the participants now included 9th grade students who had never learned trigonometry. Experiment 2 divided twenty-two 9th grade students into two groups, one of which received conventional problems and the other goal-free problems. Because the 9th grade students had never been exposed to trigonometry, learning, as opposed to performance (of the 10th graders) in experiment 1, was measured. The results were analogous to experiment 1; students receiving goal-free problems had a significantly smaller error rate on the post measure than those in the control group. The results demonstrated that "reducing goal specificity greatly assisted these students in assimilating the basic knowledge needed in trigonometry" (Owen & Sweller, 1985, p.280). Experiment 3, which tested twenty 9th grade students' ability to transfer newly acquired trigonometric knowledge, also demonstrated a significantly reduced error rate in the experimental group versus the control group.

In their discussion, Owen and Sweller (1985) suggest that when students are given conventional problems they are apt to use a means-end strategy. Again, this backwards strategy imposes a heavy cognitive load leaving few, if any, cognitive resources for schema acquisition. Providing students with goal-free trigonometric problems, however, increased performance, learning and transfer. Although these three experiments used relatively small sample sizes and focused on a very specific topic, Owen and Sweller (1985, p.284) offered a generalized conclusion that "the use of reduced goal specificity procedures might be preferred in the early stages of teaching new principles" because it yields less extraneous load and can, therefore, improve learning.

Subsequent research on goal-free and goal-reduced problems has reproduced the significant findings across various domains and diverse types of learners. Ayres (1993) found that goal-free problems resulted in improved performance in middle school students (*n*=67) learning geometry. The provision of CLT-based instruction such as goal-free problems can also compensate for cognitive declines in the elderly, as suggested by van Gerven et al. (2002).

The alleviation of heavy cognitive loads through the presentation of goal-free problems can also occur in multimedia-based instruction. As an example, in a Vollmeyer & Burns (2002) study, students were given a nonlinear, multimedia-learning environment, which presented and described the numerous events that contributed to the outbreak of World War I. The learning environment was composed of 51 electronic, text-based pages, each of which contained hyperlinks to extra pages, or video or audio files designed to supplement the concepts and topics presented in the text. Because the presentation was nonlinear in nature, students were given complete control over the path that they took in order to learn the information.

The students were split into two groups: the specific goal learners (SG) and the non-specific goal learners (NSG). The SG group (*n*=47) was asked to find 20 particular events and dates and the NSG group (*n*=43) was asked to read through the presentation with the goal of being able to explain the causes for WWI to somebody else. Following the presentation, all students were assessed on their knowledge via a 34-item questionnaire. Students in the non-specific group accumulated significantly more factual and inferential knowledge than students who were asked to learn with specific goals in mind. Presumably, students in the SG group were focused on seeking answers to specific questions and therefore, had to dedicate the majority of their cognitive resources to these specific tasks. The remaining cognitive resources available may not have been sufficient for constructing knowledge about the reasons for the outbreak of WWI; thus, performance on the dependent measure suffered. Students in the NSG group had more cognitive resources available to learn, and therefore performed better than students in the SG.

Early CLT research on the use of worked examples and goal-free problems demonstrates the learning advantages of presenting instruction that is designed to reduce extraneous cognitive load. The presentation of goal-free problems within instruction can help reduce the extraneous load “caused by relating a current problem state to a goal state and attempting to reduce differences between them” (van Merriënboer & Sweller, 2005, p. 151). Worked examples can help reduce extraneous load by directing a learner’s attention to appropriate steps to a solution rather than the ineffective strategies used in means-end analyses. In addition to worked examples and goal-free problems, another cognitive load-reducing alternative to conventional problems is the completion problem.

More specific than a goal-free problem and more interactive than a worked example, completion problems can be thought of as a bridge between the aforementioned problems and conventional problems. Completion problems present a conventional problem but also offer a partial solution that the learner can use to complete the problem.

Extraneous cognitive load is lowered when using completion problems “because giving part of the solution reduces the size of the problem space, focuses attention on problem states and useful solution steps” (van Merriënboer & Sweller, 2005, p. 151).

Positive results of the completion effect have been found in a variety of domains and diverse learner types. For instance, in their 2002 study, van Merriënboer, Schuurman, de Croock, and & Paas found positive effects when presenting completion problems to novice learners in the field of computer science. Students, aged 19-26, were asked to write a small computer program using newly learned computer coding strategies. The strategies utilized were dependent upon the group that the students were randomly placed into: a conventional problem group (*n*=8), a completion problem group (*n*=10), and a learner-controlled group (*n*=8) in which learners could select either or both of the strategies used in the former two groups.

Students in each condition practiced for three hours, during which every twenty minutes students were required to rate the amount of their perceived mental effort (based on a 9-point rating scale). This scale was used to determine the level of cognitive load imposed upon them by their instruction. Afterwards, students were allowed a sixty-minute break and were then given a thirty-minute assessment designed to test their ability to transfer their newfound knowledge.

During the practice session, students in both the completion group and learner-controlled group performed significantly better than their counterparts in the conventional group. There was no difference between the completion group and the learner-controlled group, probably because the learner-controlled group demonstrated a clear preference for the completion problems; students in this group chose to use the completion problem format 76% of the time. An additional, statistically significant finding was that students in the completion problem group reported the lowest level of cognitive load (based on the mental effort scale) while the conventional problem group reported the highest load.

In addition to being advantageous for students learning computer programming, completion problems were beneficial for: low-track, German 9th graders learning about electricity within the domain of Physics; U.S. college students learning about probability within Mathematics; and, Dutch students learning statistical problem solving in a technical high school (see Renkl & Atkinson, 2003; Paas, 1992). Although there is variation in how completion problems were presented, each can be described as being falling somewhere in between a worked example and a conventional problem. In other words, some, but not all of a solution's steps are provided to the learner. Research subsequent to Sweller's initial findings has supported his assertion that completion problems yield an increased level of learning, performance and transfer of acquired skills as compared to conventional problem solving. Extraneous cognitive load is lowered and students are able to dedicate more cognitive resources to schema construction.

Because completion problems can serve as a bridge between what students know and what they have not yet learned, they can be thought of as an extraneous load reducing form of scaffolding (Renkl, Stark, Gruber, & Mandl, 1998; Rosenshine & Meister, 1992; Woolfolk, 2001; van Merriënboer, Kirschner & Kester, 2003). Completion problems, because of their ability to promote learning, are examined within this particular study. Depending upon the condition that the students are placed into, they may receive some, but not all, of the steps necessary to perform the skill being taught in the intervention. This integrated form of scaffolding will be discussed in greater detail in the Methods chapter.

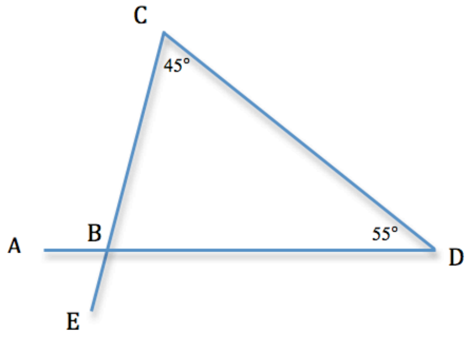
The research and exploration of alternative problem formats led to several other classic cognitive load concepts that play a large role in cognitive load-based instructional design including the split-attention effect, a primary effect postulated by CLT.

Split-Attention Effect

Although research demonstrated that alternative problem formats, such as worked examples, could be instructionally effective, there were instances in which these design techniques failed to produce significant results. In fact, in certain cases, the use of worked examples proved to hinder learning. The split-attention effect, a direct derivative of the worked example effect, is one of these cases.

The split-attention effect "occurs when two or more sources of information must be processed simultaneously in order to derive meaning from material" (Sweller et al., 1998, p. 282). The effect can be found in many conventional instructional materials that use images or diagrams to enhance text-based instruction. Oftentimes, instructional mistakes are made when unnecessary space exists between diagrams or images and the text. This space requires "learners to unnecessarily split their attention between diagrams and text" thereby forcing the learner to "hold small segments of text in working memory while searching for the matching diagrammatic entity" sometimes on an entirely different page (Kalyuga, Chandler & Sweller, 1999, p.352).

According to Sweller et al. (1998), there is overwhelming evidence that suggests instructional material that splits attention has “negative consequences and should be eliminated wherever possible” (p.281). The suggested solution to the split-attention effect is to eliminate the space existing between the image and text, and integrate the two whenever possible. This technique is demonstrated by Sweller et al. (1998) within the Geometry example shown in the following two figures. First, Figure 2.3, an example of the split-attention effect, shows a diagram-based problem along with the solution below the diagram. Next, Figure 2.4 demonstrates how the split-attention effect can be overcome through the integration of diagram and solution.



In this diagram above, find a value for Angle ABE.

Solution:
Angle CBD = 180° - Angle BCD – Angle BDC (Internal angles of a triangle sum to 180°)
= 180° - 55° - 45°
= 80°

Angle ABE = Angle CBD (Vertically opposite angles are equal)
= 80°

Figure 2.3. Trigonometric problem resulting in split-attention.

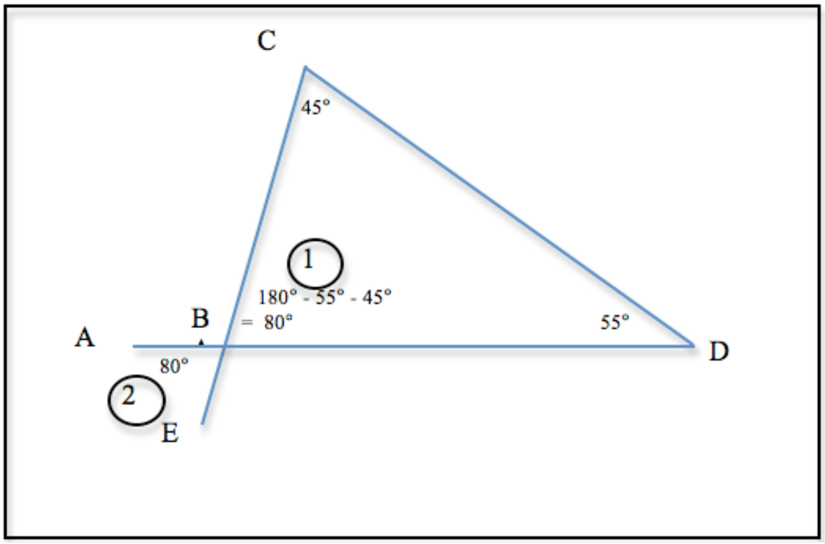


Figure 2.4. Integration of problem and solution that can reduce split-attention.

By eliminating unnecessary space between diagrams or images and text-based information, research has shown that the need to search for and then mentally integrate corresponding text and images is eliminated. The elimination thereby reduces the burden on working memory and allows for more effective learning (Ginns, 2006).

For example, Chandler and Sweller (1991, experiment 1) instructed 28 first-year trade apprentices enrolled in various technical colleges how to install megger meters, which measure insulation and circuit resistance. Students were divided evenly into two groups that received identical content through differing instructional deliveries. One group received conventional, split-format instructions and the other group received modified instructions that used an integrated format designed to reduce split-attention. Each group was given three tests subsequent to instruction: an immediate, written exam; an intermediate test comprised of a written and practical exam given one week after the initial instruction; and a delayed measure, also written and practical in nature and given 12 weeks after the initial instruction. On all measures, results demonstrated significant main effects due to instruction type and the group receiving modified, integrated instruction performed better than the conventional group.

It is noteworthy that none of the participants had had any electrical training prior to the instruction presented in the study. Additionally, it is worth noting that the presented information was highly complex; the installation of megger meters is considered to have a high level of element interactivity. That the learners had no prior knowledge of a complex concept leads to the safe assumption that a high intrinsic load was placed upon the learners' working memory. Given this, any load extraneous to the information being presented, such as that created by the split-attention effect, can create a working memory overload leaving little or no availability for germane cognitive load, or the opportunity to construct schema.

Alternatively, given the additive nature of the three sources of cognitive load, the need to decrease extraneous cognitive load when teaching a concept with a low intrinsic load is reduced because there are sufficient cognitive resources available for learning. In a meta-analysis of the split-attention effect, Ginns (2006) studied how the level of intrinsic load interacted with the split-attention effect. Ginns reviewed fifty experiments that took place between 1983 and 2004. These experiments assessed the performance of 2375 learners of various ages in multiple domains. Some of the variables included and analyzed in this meta-analysis were the educational level of the participants, the content domain, and whether the type of information being presented was considered to have high or low element interactivity. Ginns found that the mean, weighted effect size for split-attention effects found when presenting information with high element interactivity materials (*d*=0.78) was significantly larger than for those coded with low element interactivity materials (*d*=0.28). In other words, Ginns' findings supports CLT's assertion that when presenting information that has high element interactivity, which often leads to high intrinsic load, the best instructional design is one which decreases extraneous cognitive load caused by the split-attention effect.

Ginns not only explored differing levels of element interactivity and how they affect the split-attention effect, she also explored and distinguished between the two different types of the split-attention effect: the spatial contiguity effect and the temporal contiguity effect. The former refers to split-attention over space. In the aforementioned geometry example of how attention can be split, a learner would have to view the problem's solution found beneath the diagram, hold it in her working memory, and then attach it to the appropriate portion of the diagram. In other words, the learner must scan over the space that separates the instruction and the diagram.

The temporal contiguity effect refers to attention that is split not over space, but, rather over time. Although CLT primarily studied the spatial type of split-attention, effects for temporal contiguity have been found in other research, some of which even predates CLT. The research on paired-associate verbal learning by Nodine (1969), and Baggett's (1984) research on learning from a sound-tracked film for instance, are classic educational psychology studies that found support for the temporal contiguity effect. Nodine and Baggett each found evidence that when presenting verbal information, such as narration, and visual information, such as an image, which corresponds to the narration, it should be done simultaneously rather than successively. Doing so eliminates the temporal gap between the two types of information and thereby reduces the amount of time one must hold the information in the working memory.

Although not considered unimportant in CLT, the temporal contiguity effect was simply not focused upon as much as the spatial contiguity effect. This may be due in part to CLT efforts that focused on traditional instruction offered through paper-based materials and texts. As computers and their ease of use became more prevalent, however, so too did electronic and multimedia-based instruction. As a result, instructional design problems, such as the temporal contiguity effect, that were not yet fully explained by CLT, needed to be researched and explained. Richard Mayer (2001) addressed this need by developing the Cognitive Theory of Multimedia Learning (CTML). A sub-theory of CLT, CTML incorporates many of the same foundations and rules assumed in CLT; however, Mayer developed his theory specifically for multimedia learning.

Cognitive Theory of Multimedia Learning

Mayer's CTML is a computer-based, multimedia instructional design theory that uses three assumptions, which serve as the foundation for CTML: the dual-channel assumption, the limited-capacity assumption, and the active processing assumption.

The dual-channel assumption is based upon research by Baddeley (1992) and Paivio (1986) and assumes that learners possess two information-processing channels: one channel that processes visual information and another that processes verbal information. By utilizing both channels, learners are given the opportunity to build both verbal and visual mental models. By connecting these models, student learning can increase. In fact, Mayer's *Multimedia Principle* states that "students learn better from words and pictures than from words alone" (Mayer, 2001, p. 63). Just as CLT does, CTML postulates that the burden on the working memory may be lessened if both types of information are presented.

Instructional designers taking this dual-channel assumption into consideration may be able to produce more effective instruction; however, in doing so, they must also take into account other instructional obstacles. For instance, if a lesson on mitosis contains images and narration, the designer must consider the aforementioned temporal contiguity effect, and make sure to present the narration and the visual information in a simultaneous manner. Various techniques used in the instructional delivery of verbal and visual information are the central focus within CTML research and will be discussed later in more detail.

In its second assumption, CTML is again influenced by Baddeley (1992), and also by CLT, with the assumption that the working memory has a limited-capacity. As previously discussed in the information processing section, the verbal and visual processing channels within the working memory are limited in the amount of information that can be stored and processed. This is not different than what is assumed in CLT; however, whereas the research in CLT has examined the working memory limits in a broad sense, CTML has narrowed working memory research to how the two processing channels are limited when isolated from each other and when working in conjunction with each other. As an example, CTML might ask and explore the question, *Which type* *of PowerPoint presentation places a heavier burden on the working memory, one that contains images and on-screen text, or one that contains images and narration?*

Borrowing from one of CLT's fundamental rules, CTML postulates that if working memory limits are exceeded, learning can be impaired due to a cognitive overload. Two of the sources of this overload are the same in both theories: intrinsic and extraneous load. Whereas the terms intrinsic and extraneous load are shared by both theories, the third type of load within CLT, germane load, is referred to by CTML theorists as active processing and forms the basis for the theory's third assumption, the active-processing assumption. CTML assumes that when meaningful learning occurs, individuals perform three cognitive processes: paying attention, organizing incoming information, and then integrating this new knowledge into the prior knowledge that is stored within the long-term memory.

Regardless of which term is used, active processing or germane load, the desired resulting outcome of each is the learner's construction of a coherent model of the presented material. CTML focuses specifically on how multimedia-based instruction can "assist learners in their model-building efforts" (Mayer, 2001, p.52). CTML sets forth several guidelines that attempt to decrease extraneous load while promoting effective active learning. This is accomplished, according to CTML, by coordinating the sights and sounds occurring in a multimedia lesson in ways economical to working memory.

What follows is a discussion of some of these design guidelines and their relevance to multimedia instruction, specifically, the modality effect, the coherence effect, the signaling effect, and the segmenting effect.

Instructional Design Considerations in the Cognitive Theory of Multimedia Learning

The Modality Effect

The dual-channel assumption, which supposes that learners have one channel that processes visual information and another that processes verbal information, provides the foundation for the modality effect. The modality effect asserts that in multimedia-based instruction there is “better transfer when words are presented as narration rather than as on-screen text” (Mayer & Moreno, 2003, p. 46). In several studies to be discussed next, researchers found that by presenting words as narration, some of the working memory’s essential processing is off-loaded from the visual channel to the verbal channel (Mayer & Moreno, 2003). The modality effect has a multimedia-based perspective on what previous cognitive and CLT research have found –working memory capacity can be increased by using both the verbal and visual channels (Paivio, 1969; Penney, 1989; Sweller et al., 1998).

In CLT research, the modality effect was initially found under split-attention conditions when verbal information, presented with some corresponding form of visual information (e.g. a diagram), was auditory rather than written (Sweller et al., 1998). As an example, Tindall-Ford, Chandler & Sweller (1997) found that students learned electrical engineering concepts better when instruction contained both visual information (diagrams and tables) and auditory information (words presented through audio cassette-tapes) than when instruction contained only visual information (diagrams and words presented as text). The authors explained that the engineering concepts that contained a high level of element interactivity placed a significant burden on students’ working memories; however, by using both the visual and verbal modalities, the burden could be mitigated. As a result, working memory resources that could be used for schema construction, were in essence, increased. Engineering concepts with low element interactivity, on the other hand, did not create enough working memory load for the modality effect to occur.

CLT researchers examined the modality effect through the broad lens of split-attention rather than studying it on its own accord. In fact, at the time, there was neither any theoretical nor empirical reason for "supposing that dual mode presentation is effective except under split-attention conditions" (Sweller et al., 1998). This narrow line of thinking was perhaps due to CLT's focus on traditional instruction; dual mode instruction may not have been considered a practical form of instruction at the time, and, therefore, was not examined more carefully. Although dual mode presentation may not have been a traditional form of instruction at the time, Sweller et al. (1998) had enough foresight to suggest that the modality effect "may be especially important in areas such as the use of multimedia" (p.283).

As computer-based technologies became less costly and easier to use, educators have become more adept at creating dual mode multimedia-based instruction. Because of its increased prevalence in educational settings, CTML used multimedia-based instruction as its foundation when studying instructional and learning conditions like the modality effect.

The modality effect has been shown to be very robust as demonstrated by Mayer and his colleagues through a series of studies examining the effect. Six studies found that students learned scientific concepts more effectively when instruction contained animation and narration versus animation and on-screen text. For example, Mayer & Moreno (1998) found support for the modality effect in tests of recall and transfer when testing college students' ability to learn from animation depicting how lightning forms (experiment 1) and how a car's braking system operates (experiment 2). Similar results were found in a study conducted by Moreno, Mayer, Spires, & Lester (2001) when they examined how college students learned to design a plant in a multimedia environment. Results indicated a significantly better performance on tests of retention and problem-solving transfer when students received instruction that contained narrated words rather than on-screen text. The effect was found when narration was presented via an animated agent (experiment 4) or a video of a human (experiment 5). The median effect size of the six studies, 1.17, is considered large, demonstrating consistently strong findings of the modality effect.

Related to this study, the researcher has applied the modality design principle through the use of screen-captured movies containing animation and narration rather than the more traditional, text-based form of instruction. Even though screen-captured movies have not been researched, the researcher posits that previous research on narrated animation has provided an empirical justification to use screen-capture movies as a form of dual mode instruction. It is also of note that due to time constraints, as students viewed the instruction, they did not have any control over the movies. Mayer (2001) provides further validation to this type of instruction, stating, "It is important to note that this design principle has been demonstrated in situations in which the animated narration runs at a fast rate without learner control of the presentation" (p.146).

In addition to a dual mode instructional approach, during the development of the screen-captured movies used in this study, two more of Mayer's principles were considered: the coherence and the signaling effects.

The Coherence Effect

Most likely, readers of this paper have encountered presentations that use multimedia bells and whistles to a fault. As an example, think of a PowerPoint slideshow that subjects viewers to both animated and sound effects (think of a zoooooom sound every time a single letter flies in from off screen). As discussed earlier in this paper, this is a classic example of extraneous cognitive load. Despite CLT and CTML research findings, presentations frequently continue to include interesting, yet irrelevant sound effects, background music, graphics and clip-art.

Mayer (2001) argues that even if the sound or graphic is interesting, it can interfere with learning. As learners attempt to make sense of the presented materials, they are actively constructing schema within their working memory. The inclusion of sounds, words or visuals that are extraneous to the material being presented can add to the burden of the working memory, thereby reducing the capacity to learn. Therefore, any sound or visual that is not directly related to the material being taught should be eliminated from the presentation (Mayer, 2001).

If it is Mayer's suggestion to restrict the number of graphics and sounds to only those that are relevant to the material being presented, the same can be said about words.

When presenting with written text or narration, words should be used in a manner that directly and concisely relates to the material being presented. By eliminating interesting yet irrelevant visual material or by keeping narration as concise as possible, instructional designers can reduce the amount of extraneous processing that a student has to undertake. The reduction of extraneous visuals or words is called *weeding* (Mayer & Moreno, 2003).

By weeding out information that is extraneous to the material being taught, the instructional designer is applying the *coherence effect*, in which students “learn more when less is presented” (Mayer, 2001, p.132). The coherence effect was found in several studies when students receiving instruction that contained background music or irrelevant video clips demonstrated less problem-solving transfer than students who received the same instruction without the embellishments (Mayer, Heiser, & Lonn, 2001 Experiments 1, 3 and 4; Moreno & Mayer, 2000, Experiments 1 and 2). The robustness of the median effect size, .90, suggests that instructional designers should weed out any verbal and visual information that does not directly help teach the material.

The Signaling Effect

The weeding out of unnecessary verbal and visual information is not the same as the removal of embellishments in multimedia instruction altogether. In fact, embellishments can actually be helpful when they serve as signals or cues that direct a learner towards relevant information. This is especially true for novice learners who oftentimes lack the knowledge needed to select the relevant information from animated or video-based multimedia instruction (Kettanurak, Ramamurthy, & Haseman, 2001; Moreno, 2007).

Promoting attention to relevant information through signaling, also called cueing, has been found to positively affect: *retention* in a lesson on instructional design in a non-laboratory setting (Tabbers, et al., 2004), *transfer* in a lesson on the Bernoulli Principle (Mautone & Mayer, 2001); and learning outcomes (de Koning, Tabbers, Rikers, & Paas, 2007; Kalyuga, Chandler, & Sweller, 1999). CLT and CTML literature explains these findings: learners, when presented with signals, can use their cognitive resources for schema construction (germane load) rather than for the haphazard scanning for what is relevant (Ayres & Paas, 2007a; de Koning et al., 2007; Mautone & Mayer, 2001; Patrick, Carter, & Wiebe, 2005).

Signals are effective based on the properties of human automatic attention, or attention given naturally to certain information based on properties such as movement or contrast (Kiewra & Dubois, 1998). For instance, some common signals used in multimedia instruction include arrows, circles, color-coding, or underlining (contrasts).

Signals are often found in screen-captured movies and they take many forms. First, through narration, words can serve as verbal signals. For example, during playback of a movie that is displaying a spreadsheet, the narrator may provide a verbal signal such as, “now, I will go to the File menu at the top of the screen” which cues the learner to look towards the top of the screen.

Another example of signals found in screen-captured movies is the color changes seen during interactions with a menu. When the narrator clicks on the File menu, the word “file” is highlighted in blue, which gets the learner’s attention and directs her to look in the relevant location. When providing software training through a screen-captured movie, it is the author’s assertion that the mouse, or cursor, that has been recorded and is being displayed on screen, acts as a continuous signal that directs the learner’s attention to the relevant area.

Occasionally, research has found no or negative effects of signaling. Explanations of these negative findings varied; some suggest that the lack of effect of cueing is that the design or implementation (i.e. the salience) of the cue was not sufficient to guide the learner’s attention; perhaps the color or size of the cue did not stand out amongst the other instructional components (Mautone & Mayer, 2001). Another suggestion for why cueing failed is that they were not found to be necessary if the animation or image used in the instruction is simple enough to understand without the cues (de Koning et al., 2007; Mautone & Mayer, 2001). By and large, however, signaling has been found to be an effective design technique that should be incorporated into multimedia instruction. CTML research has also made the case for another suggested multimedia design technique, segmenting.

The Segmenting Effect

The continuous nature of animation and video—the constant stream of information—can overburden working memory and subsequently diminish students’ potential to learn, especially if instruction is lengthy (Ayres & Paas, 2007b; Hasler, Kersten & Sweller, 2007; Moreno, 2007). One method to overcome this impediment to learning is to segment the long, continuous material into smaller sections that are shown individually and successively. This process is called segmenting and research has found that segmented instruction can result in better learning in multimedia-based learning environments that integrate animation or video (Hasler et al., 2007; Mayer and Chandler, 2001; Moreno, 2007).

If examined from the perspective of cognitive load theory, CTML's proposed advantage of segmented instruction is "consistent with the argument that extraneous load caused by transitory animations or video-recordings can be reduced by dividing the presentation into smaller parts" (Ayres & Paas, 2007a, p.813). Moreover, segmenting animated instruction not only reduces extraneous load, it can lead to an opportunity for germane load. The breaks in instruction that fall in between each segment offers an opportunity for the learner to make connections to prior knowledge and thereby, construct new schema (Ayres & Paas, 2007b; Hasler et al., 2007).

Some may assume that because segmented video and animations are more effective than non-segmented instruction, segmented screen-captured video would show the same effects. However logical the assumption is, there can be no empirical conclusion until it is studied. Screen-captured movies, although animated, are not the same type of animation used to demonstrate what causes of the daytime lightness and the darkness of nighttime (see Hasler et al., 2007). Nor are they exactly like videos that might present information such as exemplary teaching practices (see Moreno, 2007, Experiment 1). In fact, screen-captured movies are their own entity that should be studied separately.

Because of their inherent ability to reproduce exactly what learners see on their own computers, screen-captured video might contain less extraneous load and therefore might not need to be segmented. Of course, this notion could be entirely wrong; it cannot be known until it is studied. There are other unique qualities to the screen-captured movies used in this particular study. They are conveying procedural knowledge, as opposed to conceptual knowledge such as lightning formation being taught via animation in Mayer and Chandler's 2001 study. In addition, the learners in this study viewed the movies without the ability to control or interact with them, as was the case in the study by Hasler et al. (2007).

Limitations of CLT and CTML

CTML and CLT research has produced instruction design techniques that consistently have shown positive learning effects. Human cognitive architecture is the foundation of this research that examines instructional designs that can help learners organize and construct schema when dealing with new information. According to some cognitive psychologists leading this research, knowing how people learn is essential and "any instructional procedure that ignores the structures that constitute human cognitive architecture is not likely to be effective" (Kirschner, Sweller, & Clark, 2006, p.76).

While this assertion is hardly controversial, the same psychologists have managed to create a great deal of controversy as they contend that direct instruction is the most effective teaching method and that constructivist approaches to instruction simply do not work. According to them, constructivist learning, discovery learning, experiential learning, problem-based learning, and inquiry learning all contain minimal teacher guidance and none is conducive to learning (Kirschner et al., 2006). Constructivist approaches, they claim, present too many options to students, which places an unnecessary burden on their working memories. Sweller, Kirschner, and Clark (2007) explain:

> The process of discovery is in conflict with our current knowledge of human cognitive architecture which assumes that working memory is severely limited in capacity when dealing with novel information sourced from the external environment but largely unlimited when dealing with familiar, organized information sourced from long-term memory. If this view of human cognitive architecture is valid, then by definition novices should not be presented with material in a manner that unnecessarily requires them to search for a solution with its attendant heavy working memory load rather than being presented with a solution. (p.116)

Constructivists have expressed several points of contention with Sweller et al.'s assertions. First, they argue that the assertion that all constructivist-teaching approaches are pure discovery or minimally guided is a sweeping generalization. They additionally claim that two constructivist approaches, inquiry learning and problem-based learning, extend far beyond the minimally guided categorization. Effective implementation of each approach provides the structure, guidance, and scaffolding designed to promote learning (Hmelo-Silver, Duncan, & Chinn, 2007). The "structure of problem-based instructional activities may require the most complex and demanding instructional design" of all instructional approaches, including direct instruction (Kuhn, 2007, p.112).

Staunch constructivists oppose the view that constructivist approaches to learning are ineffective. In fact, they are not the only opponents, as even some CLT researchers disagree. In a paper by Schmidt, Loyens, van Gog, & Paas (2007), two of the authors (Paas and van Gog) are well known and respected CLT researchers who argue that the fundamental principles of constructivist instruction are very much aligned with how human cognitive architecture is structured. Intrinsic, extraneous, and germane cognitive load can all be accounted for if constructivist instruction is effectively designed. Moreover, because of the flexibility and adaptability typical of constructivism, this approach is "potentially more compatible with the manner in which our cognitive structures are organized than the direct guided instructional approach" (Schmidt et al., 2007, p.91). The debate between instructional approaches is a passionate yet healthy one. The researcher's opinion is aligned with the belief that direct and constructivist approaches both have merit and therefore a place within education (Kuhn, 2007; Schwartz & Bransford, 1998).

As opposed to some of CLT and its leading researchers, Mayer and his cognitive theory have largely escaped criticism from the constructivist camp, no doubt because of his constructivist belief that "learners are active sense makers who seek to build coherent and organized knowledge" (Mayer, 2004, p. 14). His willingness to accept and use certain constructivist approaches notwithstanding, he warns that all instruction should be designed based upon theoretical models of how people learn, a principle not criticized by the constructivist camp. Still, CTML has its critics and limitations.

Much of the CTML research by Mayer and his colleagues used brief, animated clips designed to instruct some type of conceptual knowledge (e.g. lightning formation). These instructional animations were studied in tightly controlled experiments and as discussed previously, consistently produced positive effects. However, as with many experimental studies, results do not always translate to traditional, classroom learning.

Many lessons or concepts that require more than two minutes worth of instruction might not produce the same positive effects found within the studies of Mayer and his colleagues. For instance, one study sought to test the generalizability of CTML's modality effect through a multimedia-based lesson, presented in a valid classroom (not laboratory) setting which was over an hour in duration (Tabbers et al., 2004). Results of the study showed that the increase in instructional time and content may have diminished the long-term effects of extraneous load reduction observed in short-term learning in previous CTML studies (Tabbers et al., 2004).

Tabbers et al. (2004) have called for fewer short laboratory experiments in favor of research that "might produce more specific design principles for multimedia instructions that can successfully be applied in real-life educational settings" (p.80). One of the goals of this dissertation study was to provide a lesson that students would be likely to receive in an Instructional Technology course for educators. The instruction was procedural in nature, rather than conceptual, and it lasted just over 20 minutes as opposed to a few minutes or longer than an hour.

Implications for Research

Again, given the sheer amount of research that has been conducted on CLT and CMLT, it might seem surprising that no research has explored the effective design of screen-captured video instruction. Screen-captured video technology falls somewhere between animation and video as a form of multimedia instruction. As a result, both animation and video have been researched extensively through CLT and CTML lens/lenses. In fact, an entire issue of Applied Cognitive Psychology (September, 2007) was dedicated to cognitive load research on instructional animation. Therefore, the extant CLT and CTML research findings might be applicable to the design of screen-captured video instruction. As a result, I have chosen to situate this proposed study within both CLT and CTML. Further research is needed to assess the conditions, if any, under which this type of instruction is effective. This is especially true considering screen-captured video has become and continues to grow more popular as a form of digital instruction (Allen & Seaman, 2007; Harrell & Harris, 2006; Kleiner et al., 2007; Skylar et al., 2005).

In some cases, complex animations (such as screen-captured videos) may not be instructionally sound because they potentially can create a high extraneous cognitive load (Ayres & Paas, 2007b). Consider, for instance, ineffectively designed instruction that presents 20-minutes worth of material without giving the learner a chance to process the information. Nonetheless, an instructional designer may be able to reduce extraneous load by following design guidelines established by research within the theoretical frameworks of CLT and CTML.

First, the modality principle suggests that students learn better from animation and narration than from animation and on-screen text (Mayer, 2001). Thus, one might expect screen-captured video instruction to be more beneficial when narration is presented in lieu of text. Second, segmenting large animations into smaller sized sections might improve the effectiveness of instructional animation and should be included when possible (Ayres & Paas, 2007a; Moreno, 2007). Thus, one would expect the segmentation of screen-captured video instruction to yield positive consequences for learning. Third, research suggests that for instruction that utilizes complex animations, signaling should be included in order to direct the learners' attention (Ayres & Paas, 2007; de Koning et al., 2007; Patrick et al., 2005). Thus, one might expect a cueing effect to emerge in research testing different formats of screen-captured video instruction that displays mouse movements. Finally, scaffolding instruction through the use of hints or prompts can benefit learners who are being taught new material (van Merriënboer et al., 2003). Thus, one might expect that a screen-captured video lesson that effectively scaffolds student learning would be more effective than similar instruction without scaffolds. The next chapter presents the study’s purpose, hypotheses, experimental design, materials, and procedure.

CHAPTER 3

METHOD

Based on the previous chapter's theoretical framework and literature review, an examination of how best to deliver screen-captured video instruction seems especially timely. Whereas cognitive theories of learning and instructional design have been applied fruitfully in experiments addressing the uses of various multimedia, the same principles have not been applied to screen-captured video. In the remainder of this chapter, I elaborate on the study's purpose, hypotheses and subsequent predictions, experimental design, materials, and procedure.

The purpose of this study was to explore the effects of different instructional designs of a screen-captured video lesson of Microsoft Excel® skills for University students. An explanatory mixed methods design (Creswell & Plano-Clark, 2006) was used. In the initial, quantitative phase of study, an experiment (2 x 2 factorial design) tested the learning effects associated when each of 108 students at a Southeastern university viewed one of four different versions of a screen-captured video lesson (Figure 3.1). In the follow-up, qualitative phase, semi-structured interviews were conducted in order to explore how different participants were affected by those different lessons. In short, the reason for the explanatory follow-up was to better understand the quantitative results from the first phase of the study.

Hypotheses

For the purposes of this study, three hypotheses were proposed. The *segmented instruction hypothesis* postulates that segmented instruction is superior to instruction that is not segmented. This hypothesis is supported by the research addressing Cognitive Load Theory and Cognitive Theory of Multimedia Learning (Ayres & Paas, 2007b; Hasler et al., 2007; Mayer & Moreno, 2003). Pertaining to this study, the segmented instruction hypothesis predicts that students who receive segmented instruction within a screen-captured video environment will perform better on immediate and delayed tests of learning transfer than students who do not receive segmented instruction.

The *scaffolded instruction hypothesis* postulates that instruction containing scaffolds is superior to instruction that does not. This hypothesis, too, is supported by other research on Cognitive Load Theory and Cognitive Theory of Multimedia Learning (Renkl et al., 1998; van Merriënboer et al., 2003; van Merriënboer & Sweller, 2005). In this study, the scaffolded instruction hypothesis predicts that students who receive scaffolded instruction during a screen-captured video lesson will perform better on immediate and delayed tests of learning transfer than students who do not receive scaffolded instruction.

Finally, the *interaction hypothesis* postulates that instruction that contains both instructional design aids (segments and scaffolds) is superior to that which has neither aid. Therefore, this hypothesis predicts that students who receive instruction that includes each of these supposed benefits should perform better on immediate and delayed tests of learning transfer than other students who receive instruction with fewer or none of the benefits. Figure 3.1 presents the 2 x 2 experimental design.

Screen-captured Video Instruction

		Non-Segmented Instruction	Segmented Instruction
PRACTICE	**Non-Scaffolded Instruction**	Group 1	Group 2
	Scaffolded Instruction	Group 3	Group 4

Figure 3.1. Four experimental conditions based on CLT and CTML.

Participants

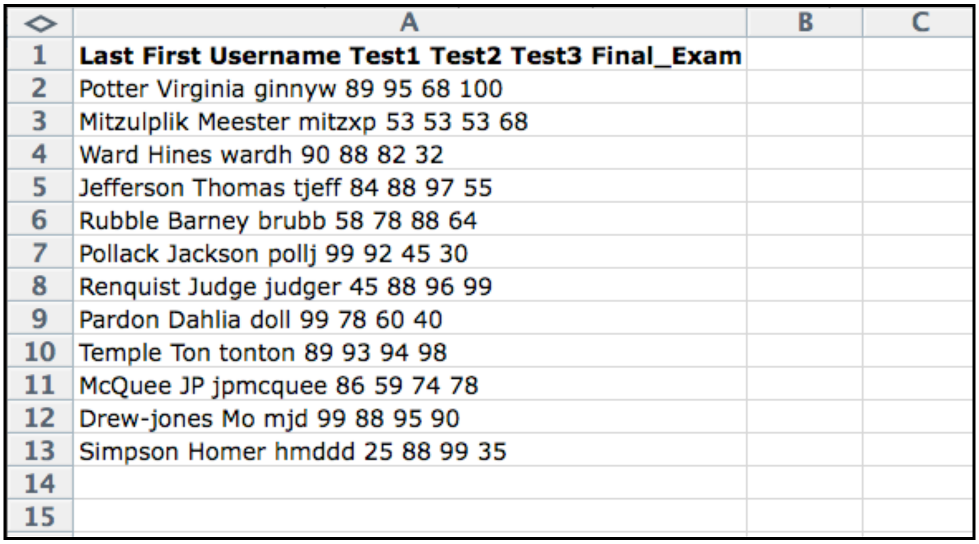
One hundred and eight preservice teachers enrolled in an introductory instructional technology course at a university in the Southeastern United States, participated in the study. The students' participation was entirely voluntary and the university's Institutional Review Board (IRB) protected their rights and welfare (Appendix A). Among them were 87 females and 21 males with a mean age of 20.81 years (*SD* = 3.68). The reported races were 100 White Americans, six African Americans, and two Hispanic Americans. The students identified their majors as follows: 14 in early childhood education, 30 in elementary education, 23 in special education, and 41 in secondary education. Students were instructed and tested in two adjacent computer labs. Twenty-eight students were assigned to the non-segmented/non-scaffolded (NNSc) condition and the segmented/non-scaffolded (SNSc) condition, 26 students in the non-segmented/scaffolded (NSc), and segmented/scaffolded (SSc) conditions.

Materials

Screen-captured Video Presentations

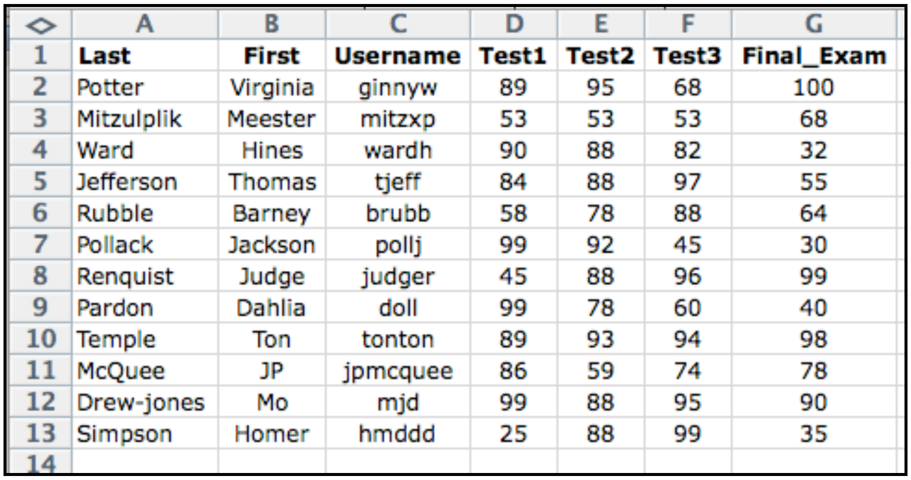
All video-based presentations were developed with Techsmith Camtasia®, a software program that captures on-screen movements and voice-over narration. Using the 2003 version of Microsoft Excel® for the Microsoft Windows® platform, the researcher recorded two different video presentations: a prior knowledge presentation and an instructional presentation.

Prior Knowledge Videos. A screen-captured video was developed in a manner that demonstrated the results of a particular skill, but not how to perform the skill. This was accomplished via narrated before-and-after screen-captured video. The two figures (3.2 and 3.3) below illustrate this technique using static images exported from the actual video. In this example, the video first showed an unformatted Excel worksheet containing data, all of which resided in Column A (see Figure 3.2). Then the video continued, explaining that, "*Excel has a handy, built-in feature that can separate the data from a column so all of the data that was in column A has been separated into multiple columns*" [see figure 3.3]. Again, it is important to emphasize that the skills needed to separate the data were not demonstrated in the video. Rather, the video simply showed before-and-after versions of the worksheet.



◇	A	B	C
1	**Last First Username Test1 Test2 Test3 Final_Exam**		
2	Potter Virginia ginnyw 89 95 68 100		
3	Mitzulplik Meester mitzxp 53 53 53 68		
4	Ward Hines wardh 90 88 82 32		
5	Jefferson Thomas tjeff 84 88 97 55		
6	Rubble Barney brubb 58 78 88 64		
7	Pollack Jackson pollj 99 92 45 30		
8	Renquist Judge judger 45 88 96 99		
9	Pardon Dahlia doll 99 78 60 40		
10	Temple Ton tonton 89 93 94 98		
11	McQuee JP jpmcquee 86 59 74 78		
12	Drew-jones Mo mjd 99 88 95 90		
13	Simpson Homer hmddd 25 88 99 35		
14			
15			

Figure 3.2. A static example of the 'before state' of what the students would see in video form.

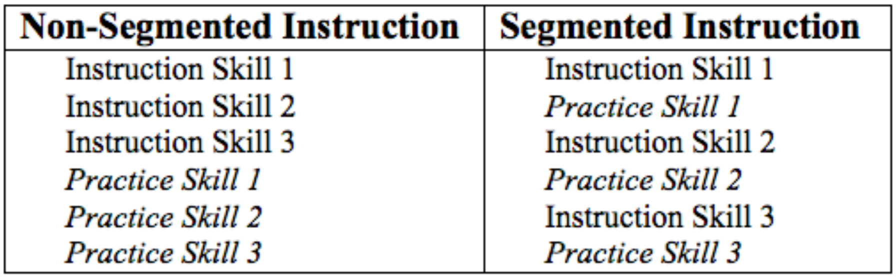


◇	A	B	C	D	E	F	G
1	**Last**	**First**	**Username**	**Test1**	**Test2**	**Test3**	**Final_Exam**
2	Potter	Virginia	ginnyw	89	95	68	100
3	Mitzulplik	Meester	mitzxp	53	53	53	68
4	Ward	Hines	wardh	90	88	82	32
5	Jefferson	Thomas	tjeff	84	88	97	55
6	Rubble	Barney	brubb	58	78	88	64
7	Pollack	Jackson	pollj	99	92	45	30
8	Renquist	Judge	judger	45	88	96	99
9	Pardon	Dahlia	doll	99	78	60	40
10	Temple	Ton	tonton	89	93	94	98
11	McQuee	JP	jpmcquee	86	59	74	78
12	Drew-jones	Mo	mjd	99	88	95	90
13	Simpson	Homer	hmddd	25	88	99	35
14							

Figure 3.3. A static example of the 'after state' of what the students would see in video form.

The presentation contained 12 of these before-and-after video vignettes. Subsequent to each vignette was a video countdown used to keep track of the time allotted to answer the prior knowledge questions. This video began by displaying the numeral 45 and counted down until reaching 0. The video was a silent countdown except for two announcements that declared when 30 and 15 seconds remained.

Instructional Videos. A video was recorded for each skill necessary to build a spreadsheet-based gradebook. All students viewed one of two video-based presentations that demonstrated how to build a classroom grade book using Microsoft Excel®. Although the content within the two presentations was identical, the instructional design differed. One version of the instruction, *non-segmented,* presented all instructional segments prior to the provision of opportunities to practice each skill. A second instructional condition, *segmented,* presented one instructional segment followed by an opportunity to practice the skill taught in that segment. This instruction-practice sequence was repeated for each skill and is illustrated by Figure 3.4.



Non-Segmented Instruction	**Segmented Instruction**
Instruction Skill 1	Instruction Skill 1
Instruction Skill 2	*Practice Skill 1*
Instruction Skill 3	Instruction Skill 2
Practice Skill 1	*Practice Skill 2*
Practice Skill 2	Instruction Skill 3
Practice Skill 3	*Practice Skill 3*

Figure 3.4. Design approximation of non-segmented instruction v. segmented instruction.

The skills, their descriptions and durations (minutes:seconds) were:

1) *Separating Data* - how to parse data from one column into multiple columns using the “Text to Columns” tool (2:25).
2) *Combining Data* - how to concatenate data from multiple columns into one column (3:10).
3) *Weighted Grades* - how to calculate a weighted, final grade using a calculation formula (3:20).
4) *Letter Grades* - how to assign letter grades to numerical grades using the *lookup* function (1:10).
5) *Absolute References* - how to create an absolute reference (3:15).
6) *Smart Formatting* - how to apply conditional formatting (1:20).
7) *Grade Distributions* - how to create a distribution of letter grades using the *countif* function (1:10).

For the purposes of keeping track of the allotted time to practice, a 60-second countdown video was created. After considering the amount of time consumed by the experiments introduction and instructions, the instructional videos and the testing, and comparing it with the duration of the class period, the amount of practice time was designated to be 60-seconds. This video began by displaying the numeral 60 and counted down until reaching 0. The video was a silent countdown except for two announcements that declared when 30 and 15 seconds remained.

The individual videos were compiled into two single presentations. The first was presented to the *segmented* group and utilized the instruction-practice repetitive sequence. The second was presented to the *non-segmented* group and all skills were presented first, followed by seven opportunities to practice each skill. During practice opportunities, irrespective of condition, a 60 second countdown was displayed to the students. In addition to the two announcements declaring when 30 and 15 seconds remained, each countdown video had a brief introductory narration telling the students which skill to practice. The videos, identical for all students, were displayed via digital projector with built-in speakers for the voice-over narration. The instructors had only to press the play button once, which started the video lesson. Students needed only to view the videos, not interact with them.

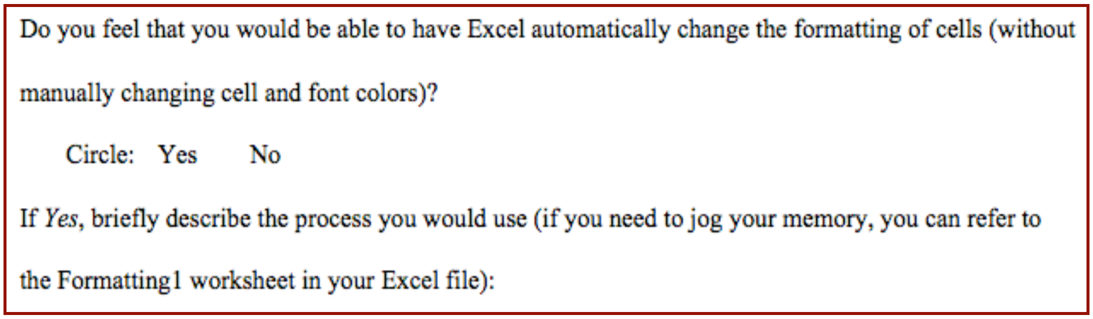
Demographic Sheets

Students completed demographic sheets (Appendix B), allowing for the collection of information identifying their age, year, major, gender, and race. See the *Participants* section for the results. The demographic sheets were printed and distributed on 8 ½ x 11-inch paper with 12 point, Times New Roman font. All other printed materials followed this formatting.

Dependent Measures

Prior knowledge questionnaire and spreadsheet. Because “well designed multimedia presentations work best for learners who are low rather than high in prior knowledge about the subject matter” the prior knowledge of students was assessed (Mayer, 2001, p.189).

Two items were given to the students to assess their knowledge of particular features of MS Excel: a packet of papers containing questions (Appendix C) and a related, blank spreadsheet. Students were assessed for prior knowledge through the additive completion of these measures; that is, they were asked if they knew how to perform a particular skill (as was illustrated in the video) and if they answered *yes*, they were asked to explain how they would do so. Ample space was provided for the students to write down their answers to the questions. In addition to the paper-based questionnaire, students were given a blank, electronic spreadsheet that they could reference if they believed they knew how to complete a particular skill but needed the spreadsheet retrieval cue to “jog” their memory. For clarity, consider the sample question provided in Figure 3.5.



Do you feel that you would be able to have Excel automatically change the formatting of cells (without manually changing cell and font colors)?

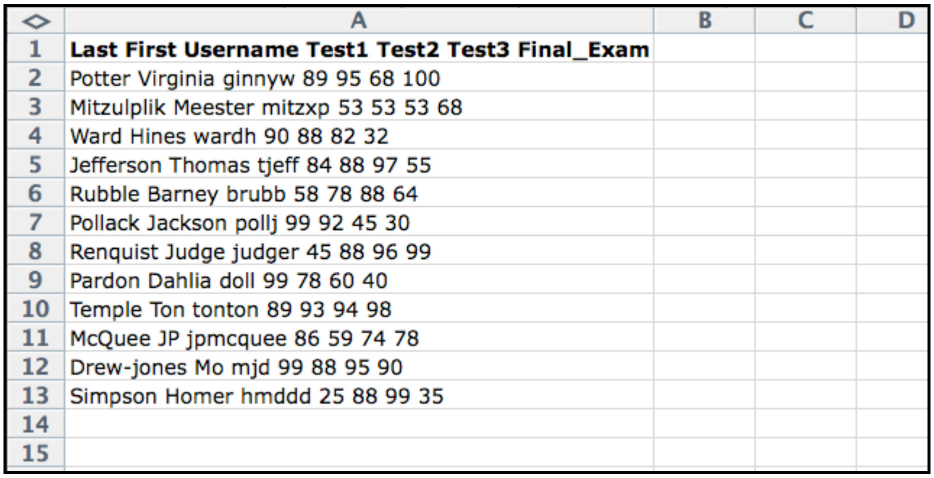
Circle: Yes No

If *Yes*, briefly describe the process you would use (if you need to jog your memory, you can refer to the Formatting1 worksheet in your Excel file):

Figure 3.5. Sample question on the prior knowledge assessment.

Practice spreadsheet and packet. All students were given an electronic spreadsheet with which they were able to practice the skills taught in the video lesson. The spreadsheet contained a separate worksheet for each skill. Also, students received a practice packet (Appendix D), which contained several pages of paper that provided directions as to how to use this spreadsheet during their practice opportunities. The practice spreadsheet was built and copied to all computers by the researcher prior to the intervention. It contained all of the data needed for the students to practice the skills taught during the instruction. Students did not need to enter the data: they only had to manipulate it.

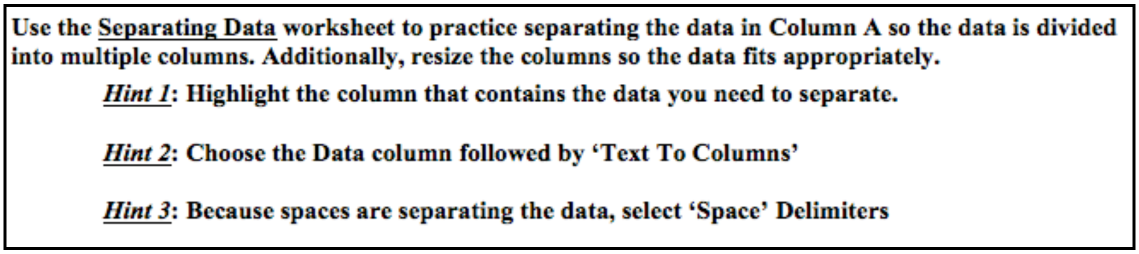
An example of this spreadsheet can be seen in Figure 3.6. In this case, students were asked to practice separating the data found in column A so that they are dispersed into multiple columns (A-G). Again, because the researcher had completed data entry prior to the intervention, students had only to manipulate the data via a menu driven procedure, function, or formula.



◇	A	B	C	D
1	**Last First Username Test1 Test2 Test3 Final_Exam**			
2	Potter Virginia ginnyw 89 95 68 100			
3	Mitzulplik Meester mitzxp 53 53 53 68			
4	Ward Hines wardh 90 88 82 32			
5	Jefferson Thomas tjeff 84 88 97 55			
6	Rubble Barney brubb 58 78 88 64			
7	Pollack Jackson pollj 99 92 45 30			
8	Renquist Judge judger 45 88 96 99			
9	Pardon Dahlia doll 99 78 60 40			
10	Temple Ton tonton 89 93 94 98			
11	McQuee JP jpmcquee 86 59 74 78			
12	Drew-jones Mo mjd 99 88 95 90			
13	Simpson Homer hmddd 25 88 99 35			
14				
15				

Figure 3.6. A screen-captured image of the worksheet used on the first practice question.

Practice packets varied dependent upon experimental condition. Students assigned to the *scaffolded* condition were given a practice packet that contained hints developed to diminish working memory burden and serve as reminders of how to perform the skills that were taught in the instruction. Other students received a practice packet that had *no scaffolds*. All students, irrespective of condition, were given equal time, 60 seconds, to practice. An example of scaffolded practice appears in Figure 3.7, below. The no-scaffolded practice condition simply eliminated the hints.



Use the Separating Data worksheet to practice separating the data in Column A so the data is divided into multiple columns. Additionally, resize the columns so the data fits appropriately.

***Hint 1*: Highlight the column that contains the data you need to separate.**

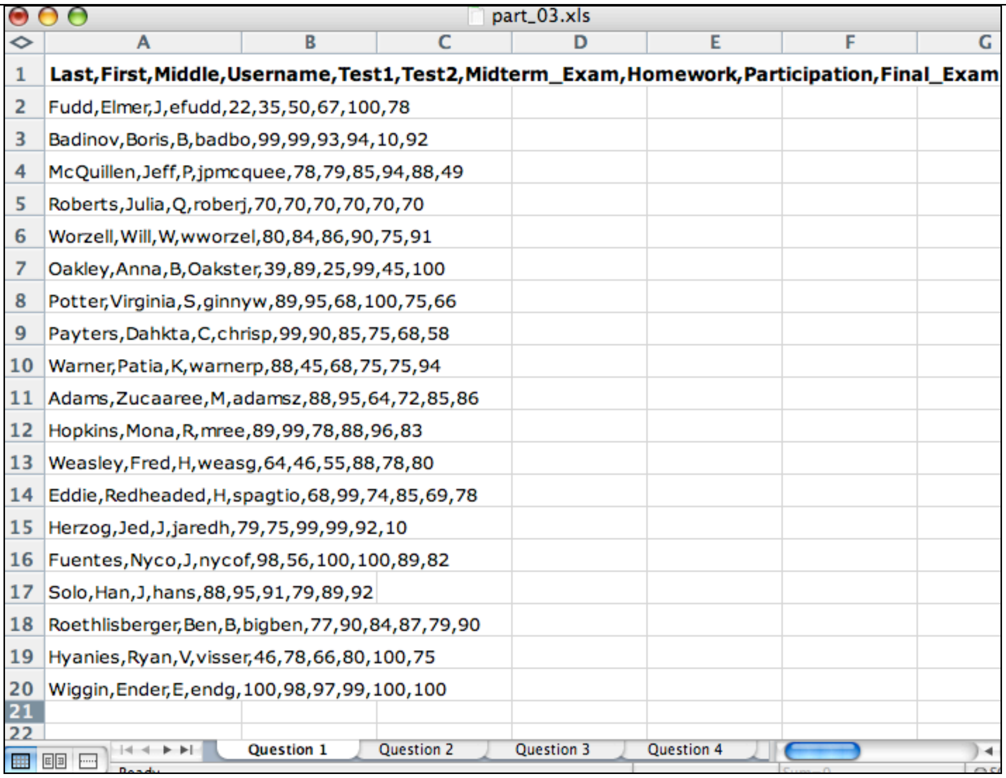
***Hint 2*: Choose the Data column followed by 'Text To Columns'**

***Hint 3*: Because spaces are separating the data, select 'Space' Delimiters**

Figure 3.7. An example of the scaffolds (hints) used in the scaffolded-instruction condition.

Immediate transfer test. An *immediate transfer test* (Appendix E) was designed to assess students' procedural knowledge of the skills taught and practiced during the intervention. Rather than assess their ability to remember and recall the information, the test assessed the students' ability to transfer what they learned and apply it in a new way. Thus, the test measured the first three items (*Remembering, Understanding,* and *Applying*) within Bloom's Revised Taxonomy (Anderson & Krathwohl, 2001). To do this, the test simply presented the student with a novel example for each of the problems from the instruction. Despite the variation between the problem shown in the instruction and the problem students were asked to solve, the skill required to solve each problem remained the same. Students were given a handout containing the test questions, as well as a spreadsheet that contained multiple pre-designed worksheets (one worksheet per question) on which they solved the problems. Students were allowed 60 seconds to answer each question. Figure 3.8 provides a sample test question, as well as a screen-captured image of the spreadsheet on which students worked.

Sample Test Question: Use the worksheet entitled "Question 1" to separate the data within Column A so the data is divided appropriately into multiple columns.



	A
1	**Last,First,Middle,Username,Test1,Test2,Midterm_Exam,Homework,Participation,Final_Exam**
2	Fudd,Elmer,J,efudd,22,35,50,67,100,78
3	Badinov,Boris,B,badbo,99,99,93,94,10,92
4	McQuillen,Jeff,P,jpmcquee,78,79,85,94,88,49
5	Roberts,Julia,Q,roberj,70,70,70,70,70,70
6	Worzell,Will,W,wworzel,80,84,86,90,75,91
7	Oakley,Anna,B,Oakster,39,89,25,99,45,100
8	Potter,Virginia,S,ginnyw,89,95,68,100,75,66
9	Payters,Dahkta,C,chrisp,99,90,85,75,68,58
10	Warner,Patia,K,warnerp,88,45,68,75,75,94
11	Adams,Zucaaree,M,adamsz,88,95,64,72,85,86
12	Hopkins,Mona,R,mree,89,99,78,88,96,83
13	Weasley,Fred,H,weasg,64,46,55,88,78,80
14	Eddie,Redheaded,H,spagtio,68,99,74,85,69,78
15	Herzog,Jed,J,jaredh,79,75,99,99,92,10
16	Fuentes,Nyco,J,nycof,98,56,100,100,89,82
17	Solo,Han,J,hans,88,95,91,79,89,92
18	Roethlisberger,Ben,B,bigben,77,90,84,87,79,90
19	Hyanies,Ryan,V,visser,46,78,66,80,100,75
20	Wiggin,Ender,E,endg,100,98,97,99,100,100
21	
22	

Figure 3.8. A sample test question and screen-captured image of the spreadsheet that students used to answer test questions.

The researcher and an associate professor with expertise in instructional technology developed a grading rubric (Appendix F) to assess the immediate measures. Two individuals graded the immediate transfer test and the inter-rater reliability was clearly acceptable (Cohen's $K = .95$).

Delayed transfer test. A delayed measure (Appendix E) was identical to the immediate test, and it was administered two weeks after the initial instruction. The same individuals who graded the immediate test graded the delayed test, applying the same rubric (Appendix F) used to grade the immediate test. The inter-rater reliability again was clearly acceptable (Cohen's $K = .95$). In order to avoid skewing the results of the delayed test, feedback on their performance on this test was not provided to the students.

Procedure

Session 1. Students were informed of the study and given a letter of consent to sign in a class meeting that preceded the experiment by one week. Because the instruction that students received during the study was a required component to their course, their participation in the instruction was required; however, they were assured that their data would be withheld from data analysis if they chose to not sign the letter of consent. Students were told that their full participation would have no impact on their grade or standing in the course. All students chose to fully participate. Also in this meeting, students completed the *demographic sheet*. The researcher collected and secured these forms.

Session 2. One week after Session 1, students completed the prior knowledge assessment. This assessment included three components: a screen-captured video, a paper-based prior knowledge questionnaire, and a Microsoft Excel spreadsheet. Students viewed a prior knowledge video vignette (described above in the *Prior Knowledge Videos* section) and were then instructed to answer the questions in 45 seconds using their packet (see the *Prior knowledge questionnaire and spreadsheet* section above). Students were also able to use to a pre-existing spreadsheet developed by the researcher, in case students were generally familiar with how to perform the skill in question but were unable to specifically write out the required procedures without referring to a spreadsheet. The process was repeated for each skill.

The prior knowledge assessed on Session 2 addressed 12 skills that could be used within MS Excel. However, only 7 of these skills were demonstrated during the intervention that occurred on Session 3. The rationale for testing prior knowledge for 12 skills, rather than 7, was to prevent a priming effect. That is, the inclusion of red herrings was a precautionary measure to minimize the likelihood of students seeking beforehand to learn the skills in the upcoming experiment. Upon completion of the prior knowledge assessment, the researcher collected and secured all paper and digital files completed or used by the students.

Session 3. Two days after Session 2, students arrived to the computer lab and were randomly given a piece of paper with a number (1-4) designating their group number. Because of seating limitations, the students were divided into two adjacent computer labs based upon shared condition assignment (see Figure 3.9). Instructors spaced the students so they sat in every other seat. Once seated, students were given paper packets of materials relevant to their condition. The packet contained the practice sheet and the immediate transfer measure. Students were asked to not open it until they were instructed to do so.

Section 1: Groups 1 & 3 in lab 213 (Instructor A)
Groups 2 & 4 in lab 211 (Instructor B)
Section 2: Groups 1 & 3 in lab 211 (Instructor B)
Groups 2 & 4 in lab 213 (Instructor A)
Section 3: Groups 1 & 3 in lab 213 (Instructor B)
Groups 2 & 4 in lab 211 (Instructor A)
Section 4: Groups 1 & 3 in lab 211 (Instructor A)
Groups 2 & 4 in lab 213 (Instructor B)

Figure 3.9. Separation of groups for experimental iterations.

Two instructors, one for each lab, led the study for four 50-minute sections. To help counter any environmental influences, the instructors switched labs between iterations of the experiment.

Instructors addressed the class and stated with the use of a script, "*Please do not talk during the remainder of the class period. Once you begin and open your packet, stay on the task that the video is discussing. Do not turn your packets forward or backward during instruction without being told to do so.*"

To access the pre-built Excel spreadsheets, students logged in to the computers and then were asked to locate a folder on their hard drive that had been placed there by the researcher. For identification purposes, students were instructed to change the name of the folder to their university username. Within this folder, there were 2 folders (*part 1* for the practice measure, and *part 2* for the immediate transfer measure). Students were asked to open the spreadsheet entitled “part1.xls” and wait. The instructors then explained the procedure by reading the following script:

“This next part of the class will teach you how to use the various skills needed when building an Excel-based grade book. You will view about 15 minutes worth of video-based instructions and will have opportunities to practice these skills before your retention is assessed. Listen and watch carefully as the videos contain not only skill demonstration, but also provide procedural instructions that you need to follow during the next 45 minutes.

Before you begin, turn to the next page in your packet and ***carefully*** *read the instructions. Some of you may have slightly different instructions, so please read carefully.”* [The instructions differed only in the part pertaining to the practice sheets. The two scaffolded groups were given instructions that contained scaffolds where as the other two, non-scaffolded groups were given instructions that contained no scaffolds].

After allowing sufficient time for students to read instructions, the instructor began the video-based screen capture video. As the video was playing, the instructors walked around the room, made and recorded observations (which were used during the qualitative phase elaborated on in Chapter 4 of this dissertation), and helped students with any technical troubleshooting.

Once the actual instruction was complete, students completed an activity that, unbeknownst to them, served as a cognitive distraction. Students were directed to go to the final worksheet within their spreadsheet, which contained two columns: one labeled “Nouns” and another labeled “Adjectives.” Students then were told, “Over the next several minutes, you will watch a video. Please type in as many nouns and adjectives that you can think of while watching this video." A 5-minute *Youtube* video (Harding, 2006) then was shown in which an adult male was seen dancing a silly jig in roughly 35 different locations around the world. After the distraction, the instructor asked the students to save and then close their files.

The instructor then introduced the next phase of the study by reading aloud the following script: *Now we are going to see how well you learned from the instruction. There will be no video to go along with this test. Rather, use your handout, which provides the questions. You will have 60 seconds to answer each question. Please do not change pages or advance the spreadsheet until you are told to do so.*

For the immediate measure, students were instructed to open a new spreadsheet (part2.xls) previously copied to their desktops. Additionally, they were asked to turn to the appropriate page of their paper packet. The instructor asked the students to begin and upon doing so, played a video displaying a 60 second countdown. The video was a silent countdown except for two announcements that declared when 30 and 15 seconds remained.

Once 60 seconds had elapsed, the instructor asked the students to save their work, advance to the next worksheet, turn to the next page in their handout, and begin the next question. Once all of the questions were completed, the instructors asked the students to save and close their files. The researcher collected and secured all paper and digital documents.

Session 4. Two weeks after the intervention, students were once again brought into the lab and were given the delayed measure. The delayed measure was identical to the immediate measure, and the procedure was identical to the one used during the immediate measure. After students finished the delayed measure, the researcher collected and secured all paper and digital documents.

In the next chapter of this dissertation, I elaborate on the statistical results of this experiment. As you shall see, however, some results were puzzling and could not be explained from a purely quantitative lens. Thus Chapter 4 includes also a description of a follow-up qualitative phase of study in which interview and observational data were collected and analyzed to explain the experimental results more fully.

CHAPTER 4

RESULTS

Prior Knowledge

In order to ensure that students' prior knowledge did not skew the results of the immediate and delayed measures, students' familiarity with each of the seven skills were assessed and analyzed. Results showed that many of the students were already capable of performing the *Weighted Grades* skill (skill #3) prior to the treatments. In fact, nearly 40% of all students first reported knowing how to perform this skill, and then they consistently executed the skill. This percentage was considerably higher than the other individual skills. Student knowledge of the *Separating Data* skill (skill #1), for example, was much lower, with only 3.8% of the students reporting knowing how to perform the skill. Withholding the scores for the *Weighted Grades* skill, 6.5% of the students reported having valid knowledge of the remaining six skills. Thus, the *Weighted Grades* skill has been eliminated from the tables and statistical comparisons below.

Scaffolded Instruction Hypothesis (Immediate Measure)

A series of one-way multivariate analyses of variance (MANOVAs) was conducted to test the hypotheses. The first MANOVA pertained to scaffolded instruction, which hypothesizes that students who receive scaffolded instruction during a screen-captured video lesson would perform better on immediate tests of learning transfer than students who do not receive scaffolded instruction. The immediate test was examined first.

The condition, scaffolded or non-scaffolded, was used as the independent variable and each of the 6 immediate test questions were the dependent variables. No main effect was observed, F(6, 101) = 1.38, p = 0.23. Table 4.1 presents the means and standard deviations for each skill and to provide a broader understanding, Table 4.2 presents the means and standard deviations of the total score of the immediate test. Although the scaffolded group mean score was higher, as hypothesized, the presence or absence of scaffolds during the lesson did not significantly influence student learning.

Table 4.1

Descriptive Statistics for Immediate Test Questions for the Non-Scaffolded v. Scaffolded Groups

	Non-Scaffolded		Scaffolded	
	M	*SD*	*M*	*SD*
Immediate test question 1	1.30	1.45	1.81	1.44
Immediate test question 2	1.91	1.03	1.88	1.00
Immediate test question 4	1.59	1.35	1.75	1.34
Immediate test question 5	1.41	1.44	1.50	1.48
Immediate test question 6	1.73	1.41	1.62	1.40
Immediate test question 7	1.05	1.24	1.46	1.41

Note. Skill 3 (test question 3) was not included in this or the tables that follow for reasons of prior knowledge. The minimum score = 0 and the maximum score = 3.

Table 4.2

Descriptive Statistics for the Total Immediate Test Scores for the Non-Scaffolded v. Scaffolded Groups

	M	*SD*
Non-Scaffolded	9.00	5.93
Scaffolded	10.02	5.83

Segmented Instruction Hypothesis (Immediate Measure)

A MANOVA was conducted to determine the effect of segmented v. non-segmented instruction on the dependent variables, the six questions on the immediate test. A significant main effect was observed, Wilks's $\Lambda = 0.86$, $F(6, 101) = 2.85$, $p < .05$, indicating that the null hypothesis can be rejected. The relationship between the type of instruction students received and performances on the dependent variables was strong (Green & Salkind, 2004), accounting for 15% of the observed variance in scores ($\eta^2 = .15$). As hypothesized, the segmented group performed better than the non-segmented group. Table 4.3 presents the means and standard deviations for each skill and to provide a broader understanding, Table 4.4 presents the means and standard deviations of the total score of the immediate test.

Table 4.3

Descriptive Statistics for Immediate Test Questions for the Non-Segmented v. Segmented Groups

	Non-Segmented		Segmented	
	M	*SD*	*M*	*SD*
Immediate test question 1	1.30	1.46	1.80	1.43
Immediate test question 2	1.94	0.98	1.85	1.05
Immediate test question 4	1.43	1.37	1.91	1.28
Immediate test question 5	1.26	1.43	1.65	1.46
Immediate test question 6	1.72	1.41	1.63	1.40
Immediate test question 7	0.93	1.26	1.57	1.34

Table 4.4

Descriptive Statistics for the Total Immediate Test Scores for Non-Segmented v. Segmented Groups

	M	*SD*
Non-Segmented	8.57	5.52
Segmented	10.41	6.13

Because the MANOVA was significant, an analysis of variance (ANOVA) was performed on each dependent variable (individual skill performances). Among these, one significant effect was observed for immediate test question 7, *Grade Distributions,* $\underline{F}(1, 106) = 6.72$, $\underline{p} < .05$, $\eta^2 = .06$. Students in the segmented group ($\underline{M} = 1.57$/ $\underline{SD} = 1.34$) outperformed their counterparts in the non-segmented group ($\underline{M} = 0.93$/ $\underline{SD} = 1.26$). See Table 4.3 for the means and standard deviations.

Although the ANOVA reported in the previous paragraph was the only statistically significant test, results of two ANOVAs were in the hypothesized direction and likely contributed to the significant MANOVA result. Students in the segmented condition ($\underline{M} = 1.8$/ $\underline{SD} = 1.43$) seemingly outperformed their counterparts in the non-segmented condition ($\underline{M} = 1.3$/ $\underline{SD} = 1.46$) for test question 1, *Separating Data*, $\underline{F}(1, 106) = 3.22$, $\underline{p} = .075$. Question 4, *Letter Grades*, was found to have a similar result, $\underline{F}(1, 106) = 3.57$, $\underline{p} = .061$, with the segmented group ($\underline{M} = 1.91$/ $\underline{SD} = 1.28$) seemingly outperforming the non-segmented group ($\underline{M} = 1.43$/ $\underline{SD} = 1.37$). In short, although only one ANOVA was of statistical significance, results of two other ANOVAs were in the hypothesized direction, possibly contributing to the main effect observed in the MANOVA.

Interaction Hypothesis (Immediate Measure)

A multivariate analysis of variance (MANOVA) was conducted to determine the effect of the interaction on the dependent variables, the seven questions on the immediate test. The test indicated no significant interaction effect, Wilks's $\Lambda = .76$, $\underline{F}(18, 281) = 1.57$, $\underline{p} = .068$. Thus, the interaction hypothesis was not confirmed. Table 4.5 presents the means and standard deviations for each skill and to provide a broader understanding and Table 4.6 presents the means and standard deviations of the total score of the immediate test.

Table 4.5

Descriptive Statistics for Immediate Test Questions for all Groups

	Non-Segmented Non-Scaffolded		Non-Segmented Scaffolded		Segmented Non-Scaffolded		Segmented Scaffolded	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Immediate test question 1	1.14	1.43	1.46	1.50	1.46	1.48	2.15	1.32
Immediate test question 2	1.93	1.09	1.96	0.87	1.89	0.99	1.81	1.13
Immediate test question 4	1.32	1.36	1.54	1.39	1.86	1.30	1.96	1.28
Immediate test question 5	1.21	1.40	1.31	1.49	1.61	1.47	1.69	1.46
Immediate test question 6	1.89	1.37	1.54	1.45	1.57	1.45	1.69	1.38
Immediate test question 7	0.68	1.06	1.19	1.41	1.43	1.32	1.73	1.37

Table 4.6

Descriptive Statistics for the Total Immediate Test Scores for all Groups

	M	*SD*
Non-Segmented Non-Scaffolded	8.18	5.36
Non-Segmented Scaffolded	9.00	5.77
Segmented Non-Scaffolded	9.82	6.45
Segmented Scaffolded	11.03	5.82

Delayed Transfer Measures

A series of MANOVAs was conducted to test the three hypotheses with regards to the delayed measure. There was no main effect for the scaffolded hypothesis, F(6, 96) = 0.31, p = 0.93, the segmenting hypothesis, F(6, 96) = .513, p = .798, or the interaction hypothesis, F(18, 266) = .520, p = .948. Tables 4.7, 4.8, and 4.9 show respectively the means and standard deviations for the total score of the delayed measure by instructional group. All scores, irrespective of condition, were quite low.

Table 4.7

Descriptive Statistics for the Total Delayed Test Scores for the Non-Scaffolded v. Scaffolded Groups

	M	*SD*
Non-Scaffolded	4.37	4.56
Scaffolded	4.94	4.00

Table 4.8

Descriptive Statistics for the Total Delayed Test Scores for the Non-Segmented v. Segmented Groups

	M	*SD*
Non-Segmented	4.63	4.32
Segmented	4.67	4.29

Table 4.9

Descriptive Statistics for the Total Delayed Test Scores for all Groups

	M	*SD*
Non-Segmented Non-Scaffolded	4.58	4.88
Non-Segmented Scaffolded	4.68	3.74
Segmented Non-Scaffolded	4.15	4.31
Segmented Scaffolded	5.19	4.29

Brief Discussion of Quantitative Results

Recall the three proposed hypotheses previously discussed: the scaffolded instruction hypothesis, the segmented instruction hypothesis, and, the interaction hypothesis. Results demonstrated that on the immediate and delayed measures for learning, no statistical support was found for the scaffolded instruction hypothesis. Groups performed similarly whether they received scaffolded instruction or not. Likewise, no significant findings were found for the interaction hypothesis. Irrespective of instructional condition, groups performed in similar fashion.

Support was found for the segmented instruction hypothesis but only on the immediate measure. Students who received segmented instruction performed significantly better than those who received all of the instruction at once. Presumably, the segmented instruction condition may have alleviated some working memory burden at first. However, no significant findings were found for the segmented instruction hypothesis with regards to the delayed transfer measure.

It is worth mentioning that all of the aforementioned MANOVAs were not only conducted as previously discussed, they were also conducted with various covariates from student demographics. However, there were no significant findings. Gender, race, major and age did not significantly influence the conditions in either the short-term or the long-term.

In short, although the experiment yielded some short-term learning effects, those effects were no present on the delayed measure, which was designed to assess how well students could recall and transfer the information taught in the initial instruction. Clearly, students were unable to produce the desired results of long-term retention and transfer, and the obvious question is, *why not*? Because the quantitative results do no offer reasons for the lack of long-term learning, a qualitative follow-up was needed to answer the question, *what factors contributed to this lack of long-term transfer of knowledge*?

Qualitative Follow-up

Need for Qualitative Follow-up

In this explanatory mixed-methods study (Creswell & Plano-Clark, 2006), a qualitative phase of investigation was used to further explain the experimental results. On occasion when quantitative data are “inadequate by themselves,” qualitative data can be collected to “explain or build on initial quantitative results” (Creswell and Plano-Clark, 2006, p. 96). In this study, I collected observations and conducted interviews in an effort to provide more understanding than the quantitative data can offer.

Data Collection

Observations. During instruction and assessments, I made and recorded observations of the students. In addition to the primary researcher, the instructor who led the study in the second lab was asked also to note observations. These observations were used in conjunction with meaningful data collected from student interviews in order to create a “composite summary” (Shank, 2006) that is discussed later in this dissertation.

Interviews. During the week that followed the delayed measure, an email was sent out to participating students requesting their voluntary participation in brief interviews. Interviews were conducted on a first come, first serve basis, and although many students volunteered their time, only the 12 of the first 15 students were interviewed. In order to have an equal number of students representing all conditions, I had to turn down three students who volunteered their time.

The 12 students who were interviewed participated in semi-structured interviews addressing their perceptions related to the conditions in which they were placed, the screen-captured video instruction that they received and each of the assessments. During the interviews, each student was given his or her paper packets for reference. Also, students were able to view the immediate and delayed spreadsheets on which they worked. The students were asked several questions prompting them to discuss their thoughts with respect to screen-captured video, the experiment, the condition in which they were placed, and their performances on immediate and delayed transfer measures and were prompted to elaborate on or clarify their answers when needed. Interviews lasted 10 – 15 minutes, were recorded on a digital audio recorder, and were transcribed via a word processor.

Data Analysis and Results

Analytic Procedure. I analyzed the interview data according to a five-step phenomenological technique adapted from Groenewald (2004) and Moustakas (1994). First, a *phenomenological reduction* was performed in which I listened to the interviews three times. The primary purpose of this reduction was simply to help me gain a "holistic sense" (Shank, 2006) of the data. The data were neither coded nor sorted; the audio recordings were simply listened to in order to better understand the nature of the data, as a whole.

In the second step of data analysis, I read transcripts of the interview data and identified *meaning units*, the first level of coding. I performed this step by extracting all significant phrases from the raw interview data. Inspecting these statements, I grouped repetitive ideas into groups relevant to the phenomena of interest, in this case screen capture video instruction and immediate and delayed test performance. For example, when asked about his poor performance on the delayed test, a student simply stated, "I didn't remember any of that stuff." After being probed to elaborate, he responded with the significant statement, "there was no…repetitive practice…so I forgot everything…anything that I did know, the little that I did know, was gone two weeks later.” In another significant statement, a student explained her weak performance: “It probably would have been different if I was practicing every day or once or twice a week.” These two statements were representative of seven others, which I grouped together in order to create a meaning unit labeled ‘lack of practice opportunities subsequent to instruction.’ I created several more meaning units including ‘lack of control’ (which contained eight statements concerning the inability to pause or rewind the video instruction) and ‘information overload’ (containing eight statements addressing the difficulty in trying to learn a lot of new things in one sitting).

In the third step in the data analysis, I coded the meaning units into *meaning clusters*. Through a comparison and examination of the meaning units, relationships among certain meaning units emerged. Thus, I coded the subordinate meaning units into superordinate meaning clusters, leading to the emergence of potential explanatory themes. As an example, the meaning units ‘information overload’ and ‘new learning’ were categorized into a superordinate cluster labeled *Overwhelming novel information*. I identified three other superordinate meaning clusters: *Experimentally induced constraints to learning*, *Lack of generative thinking*, and *Students’ perceived benefits of screen-captured video*.

After identifying these four clusters, I compared the major themes to the original data, the fourth step of data analysis. I made this comparison in an effort to verify that the fundamental nature of the interview had been properly ascertained (Groenewald, 2004). I examined the student statements according to their experimental condition. Condition was not found to be a determining factor in what the students had to say. Students who received scaffolds and segments were just as likely to discuss the overwhelming nature of the material and the instruction as the students who received one or none of the aids. Additionally, I found no meaningful statements that were contrary to the major themes, suggesting that there were no inconsistencies between the raw data and the major themes formulated during the first three phases in this phenomenological reduction. Still, in an effort to further establish trustworthiness of these qualitative findings, I asked the chair of this dissertation to perform an external audit. An expert in qualitative data analysis, he reviewed the raw data and related to me that the themes were reasonable and seemed to fit with the message intended in the interview data. Further, he offered advice in changing some of the labels I initially assigned to some of the major themes and subthemes. These are reflected in Figure 4.1, a spatial display of the outcome of the first four steps of this analysis, where the main headings refer to meaning clusters (or major themes), the next level of headings refer to subordinate meaning units (or subthemes), and the remaining lists of significant statements were identified from the raw interview data. Seventy-three significant statements led to 12 subthemes, which, in turn were clustered into four major themes.

OVERWHELMING NOVEL INFORMATION

Information Overload

very overwhelming

so many new things

too many new techniques at one time

I can't remember all of the steps and then I get overwhelmed

I couldn't remember all of the parts [formulas]

it [instruction] was too much

I remembered like maybe the first little part and I was like umm I don't know where to go from here

it was way too much and it was so fast paced that I just felt like I wasn't going to do well anyway so I just stopped trying

Difficulty Learning New Formulas/Functions

it was really hard to remember formulas

I had never worked with those formulas before and by the time they finished saying it, I didn't know what they were saying

I didn't do as well on it with the functions, it was something I didn't already know

hard because I had never worked with those formulas before

EXPERIMENTALLY INDUCED CONSTRAINTS TO LEARNING

Unrealistic Instructional Pacing

it got to a point where I would remember the first thing after you said it on the video how to do it and then it would get to the second thing, it was like, uhh, I don't remember how he did that and then after you didn't remember the one thing then you were messed up for the rest of them so it got to the point where I couldn't even do the rest of them

it was way too much and it was so fast paced that I just felt like I wasn't going to do well anyway so I just stopped trying

went really fast

I didn't have time to memorize

also, there wasn't enough time

> we were kinda crunched for time. I just started doing what I remembered and then if I got stuck I would look at it…I would go to it only if I needed it
>
> too fast
>
> overall it was too fast
>
> by the time they finished saying it, I didn't know what they were saying
>
> on two of them, I just didn't have time to finish them, like, I remembered how to do them, I just have time to finish them

One-Off Instruction (instruction was only shown/seen one time)

> it would have been easier if the movie showed it more than once
>
> if I could have just watched each technique one more time I would have done a lot better
>
> it was only instructed once and I'm more of a I have to do it kinda everyday or more often.
>
> I didn't do well [on delayed] because it was hard to remember everything because we only saw it once

Lack Of Control

> it would have been better if it could have been rewound
>
> if you could rewind it, it would have been sufficient
>
> if we were able to pause and rewind, it would be beneficial, I could go at my own pace
>
> as long as you can pause it/rewind it so each student can go at their own speed it would be good
>
> [Rather have the text than video] because weren't able to pause or rewind
>
> didn't like it because I couldn't ask questions or rewind or pause it
>
> I like the written instructions better because it is easy to reread if you, like, don't understand it, ya know, the first time
>
> I would have like to pause it in order to work on it right then

LACK OF GENERATIVE THINKING

Shallow Thinking

> there was like no connection made cause a lot of it wasn’t familiar to begin with so it was just like I was just watching something and nothing was happening in my head
>
> part of why I did well on the things I didn’t already know was that I repeated over and over, in my head how to do the skill [immediate]
>
> I just tried to remember where the mouse went…didn’t care about understanding why

No Or Inaccessible Schema

> I remembered how to do everything [on the immediate measure] and on the [delayed] – I didn’t remember
>
> [delayed] I didn’t remember any of that stuff
>
> [delayed] that was after a while [2 weeks] so I didn’t remember it I guess
>
> it never got into my long term memory
>
> I did better on the first test because I could remember most of it.
>
> I never committed it to long term memory

Lack Of Practice Opportunities Subsequent To Instruction

> I didn’t remember anything because lack of practice
>
> probably needed more practice problems to really get into it
>
> would have been able to do better if had practice throughout the 2 weeks b/w instruction and delayed
>
> it probably would have been different if I was practicing every day or once or twice a week
>
> [poor performance on delayed] because I hadn’t done it in a while
>
> it was hard enough to remember the things right after you said how to do them [initial instruction] but at least I could remember parts of them but then two weeks later there was no, you know, repetitive practice on it so I forgot everything, I mean, anything that I did know, the little that I did know, was gone two weeks later
>
> not practicing hurt
>
> I did poor because 2 weeks is a long time especially because I, like,

didn’t master it the first time

not enough practice

I didn’t do as well on [the skills] with the functions, it was something I didn’t already know and didn’t practice it

it was a lot and on the second test I couldn’t remember

STUDENTS’ PERCEIVED BENEFITS OF SCREEN-CAPTURED VIDEO

Personalized Narration

it’s kind of less intimidating because, you know, it’s a real person explaining it

I could see how some people would like hearing a real voice versus something automated or something written

it felt more personal, like it gave me more help than written instructions

it [having a voice] helps; it kinda put me at ease

Search Reduction

it’s [screen cap] a little bit easier [than text-based instruction] because it kind of eliminates, that, like, gap, you know, between reading and then going to look at it

I had troubles with previous text-based instruction because I got lost between reading and doing

[instructions] are more clear when you can actually see what you need to be doing instead of just reading because you can interpret it differently

because it didn’t just say oh ‘go to the tools menu’, like, it showed you where the tools menu was; cause you’d waste time trying to find where that was

Sights and Sounds

it’s like putting it in your mind in two different ways

I like it, I think it’s helpful because you’re hearing it and seeing it at the same time

I think it works more with your senses, you know, the different learning styles. You have visual and you also have the audio

A Visual Preference To Learning

> I thought it [screen cap] was neat. It helped like just being able to see what you were doing as you were explaining it so it was very easy to understand
>
> I liked it because it was step by step and it wasn’t just all written; I mean, I saw it happening. You know if I forgot what, like, it was called, I knew it was under ‘File’ cause I could see it, ya know? Visual.
>
> when you do this action, that’s what it’s going to look like on your screen
>
> I like it because I’m a real, like, visual learner. I like to see things done and so, that kind of gave me, instead of you saying go to this button then do this, like, I saw you do it so it was easier to just remember ‘oh I just go to this button and it’s right here. You know, you don’t have to look for it and orient yourself with it cause it’s explained to you where it is
>
> I liked being able to see the mouse moving around
>
> I’m visual
>
> I really liked the screen capture and how I could see everything happening on the screen.
>
> I never saw it [screen cap] before but it made it very clear. It helped me because I was able to visualize the process

Figure 4.1. A spatial representation of the meaning clusters, meaning units and significant statements that resulted from the qualitative analysis.

In the fifth and final step of data analysis, the researcher constructed a “composite summary” (Shank, 2006) of the qualitative data using the themes found in the first four steps of the analysis. In mixed-methods fashion, findings from the quantitative phase of the study were mixed with the qualitative composite summary in order to create a rich explanation of the study’s findings. This summary now is presented in the last chapter of this dissertation.

CHAPTER 5

DISCUSSION

This final chapter presents a culminating discussion of the present mixed-methods, dissertation study. First, I present a composite summary of the overall results from the study, where the results of the experiment are mixed with those of the qualitative phase, as well as previous research and learning theory. Next is an in-depth discussion of this data mixing, which attempts to present a rich explanation of the findings. Finally, I present the theoretical, educational, and research implications of this study, before elaborating on the study's limitations.

Composite Summary

Results from the delayed test of transfer in the quantitative phase of this study indicated that students performed poorly, especially when compared to the results of the immediate test. The goal of the qualitative phase of this experiment was to explain the lack of desired long-term learning effects. Based on the triangulation of the quantitative results of this study's experiment, the findings from the qualitative interviews, and the research within Cognitive Load Theory, I briefly discuss the short-term learning effects and then present three explanations for the much lower levels of long-term transfer among the experimental, instructional groups.

The experimental results, in brief, demonstrated that the variations in instructional design tested in the experiment affected only short-term learning. Although positive long-term learning gains have been associated with completion problems in other research (see e.g., van Merriënboer & Sweller, 2005), this study failed to replicate those findings.

There was no evidence that the scaffolds, either alone or in presence of segmented instruction, were significant contributors to short-term learning. The qualitative data then suggested that the students did not effectively utilize the scaffolds, offering one explanation for the lack of a short-term scaffolding effect.

As opposed to scaffolding, segmenting the video-based instruction into smaller pieces was significantly associated with short-term transfer effects. Presumably, based on CLT, the segmentation of instruction reduced the extraneous load placed on students' working memory, thus boosting learning. These results replicate the support for segmenting found in other research (see e.g., Hasler et al., 2007; Mayer and Chandler, 2001; Moreno, 2007). Although short-term learning is desirable, of more importance and interest is long-term learning, the ultimate goal of instruction. I now present three, triangulated explanations for the consistently low levels of long-term transfer.

First, recall that intrinsic cognitive load refers to the burden placed on working memory by the inherent difficulty of a particular task (Sweller et al., 1998). The difficulty of the information being addressed depends on the number of interacting informational elements being processed simultaneously; a high number of interacting elements will result in more intrinsic load than a low number of elements. In this case, students attempted to learn seven skills within Microsoft Excel®, each of which contained several steps. One explanation for this study's lack of long-term transfer effects, then, is that there simply was too much information presented in the instruction—too high an intrinsic load for students to learn efficiently. As you shall see in the more elaborate discussion in the following section, this theoretical explanation is supported by a robust qualitative theme that emerged from participant interviews, where students described an overwhelming amount of information present in the screen-captured video.

Another reason for the lack of long-term effects might be a high level of extraneous cognitive load, the unnecessary load placed on working memory by ineffective instruction (Sweller et al., 1998). The instruction in this study may have imposed too much extraneous load despite measured attempts to minimize it through the use of scaffolded and segmented instruction. Again, a qualitative theme from the interviews suggests that that a high level of extraneous load may have been inadvertently imposed by the experimental conditions, possibly contributing to the lack of desired long-term transfer.

A last explanation for the lack of long-term learning effects is that insufficient germane cognitive load was imposed by the instruction. Germane load is the burden placed on the working memory when a learner actively constructs or manipulates schema by attaching new information to their prior knowledge (Sweller et al., 1998). Schema construction is desirable and necessary for meaningful learning to occur; therefore effective instruction should encourage germane load and students must also be willing and able to engage in this cognitive process if meaningful learning is to occur. It is possible, according to another theme from the qualitative phase of study, that neither scenario was realized: the instruction may not have sufficiently promoted germane load, or the students may have been unwilling or unable to engage in any opportunities for germane load that did exist. Either scenario can be attributed to the lack of long-term learning effects observed in this study.

In the next section, I will briefly discuss the short-term learning effects and their relation to the qualitative data and CLT research before elaborating on the three explanations for the lack of long-term learning effects.

Short-Term Learning Effects

Scaffolded Instruction Hypothesis. Results of the immediate measure of learning revealed no support for the scaffolded hypothesis; the performance of students receiving scaffolds in their instruction did not significantly differ from those who did not. The scaffolds, or hints, as they were referred to in the materials and practice opportunities, were designed to serve as a bridge between what they learned via the video lesson and what they were asked to practice (using their spreadsheet). The scaffolded practice questions acted as completion problems in which partial solutions to the problems (performing the skills) were provided.

One explanation of why the scaffolds did not have a significant influence might be because the students did not effectively use them, as indicated by the qualitative subtheme, *haphazard use of scaffolds*. There were six significant statements that suggested the students did not take full advantage of the scaffolds. For example, one student explained that she used "some of them for the ones [questions] with the harder skills…the formulas," whereas another student used scaffolds for the "two that were kind of complicated."

A qualitative subtheme that might explain this haphazard use is *Unrealistic Instructional Pacing*. Due to the experiment's time constraints, the duration for each practice opportunity was only 60 seconds, which according to one student, "wasn't enough time." Said another student referring directly to his use of scaffolds, because "We were kinda crunched for time. I just started doing what I remembered and then if I got stuck I would look at [the scaffold]…I would go to [the scaffold] only if I needed it."

Segmented instruction hypothesis. The positive effects for segmentation found in this study extend the already robust segmentation effect documented in CTML literature. This is the first time the effect was found to be applicable to screen-captured video. Also, the effect was found in a lesson that conveyed procedural knowledge versus conceptual kinds of knowledge used in other research (e.g. how lightning forms). Lastly, the effect was found under conditions absent student control (i.e., they were unable to pause or rewind the instruction).

Results demonstrated that only one (out of seven) question had statistical significance (question 7). Two others (questions 1 and 4) were in the hypothesized direction and quite possibly contributed to the positive main effect. Interestingly, questions 4 and 7 each required the use of spreadsheet-specific functions (*countif* and *lookup*, respectively). Function-driven skills contain many sub-skills that are necessary to effectively implement the functions as opposed to menu-driven skills, which require fewer sub-skills. Most certainly, the number of interacting elements when learning a function is higher than the number interacting within menu-driven skills. By definition then, spreadsheet functions place a higher level of intrinsic load upon the working memory than do menu-driven procedures. There is a caveat, however. Prior knowledge of these function-driven skills would greatly reduce the level of intrinsic load. Therefore, I examined the students' prior knowledge of the aforementioned three questions and found that for these skills, they had the smallest amount of prior knowledge. In other words, the skills that were most affected by the segmented instruction were also the ones that students were least able how to perform before the instruction. Thus, it may be concluded that the segmented instruction effects were most profound for the skills that were least familiar to students.

Interaction hypothesis. Performances on the immediate transfer test were consistent, albeit non-significant, with the interaction prediction. The group with the highest average score was the one that received both aids, scaffolded practice and segmented instruction. The group that followed was that which received segmented instruction with no scaffolds, followed by the group that received non-segmented instruction with scaffolds. The group with the lowest average score was that which received neither aid (see table 5.1). However, despite the results being aligned in the hypothesized direction, no statistical significance was found. The primary explanation for this is that the positive effects of the segmented instruction simply were not enhanced by the presence of scaffolds.

Long-term Learning Effects

Whereas an immediate test of learning transfer suggested that the effectiveness of the four instructional designs varied, the delayed measure of transfer indicated that any initial differences were fleeting. On average, student scores declined 51% during the two weeks between the immediate and delayed measure (Table 5.1).

Table 5.1

Mean Total Scores for Immediate and Delayed Measures and Drop-off percentages for Each Condition

	Immediate	*Delayed*	*Drop off %*
Non-Segmented Non-Scaffolded	8.18	4.58	44%
Non-Segmented Scaffolded	9.00	4.68	48%
Segmented Non-Scaffolded	9.82	4.15	58%
Segmented Scaffolded	11.03	5.19	53%
Avg	9.51	4.65	51%

What follows are three explanations for the consistently low levels of long-term transfer observed in the results of the delayed measure of learning: intrinsic load, extraneous load, and germane load.

Intrinsic Load. Learning new material can be difficult. If the material itself is inherently difficult, a high level of intrinsic load can occupy the resources within working memory, thus impeding the cognitive processing needed for meaningful learning (Sweller et al., 1998). How may the material presented in this study have impacted student learning? One possibility is that too much content may have been presented. Much of the CTML research by Mayer and his colleagues used short animated clips designed to instruct some type of conceptual knowledge (e.g. lightning formation). This study used a different approach, one suggested by other research calling for fewer short laboratory experiments and more realistic classroom-based experiments in attempts to generalize the research of Mayer et al. As a result, I presented a greater amount of information over a longer period of time, more analogous to a classroom lesson. Perhaps there was too much information presented in the lesson.

Qualitative data support this notion, as students, irrespective of condition, made similar statements in post-experiment interviews concerning the inordinate amount of material that was taught. “Very overwhelming”, “It was too much,” and “I can’t remember all of the steps and then I get overwhelmed,” are representative of statements made by the students that were classified under the subtheme *Information Overload*. If the material itself overloads the working memory, there is little chance for long-term learning. Pieces, but not all, of information may be recalled by the students, which is reflected in this statement, “I remembered like maybe the first little part and I was like umm I don’t know where to go from here.” Incomplete learning was also observed in the grading process for both the immediate and delayed measures. For example, instead of using the proper *countif* function, several students typed *countit*, thereby indicating possible reconstruction error.

The *countif* function caused particular trouble to the students, as did the *lookup* function. Students referred to these difficult skills as being obstacles. One student stated, “I had never worked with those formulas before and by the time [the narrator] finished…I didn’t know what [he was] saying.” Another, in comparison to some of the other skills from the videos, said, “I didn’t do as well on [the skills] with the functions, it was something I didn’t already know.” Each of these statements fell under the subtheme *Difficulty Learning New Formulas/Functions*.

Similar to other research testing more realistic classroom conditions, the longer period of time and instructional content in this study may have diminished any long-term effects that were originally observed in short-term learning. As more time is spent and more instruction is delivered, these short-term effects “may lose their influence as more time-related factors become dominant in the learning process, such as concentration and span of attention” (Tabbers, Martens & van Merriënboer, 2004, p. 79-80).

Clearly, then, according to the experimental results, the qualitative data, and the supporting CLT research, the intrinsic load placed on the working memory by the content was substantial and likely contributed to the lack of long-term learning effects found in this study. In addition to the high level of intrinsic cognitive load, another possible contributor to the lack of long-term learning effects is the high level of extraneous cognitive load.

Extraneous Load. I based the instructional design of this study on researched techniques that consistently have been shown to reduce extraneous load. I took careful and measured actions to minimize extraneous load by integrating scaffolded practice and segmentation into the instruction. Between these aforementioned efforts and screen-captured video’s innate ability to reduce split-attention and provide cognitive benefits through signaling and the modality effect, the level of extraneous load should have been greatly minimized. However, despite the intent of this study to reduce extraneous load caused by the design of a screen-captured video lesson, some complications arose. Due to the time constraints of the experiment, and the very nature of experimental control, students were subjected to extraneous load I neglected to foresee.

Instances of this extraneous load caused by the experiment were identified in the qualitative data analysis and were categorized under the meaning cluster labeled *Experimentally Induced Constraints To Learning*. One of the subthemes under that cluster, *Unrealistic Instructional Pacing*, contained many significant statements made by the students, irrespective of experimental condition, including, "overall, it was too fast" and "there wasn't enough time." Not only does an impractical instructional pace restrict schema development, it can negatively affect motivation as indicated by this statement: "It was way too much and it was so fast paced that I just felt like I wasn't going to do well anyway so I just stopped trying." Unfortunately, the time in which this experiment was to be conducted was limited to 50 minutes necessitating the need for instructional alacrity.

Also resulting from experimental and time constraints was the subtheme *One-Off Instruction*—the instruction was shown and viewed only once. Students in a non-experimental setting may have had the ability to access the instruction more than one time, but due to the constraints, they were not given this option. Students noticed and reported this as being a factor for their inability to learn the material. For example, one student said, "If I could have just watched each technique one more time I would have done a lot better." Here, another student explained his poor performance on the delayed test, “I didn’t do well because it was hard to remember everything because we only saw it once.”

Finally, several student statements composed the subtheme *Lack of Control*. Whether referencing their inability to pause or rewind, students expressed their desires to have had some form of control of the instruction. One student stated, “If we were able to pause and rewind, it would be beneficial, I could go at my own pace,” and another reported, “I would have like to pause it in order to work on it right then.” However, there simply was not enough time to give students the ability to rewind and replay a portion, or several portions of the instruction. The experiment could not have been conducted within the time allotment.

Clearly, the unrealistic pace induced by experimental control may have contributed an amount of extraneous load in this study, especially considering that intrinsic and extraneous loads are additive. When combined, it is possible that high levels of intrinsic and extraneous loads can consume much, if not all of the working memory resources, leaving little, if any space for germane load.

Germane Load. The lack of positive, long-term effects observed in the results of this study’s experiment clearly indicates that the students did not engage in germane load activities. One possibility for this is that the intrinsic load caused by the spreadsheet material taught in the lesson, when combined with any extraneous load caused by experimental constraints may have reduced, if not eliminated, any opportunity to engage in constructive mental processes. Therefore, meaningful, long-term learning effects would be minimal at most, as was supported by the experimental results.

Qualitative findings further substantiated the lack of germane load. For example, one student commented on her poor performance on the delayed measure by stating, “I remembered how to do everything [on the immediate measure] and on the [delayed], I didn’t remember.” Another summed up his experience quite simply: “I never committed it to long term memory.” Because cognitive loads of any type cannot be empirically measured, it is impossible to conclusively state that the combined levels of intrinsic and extraneous loads overloaded the working memory, leaving little, if any, room for germane load. However, given previous research and the findings in this study, it is a plausible explanation.

Another explanation contradicts the preceding explanation, but a compelling case can be made that the combined levels of intrinsic and extraneous load did *not* exceed the limits of the working memory and there *was* enough room for germane load. However, the students may simply not have taken advantage of these opportunities to construct new schema. Perhaps they did not know how to effectively learn this material, or perhaps they were not motivated.

In new-learning situations, students often apply their default learning strategies. Generally, these default strategies are not constructive, and they can even be detrimental to learning (Kiewra, & Dubois, 1998). Whether applying note-taking strategies (Igo, Riccomini, Bruning, & Pope, 2006) or strategies for learning vocabulary (Crutcher & Ericsson, 2000; Visser & Igo, 2009), these default strategies are largely ineffective. It might be, then, that students applied default processing strategies not conducive to learning during the screen-captured video lesson.

This notion, too, was supported by the qualitative data analysis, specifically in the subtheme labeled *Shallow Thinking*. One student's statement illustrated the use of maintenance rehearsal, the cognitive process of using repetition as a means to learn (O'Donnell et al., 2007). "Part of why I did well on the things I didn't already know was that I repeated over and over, in my head how to do the skill." The problem with this maintenance rehearsal approach to learning is that it works best for short-term learning. Repetitive cognitive processing is neither deep nor elaborative, and therefore does not lead to meaningful, long-term learning. For example, one student admitted, "I just tried to remember where the mouse went…didn't care about understanding why." This statement suggests both shallow processing and a lack of motivation, another possible explanation as to why students did not engage in germane load-inducing processing.

Motivation is an important consideration in student achievement, and it has not been until recently that CLT researchers emphasized its importance as a contributing factor to germane load (Morrison & Anglin, 2005). Instruction must be coupled with motivation if students are to engage fully in schema construction that yields a germane cognitive load (Paas, Tuovinen, van Merriënboer, & Darabi, 2005; van Merriënboer, & Ayres, 2005). Instructional materials, such as screen-captured video instruction, even if they have been carefully designed to "improve learning through diminishing extraneous cognitive load and freeing up cognitive resources will only be effective if students are motivated" (van Merriënboer & Ayres, 2005, p.8).

Motivation and long-term learning, in fact, were alluded to in four student interviews. A sample statement is as follows: "I didn't do so good because I didn't really care about doing well…I mean it wasn't graded." Another student stated that she "just didn't care. It didn't matter if we learned it or not." It is likely that more students were affected by lack of motivation as four of 12 interviewees expressed this. However, because there were only four significant statements within the raw qualitative data set, long-term motivation was not considered to be thematic. Nonetheless, it remains a plausible explanation for the lack of long-term learning effects.

Another possibility that can explain the lack of long-term learning effects is that the instructional design did not sufficiently induce germane load. Instruction cannot simply allow for germane load through the reduction of extraneous load; germane load must be promoted (Schmidt et al., 2007). Perhaps the instructional design used in this study failed to do so.

According to some research, this failure to promote germane load could be partly due to the very nature of screen-captured video. Screen-captured video is similar to animated instruction, which, in some instances, has been shown to actually reduce germane load (Schnotz & Rasch, 2005). Some animations stimulate behavioral activity but are unable to promote mental activity, or germane load (Moreno & Valdez, 2005; Schnotz & Rasch, 2005). Screen-captured video might provide instruction so clear that students can readily recall the material immediately after viewing it, as indicated by the positive effects found in the immediate measure. However, they may not have been sufficiently prompted to invest much effort into the cognitive processing needed for long-term learning. One student's comment supports this explanation: "It was just like I was just watching something and nothing was happening in my head." Due to a potential passivity effect created by the clarity of screen-captured videos, instructional designers may need to extend beyond their normal measures to induce germane load. One area to focus on, in respect to this study, is the opportunity for practice.

Given the large amount of material presented in the intervention, one practice opportunity for each skill taught may not have been enough of a prompt for germane load. Indeed, as a result of experimental constraints, participants were provided with limited practice opportunities. These opportunities may have been sufficient for short-term learning but not for long-term learning. In fact, *Lack Of Practice Opportunities Subsequent To Instruction* was a subtheme uncovered in the qualitative analysis. Several students stated this as an explanation for their poor performance on the delayed measure. There was “not enough practice” to perform well, recalled one student. Another contended that his delayed score “probably would have been different if I was practicing every day or once or twice a week.” Practice, according to Gagne and his colleagues (2005), is one of the events needed for the effective instructional design for procedural knowledge and its manifestations should be examined in further research.

Implications For Screen-Captured Video Instruction and Future Research

Based on the findings of this study, there are several instructional and theoretical implications that can be offered to the educational and research communities. The first is that this study began to address a gap in the research of newer multimedia technologies that are being used for instruction. Despite their poor performance, students did report an affinity for screen-captured videos and even went as far as saying that they provided benefits that are unavailable in text-based instruction. Interestingly, each thematic benefit can directly be supported by existing research. For example, students also intimated the benefits of the modality effect, which asserts that students learn better when words are presented as narration rather than text (Mayer & Moreno, 2003). One student thought that the screen-captured video used to teach spreadsheet skills was “helpful because you’re hearing it and seeing it at the same time.” Another mentioned, “It’s like putting it in your mind in two different ways.” Perhaps unknowingly, these students validated the benefits of the modality effect, which can enable some of the working memory’s essential processing to be shifted from the visual channel to the verbal channel (Mayer & Moreno, 2003).

The personalization effect was also validated by the students (Mayer, et al., 2004). According to Mayer, Fennell, Farmer, & Campbell (2004), if a narrator speaks in a conversational tone (as was the case in the instructional movies) it will increase the learner’s level of interest, possibly leading to better transfer performance. Students acknowledged that the voice heard in the narration “put me at ease,” that it “felt more personal” than text-based instruction and was “less intimidating because it’s a real person explaining it.”

One student alluded to the signaling effect, saying that she was helped by “being able to see the mouse moving around.” The mouse cursor used in the videos perhaps cued her attention towards relevant information, thus reducing haphazard scanning, which can place an extraneous load on the working memory (Ayres & Paas, 2007).

A final CLT effect uncovered in the qualitative analysis was split-attention. Several students perceived benefits specific to the way in which the screen-captured videos reduce split-attention as indicated by one student's admission that he "had troubles with previous text-based instruction because I got lost between reading and doing." Another said that the video was "a little bit easier because it…eliminates that…gap…between reading and then going to look at it." A final statement was perhaps most profound: It is "more clear when you can actually see what you need to be doing instead of just reading, because you can interpret it differently."

These perceived benefits (*personalized narration*, *search reduction*, and *sights and sounds*), all significant subthemes from the qualitative phase, were not formally studied and I cannot claim that these student perceptions are valid; more research is needed. The students' affinity for screen-captured video is promising. Screen-captured video instruction is something that seems to engage and please students; however, the only conclusive implication to arise from this study is that segmenting screen-captured video can produce short-term learning effects. More research is certainly needed on how to effectively design the instruction so it results in long-term learning.

One research direction that could result in instructional design guidelines is to explore the previously proposed passivity effect of screen-captured video instruction. Because of the clarity of the visual and audio components to the videos, students reported watching without exerting any mental effort. A program like Adobe Captivate® forces learners to press buttons, type, and click menu options as they view the movie. Perhaps this forced practice would induce more germane load than the videos used in this study.

More research on practice in general, its availability and duration, is needed. Students consistently expressed that more practice was needed. Perhaps they would have performed better were they allowed two or three minutes during their opportunities, or if they had control of the video so they could practice at will. Additionally, providing an opportunity for them to practice between the immediate measure and delayed measure might have resulted in better performance.

Further research should examine more closely the relationship between motivation and germane load. In this study, it was clear that some students were not motivated to learn or perform well. In future studies, perhaps attaching a grade or extra-credit to the assessments would act as a motivator. It may also be worth using classroom teachers in a study; compared with preservice teachers, they may have a higher level of motivation to learn useful classroom applications of technology.

Lastly, the qualitative findings in this study were able to help explain the quantitative results. Perhaps other CLT and CTLM research could be conducted in mixed methods fashion, as this study was. CLT and CTML research has typically been quantitative in nature; however, the qualitative aspect can add new layers of support, explanations and possibly, new directions that may be able to further the literature.

Limitations

Any conclusions drawn from this research should consider the limitations of the study. First, the sample used in this study was a sample of convenience. All participating students were enrolled in a teacher education program at a single Southeastern university. A high percentage (81%) of these participants were female. The sample may not be representative of the larger population and any attempts to generalize the findings should be made with caution.

Another limitation of the study is the failure to have included any motivational factors (e.g. bonus points) that perhaps would have resulted in a stronger level of willingness to engage in meaningful learning.

The researcher narrated the videos and did so in an informal way. Roughly 25% of the students who participated in the study were enrolled in the researcher's section of the instructional technology course. It is unclear as to the effects, if any, caused by this. Perhaps these students were familiar with the researcher's style of teaching and speaking, thereby having an easier time than the students who were unfamiliar with the researcher's style.

APPENDICES

Appendix A

Institutional Review Board Consent Form

Information Concerning Participation in a Research Study
Clemson University

The Effects of Differentiated Multimedia Instruction on the Cognitive
Load of Students Learning a Technology Task.

Description of the research and your participation

You are invited to participate in a research study conducted by Ryan Visser. The purpose of this research is to examine how different instructional techniques impacts learning.

Your participation will involve answering a couple of questions that will help us determine the extent of your knowledge of MS Excel. You will then be given instructions on how to perform certain tasks within Excel. Once you have been instructed in these tasks, you will be asked to perform a similar task. This process will be repeated two weeks after the initial testing. Finally, you will be asked to comment on the instruction you received.

The amount of time required for your participation will be the equivalent of three 50-minute class periods during the semester.

Risks and discomforts
There are no known risks associated with this research.

Potential benefits
There are no known benefits to you that would result from your participation in this research. However, this research may help us to understand how to best present instruction in electronic settings such as distance-learning environments or CD/DVD-based learning environments.

Protection of confidentiality
We will do everything we can to protect your privacy. Your identity will not be revealed in any publication that might result from this study.

Voluntary participation

Your participation in this research study is voluntary. You may choose not to participate and you may withdraw your consent to participate at any time. You will not be penalized in any way should you decide not to participate or to withdraw from this study; however, you will be given an alternate in-class assignment to work on while the study is being conducted.

Contact information

If you have any questions or concerns about this study or if any problems arise, please contact Ryan Visser at Clemson University at 864.656.5106. If you have any questions or concerns about your rights as a research participant, please contact the Clemson University Office of Research Compliance at 864.656.6460.

Printed Name	Signature

Appendix B

Demographic Sheet

Name________________________________

Username_____________________________

Major________________________________

Age__________________________________

Circle:

Freshman Sophomore Junior Senior

Male Female

Caucasian African American Hispanic

Asian American Native American
Other__________________

Appendix C

Prior Knowledge Questionnaire

1) Can you make Excel automatically change the formatting of a group of cells (instead of doing it manually)?

   Circle: Yes No

   If *Yes*, briefly describe the process you would use (if you need to jog your memory, you can refer to the *Formatting* worksheet in your Excel file):

   ____
   ____
   ____
   ____.

2) Using Excel, can separate data that exists in one column so it appears in multiple columns?

   Circle: Yes No

   If *Yes*, briefly describe the process you would use (if you need to jog your memory, you can refer to the *Separating Data* worksheet in your Excel file):

   ____
   ____
   ____
   ____.

3) Using Excel, can you align a cell's content so it is centered vertically?

   Circle: Yes No

   If *Yes*, briefly describe the process you would use (if you need to jog your memory, you can refer to the *Centering Text* worksheet in your Excel file):

   ____
   ____
   ____
   ____.

4) Using Excel, can you calculate a final grade that is weighted as such:

Test 1=20%; Test 2=20%; Test 3=20%; Final Exam=40%

Circle: Yes No

If *Yes*, briefly describe the process you would use (if you need to jog your memory, you can refer to the *Weighted Grade* worksheet in your Excel file):

____

____

____

____.

5) Using Excel, can you create a formula that combines the content of two cells so it appears together in a third cell?

Circle: Yes No

If *Yes*, briefly describe the process you would use (if you need to jog your memory, you can refer to the *Linking* worksheet in your Excel file):

____

____

____

____.

6) Can you create a formula within Excel that assigns a *Letter* grade based on a given *Number* grade (assuming a 10 point scale –ie. 90-100=A; 80-89=B; 70-79=C…etc.)?

Circle: Yes No

If *Yes*, briefly describe the process you would use (if you need to jog your memory, you can refer to the *Letter Grade* worksheet in your Excel file):

____

____

____

____.

7) If content is unreadable because the cell size is too small, can you adjust the size of the cell, column or row as necessary?

Circle: Yes No

If Yes, briefly describe the process you would use (if you need to jog your memory, you can refer to the *adjusting row or column size* worksheet in your Excel file):

____

____

____

____.

8) Can you make Excel automatically format text color based on a certain requirement? For instance, formatting all 'Bs' in a letter grade column so they are italic, bold with a blue font.

Circle: Yes No

If Yes, briefly describe the process you would use (if you need to jog your memory, you can refer to the *Specifying Styles* worksheet in your Excel file):

____

____

____

____.

9) Using Excel, can you create a drop-down box in each column that would enable a user to select specific occurrences of data within that column?

Circle: Yes No

If Yes, briefly describe the process you would use (if you need to jog your memory, you can refer to the *Selecting Data* worksheet in your Excel file):

____

____

____

____.

10) Given a listing of students' letter grades, can you make Excel calculate the number of As, Bs, Cs, Ds and Fs?

Circle: Yes No

If Yes, briefly describe the process you would use (if you need to jog your memory, you can refer to the *Grade Distributions* worksheet in your Excel file):

____
____
____
____.

11) When using the fill handle to copy a formula, can you create an absolute reference?

Circle: Yes No

If Yes, briefly describe the process you would use (if you need to jog your memory, you can refer to the *Absolute Reference* worksheet in your Excel file):

____
____
____
____.

12) Given a distribution of students' letter grades, can you create a chart that depicts the distribution?

Circle: Yes No

If Yes, briefly describe the process you would use (if you need to jog your memory, you can refer to the *Charting* worksheet in your Excel file):

____
____
____
____.

Appendix D

Practice Packet (with Scaffolds)*

**Note: Practice sheet for the non-scaffolded group
was identical except for the provision of hints.*

Instructions: During the following practice opportunities, practice the skill that you just viewed in the instructional video. During practice you will receive *hints* for some of the steps needed to complete the skill. The rest of the steps are missing—you will attempt these steps on your own.

Throughout the practice, please remain on the current question until you are instructed to go to the next question.

1) Use the *Separating Data* worksheet to practice separating the data in Column A so it is divided into multiple columns. Additionally, resize the columns so the data fits appropriately.

Hint 1: Highlight the column that contains the data that needs separating

Hint 2: Choose 'Text To Columns'

Hint 3: Select 'Space' Delimiters

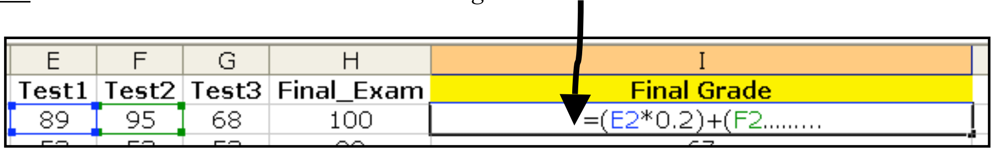
2) Use the *Combining Data* worksheet to practice combining Column B (First Name) and Column A (Last Name) so it appears as a whole name (with a space in between first and last) in Column C.

Hint 1: Begin the formula like this: =B2&

Hint 2: To create a space in between the first and last name, use quotes with a space in between them- " "

3) Use the *Weighted Grades* worksheet to practice calculating a weighted final grade where: Test 1=20%; Test 2=20%; Test 3=20%; Final Exam=40%.

Hint: Your Final Grade calculation should begin like this:



E	F	G	H	I
Test1	Test2	Test3	Final_Exam	Final Grade
89	95	68	100	=(E2*0.2)+(F2........

4) Use the *Letter Grades* worksheet to practice assigning *Letter* grades based on their Final (*Numerical)* Grades. The 10-point grading scale is given within the worksheet.
Hint 1: Use the formula that begins with: lookup(
Hint 2: Use the Final Grade for the 'lookup_value'
Hint 3: When selecting the array, do not include the "Grading Scale" or "Letter Grade" headers.

5) Use the *Absolute Reference* worksheet to practice using the fill handle so the *Grading Scale* data remains absolutely referenced.
Hint 1: Use dollar signs ($) in front of the columns and rows within the 'array'.

6) Use the *Smart Formatting* worksheet to practice applying the following to all of the 'F's in the given list of grades: bold, underlined, red, yellow background.
Hint 1: Highlight letter grades
Hint 2: In the dropdown box, set the Cell Value to 'equal to' F.

7) Use the *Grade Distributions* worksheet to practice calculating the number of 'C's.
Hint 1: use the formula that begins with =countif(
Hint 2: Place the 'criteria' in quotes (eg. "c")

8) Use the *Descriptors* worksheet to type as many adjectives and nouns that you notice in the video.

Appendix E

Immediate and Delayed Measure^*

**Note: The two tests were identical.*
^Note: On the test given to students, each question was presented on a separate page. For spaces-saving purposes, I have condensed the test to the next two pages.

Instructions: Answer the following questions within the spreadsheet entitled "part2.xls". Do not go flip the pages or change worksheets until you are told to do so.
--You will have 60 seconds to answer each question.

1. Use the worksheet entitled "**1**" to separate the data in Column A so the data is divided appropriately into multiple columns.

2. Use the worksheet entitled "**2**" to combine First, Middle and Last names so it appears as a full name (with spaces in between each) in the "Full Name" column.

3. Use the worksheet entitled "**3**" to calculate a weighted final grade for each student, where:

Test1 = 15%
Test2 = 15%
Midterm_Exam = 25%
Homework = 10%
Final_Exam = 35%

Total 100%

4. Use the worksheet entitled "**4**" to assign Elmer J Fudd* his *Letter* grade based on his Final (*Numerical)* Grade. The 10-point grading scale is given within the worksheet.

* You should determine only Elmer Fudd's Letter Grade for this question.

5. Use the worksheet entitled "**4***" to assign the *Letter* grades for the remainder of the students – you will use absolute referencing.

[*] Note that you are working within worksheet “4” for both the previous and the current question.

6. Use the worksheet entitled “**5**” to:
    - Apply a light green background and a border to all Final Grades (*Numerical*) between 57 & 63.

7. Use the worksheet entitled “**6**” to calculate the number of As, and Fs.

8. Use the worksheet entitled “**7**” to type in as many countries danced within in the *You Tube* video.

Appendix F

Immediate and Delayed Grading Rubric

0	Completely wrong; faked the formula (entered an F from keyboard rather than use lookup fnct); did not attempt
1	Attempt with significant flaws – ‘lookup d3’ instead of =lookup(d3, j3:k3) – tried but didn’t really know what they were doing
2	Attempt with moderate flaws - =countif(d3:e3, c) instead of =countif(d3:e3, “c”), or did not include middle initial in combining data, or had a red background rather than green in conditional formatting – they had a good idea of what they were doing but didn’t completely get it.
3	Completely correct

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