Signaling Instructional Video for Mathematics

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SIGNALING INSTRUCTIONAL VIDEO FOR MATHEMATICS

by

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A Dissertation Submitted to the Faculty of Old Dominion University in Partial Fulfillment of the Requirements for the Degree of

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Video provides an increasingly valuable medium for delivery of instruction in a growing number of content areas. Growth of online instructional applications has been prompted by expansion of the Internet and video streaming technology, adding to the need for design practices that produce more effective and efficient instructional videos. This study examined the use of signaling for multimedia to reduce cognitive overload and increase mental effort when learning mathematical concepts and procedures from instructional video. Signaling addresses the issue of directing the learner’s attention by using visual or verbal cues that stress importance and organization (Mayer. 2009). Effectively signaled instructional videos could improve student learning by encouraging schema formation through increased mental effort, directed attention, and reduced cognitive load. Adding to the literature on signaling multimedia, signals were divided into categories of visual and verbal to investigate their individual value to the medium of instructional video.

Results of this study indicated that visual signaling provided a greater benefit to students learning mathematics from instructional video than verbal signaling. Specifically, test performance was improved when visual signals were included in video instruction, both with and without the use of verbal signals. Retention of knowledge, however, showed improvement when visual signaling was present, but not when visual and verbal signals were combined. There was also an increase found in the learner’s perception of their performance indicating improved self-efficacy when visual signaling
was employed, along with a decrease in frustration with the learning task. Mental
demand, or cognitive load, reported by the learner, lessened with the application of visual
signals, both with and without verbal signaling. Finally, learner interest in the
instructional video showed a marked improvement with the addition of visual signals to
the presentation.

*Keywords:* instructional video, multimedia signaling, cognitive load, interest.

mental effort, mental demand.
This dissertation is dedicated to the people in my life who made it possible. My mom and dad, who were always proud of me no matter what I did; my husband, who has always made it possible to do the impossible; my daughters and their husbands, who were always there to encourage; and finally to my granddaughters, for whom the struggle to set an example is always foremost in my mind.
ACKNOWLEDGEMENTS

This dissertation has been a wonderful culmination to an inspiring PhD program, and I would be remiss if I did not acknowledge the incredible academic experience I have enjoyed due to the quality and dedication of the faculty at Old Dominion University. First and foremost of these are the members of my committee, Dr. Morrison, Dr. Watson, and Dr. Bol. Each has contributed more than they realize from both their extensive knowledge and unselfish desire to help others succeed. If I have learned anything, I have learned what it means to impart knowledge and to mentor another, and it is a gift that I hope to extend into my own teaching career.
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CHAPTER 1
INTRODUCTION AND LITERATURE REVIEW

Introduction

Video provides a powerful medium for delivery of instruction and information acquisition. Considered a cognitive aid when learning by constructing knowledge from multimedia (Mayer, 2009), instructional video offers learners the advantages of a multimodal presentation of information (Baddeley, 1986; Mayer & Anderson, 1991) while allowing learner control of pacing (Adler & Milne, 1995; Bryant & Hunton, 2000; Mabey, Topham, & Kaye, 1998). The ability to repeat complex instruction found in technical subjects such as mathematics is particularly useful, especially with novice or lower-level students (Brecht & Ogilby, 2008; Paas & van Merrienböer, 1994).

Familiarity, accessibility, and affordability combine to make the medium of video an attractive option for delivering instruction. Technological and Internet expansion has contributed to unprecedented growth of online instructional applications, emphasizing instructional videos as primary components (Dey, Burn, & Gerdes, 2009). Adding to the need for effective and efficient instructional video are advancements directed toward streaming video to a wide variety of devices, making video instruction an easily accessible tool for educational institutions and learners (Snelson & Perkins, 2009). Since educators and learners have both turned to instructional video to supplement and deliver instruction to address the needs of diverse populations, instructional design of these videos should address issues that influence learning, particularly in highly complex subjects.
Problems associated with learning from instructional video may be related to difficulties in constructing and retrieving appropriate schemata, and a lack of learner interest resulting in low motivation and expended mental effort (Cennamo, 1993; Field & Anderson, 1985; Krendl & Watkins, 1983; Salomon & Leigh, 1984). Cognitive effort, encompassing both mental effort expended by the learner and mental resources required to comprehend the instruction, is an area of interest in cognitive psychology and instructional design. Strategies that encourage learners to increase mental effort while requiring fewer cognitive resources to understand the presentation of information could lead to more efficient and effective video instruction (Cennamo, 1993). The importance of efficiently utilizing cognitive resources and directing mental effort increases with the complexity of the material to be learned, making the field of mathematics a particularly useful area for study (Paas & van Merriënboer, 1994). The failure of novice learners to adequately learn mathematical procedures has been attributed to inappropriate direction of attention and excessive cognitive load (Paas & van Merriënboer, 1994). The construction of accurate schema, a cognitive construct used by learners to solve problems according to solution moves (Ward & Sweller, 1990), is crucial for lower-level learners, and can be encouraged through carefully designed instruction.

Design issues considered effective in developing multimedia instruction should be applied to mathematics instructional videos with the goal of reducing cognitive overload while increasing mental effort and aiding schema formation. Signaling is a principle of learning in multimedia that can be applied to video instruction for this purpose (Mayer & Moreno, 2003). Signaling addresses the issue of directing the
learner’s attention by using cues that stress importance and organization (Mayer, 2009). Since these cues may be visual or verbal, they readily fit the attributes of instructional videos that provide both visual and audio instruction (Mayer, 2009; Mayer & Moreno, 2003). Effectively signaled instructional videos could improve student learning by encouraging schema formation through increased mental effort, directed attention, and reduced cognitive load. This study examines the effect of mathematics instruction for novice adult learners through signaling strategies designed to more effectively utilize cognitive resources. It addresses the need to explore specific design issues associated with quality video instruction.

**Literature Review**

The following literature review examines research concerned with increasing learning by influencing cognitive load and mental effort, with specific attention given to strategies that can be applied to instructional video. It begins with a brief description and presentation of research related to instructional video, followed by a summary of cognitive load theory applied to multimedia. Next, is a review of research pertaining to signaling in multimedia that can be applied to mathematical instructional videos, including the use of an instructor as a signaling agent.

**Instructional Video**

Four techniques commonly employed in educational video recordings have been previously categorized: (a) straight lecture, consisting of the visual image of the instructor presenting spoken verbal material; (b) lecture with digital aids, including digital aids (e.g., charts, lists) in addition to the visual image of the instructor and audio lecture; (c) interview, involving a visual image of individuals asking and answering
questions; and (d) visualized lecture, employing visual slides or films along with audio narration (Ksobeich, 1976). Two types of instructional video recordings that are applicable to this research proposal can be identified from these guidelines, video lectures and narrated video presentations. Video lectures are defined as web (e.g., streaming) and CD/DVD viewable video files providing classroom lecture content (Brecht & Ogilby, 2008), include the four techniques outlined by Ksobeich, and generally include a visual image of the instructor in the video. Narrated video presentations are similar in content, but exclude the image of the narrator or instructor. Narrated video presentations are often created from applications such as PowerPoint with voiceover narration (Dey et al., 2009).

Video has been used to replace or supplement instruction by an instructor since the widespread adoption of educational motion pictures in the form of films in the early 1900s (Anderson, 1965). Today, widespread acceptance of online and distance education with increased availability of the Internet that offers video on demand (i.e., streaming) has encouraged expanded use of video in the educational sector (Snelson & Perkins, 2009), including asynchronous recorded lectures provided as supplemental or tutor instruction (Dipaolo, 1995; Gibbons, Kincheloe, & Down, 1977). Video delivery can be used to provide instructional support for high-risk students by supplementing classroom lectures for difficult content areas and providing remediation for underprepared students (Brecht, 2012). Institutions today view video delivered online as a way to extend shrinking higher education budgets by expanding quality classroom instruction to distance learning where more students can be served with reduced costs for faculty and classroom space (Brecht, 2012).
**Acceptance and effectiveness of video as an instructional tool.** Successful learning is not dependent on the choice of video for instructional delivery, but rather the value of video as an instructional tool is indicated. Advances in technology and the availability of Internet access have encouraged today’s college students to seek an education and information that can be accessed remotely on personal computers, tablet computers, and cell phones (Crofts, Dilley, Fox, Retsema, & Williams, 2005). As a result, video provides a familiar mode of delivery (Snelson & Perkins, 2009).

Video instruction provides distinct advantages for learning and teaching in both face-to-face and online courses. Learner control of pacing, considered the ability to control viewing speed, stopping, pausing, and repeating, is a specific advantage associated with the medium (Adler & Milne, 1995; Bryant & Hunton, 2000; Mabey et al., 1998). Student acceptance of instructional video in higher education has been the subject of recent research, with students expressing appreciation of the ability to control the instruction as needed for understanding, clarification, and note taking while minimizing typical classroom distractions (Simpson, 2006).

Another use that has gained acceptance for video lectures in higher education is tutored videotape instruction, originally developed at Stanford University to provide course work in science and engineering (Dipaolo, 1995; Gibbons, Kincheloe, & Down, 1977). A similar program at the University of Missouri at Kansas City provides extra assistance for students with low skill levels in core curriculum courses (Hurley, Patterson, & Wilcox, 2006; Martin, 2001). Citing learner control as a contributing factor to student success, video-based instruction is credited with giving students "time to
think" by controlling pacing that allows deeper learning to occur (Brecht, 2012; Martin, Arrendale, & Blanc, 1997).

Research has shown the effectiveness of video for mathematics instruction. In one study, video instruction was found to be effective in teaching mathematical skills and concepts to secondary students (Henderson, Landsman, & Kachuck, 1985). Another study was designed to examine the value of online video lectures in a university financial accounting course (Brecht, 2012). Post-instructional survey results showed significant numbers of students indicated that videos made learning easier and that videos provided useful tutoring help. Additionally, students sampled from course sections including supplemental videos had significantly lower dropout rates and significantly higher end-of-course grades than the no-video samples.

Advantages of learning from dual-channels. The multimodal advantage associated with instructional video aids processing and retention through combining visuals with verbal narration (Mayer & Anderson, 1991). According to Paivio’s (1971) dual coding theory, two distinct representations of information, linguistic and imaginal, function in the human mind. Associating words with images increases the chances of memory retrieval since data are stored in two separate functional locations. In keeping with Paivio’s theory, the theoretical framework for studying how people learn through the use of video instruction assumes visual and verbal channels, limited working memory, and that active cognitive processing is necessary for meaningful learning (Clark & Paivio, 1991). Cooper (1998) posits that text or voice alone provides insufficient information for understanding complex material, suggesting the value of dual-channel presentations found in
video instruction for teaching mathematics. In a related view, Ksobiech (1976) argues that students will focus on the auditory information of the verbal channel unless they are made aware of the importance of information presented visually.

**Advantages of instructional video for math.** Highly technical or complex procedures, such as those found in mathematics, frequently call for repetition if the learner is to effectively encode the material. Videos are particularly useful for delivering material that bears repeating since the learner has control of pacing and navigation, and the videos can relieve tutors and instructors from the need to go over complex procedures multiple times (Brecht & Ogilby, 2008). Single-concept films described as self-instructional have been produced by instructors for decades, following the practices of programed instruction and the realization that a filmed presentation of an important concept is useful in developing understanding (Vernon & Gerlach, 1965). Short videos are attractive to students, and the single topic content provides an explanation that is available when the student needs it – when they are attempting to work a similar problem and need to develop appropriate and accurate schema (Sorden, 2005).

The usefulness of instructional video as a delivery method is indicated; however, to provide effective and efficient instruction, video instruction must consider the guidelines of cognitive learning imposed by the human mind. The cognitive theory of multimedia learning is considered next as a guide for developing effective video instruction.
Cognitive Theory of Multimedia Learning Applied to Instructional Video

Mayer and Moreno (2003) define multimedia instruction as presenting words (printed or spoken) with pictures either static (e.g., illustrations, graphs, charts) or dynamic (e.g., animation or video). Using this broad definition, a printed textbook page with pictures would be considered multimedia instruction, as would a computer-based narrated animation, or a video presentation of narrated mathematical worked examples. Mayer (2009) suggests that multimedia instruction can be designed to reduce cognitive load and optimize working memory for creation of schemata. The discussion of multimedia learning starts with an overview of cognitive load theory with applications to the design of multimedia instruction and building schematic structures in memory.

Cognitive Load Theory. Cognitive load theory seeks to explain how we learn and organize memory. It is concerned with the learner’s use of cognitive resources during learning and problem solving, and suggests that effective instruction must not overload the mental capacity for processing information (Chandler & Sweller, 1991; Sweller, 1988, 1994). Thus, designers must consider working memory and those resources that are used during learning.

Working memory. Cognitive load theory posits a cognitive architecture of a slightly inefficient, limited working memory with a permanent, unlimited long-term memory. Working memory, according to Baddeley (1992), provides a place for the learner to make sense of new information and associate it with information already learned. The number of verbal or visual items we can process at one time without overwhelming the learner’s limited working-memory resources is debatable (Mayer & Moreno, 1998; Paas, Renkl. & Sweller, 2003). Once thought to be around seven
items (Miller, 1956). Recent studies suggest a number between three and five (Cowan, 2000). This number is a significant limitation, especially if the material to be learned is complex or the learner is a novice.

**Intrinsic load, extraneous load, and germane resources.** Intrinsic cognitive load is described as a level of element interactivity associated with learning material (Sweller et al., 2011). High-element interactivity imposes more demands on working memory due to the number of elements that must be understood while simultaneous processing element interactions. Intrinsic load is reduced by omitting some of the interacting elements, but this reduction may not be practical when dealing with complex tasks found in learning algebra (Mayer & Moreno, 2003; Paas & van Merrienböer, 1994). While intrinsic load can be thought of as the portion of cognitive load associated with the information to be learned, extraneous load is the result of ineffective message design resulting in split attention and redundancy that require cognitive resources. Efficient instruction should eliminate extraneous load whenever possible, leaving germane resources free for schema formation (Paas, Tuovinen, Tabbers, & Van Gerven, 2003; Wittwer & Renkl, 2008). Germane resources are working-memory resources devoted to information relevant to learning the material (Sweller et al., 2011). If intrinsic and extraneous loads for a learning task are too high, remaining working memory resources may not be adequate to create effective schema or models of information stored in long-term memory (Sweller et al., 2011). Therefore, extraneous load should be minimized so that germane resources are available to devote to schema-building activities.
**Schema building.** Schema have been described as cognitive constructs allowing learners to recognize and solve problems that require similar solutions (Cooper & Sweller, 1987; Ward & Sweller, 1990). Schema assist learners in extending the capacity of working memory by allowing a multi-step process to be retrieved from long-term memory and treated as a single entity, freeing working memory and allowing complex learning to take place (Sweller et al., 2011). Since mathematical procedures build on each other to become increasingly complex, learners must build a sufficient supply of correctly identified patterns or solution paths stored as schema (Sweller, 1988). Chi, Glaser, and Rees (1982) describe this building of increasingly complex schema as the transition from novice to expert in a domain. As students learn appropriate procedures and solutions to problems and create a warehouse of correct schema to choose from, they can successfully progress along the path from novice to expert learner (Anderson & Schunn, 2000). Excessive cognitive load while trying to appropriate the correct schema has been attributed to the failure of novices to make the transition to expert learner (Paas & van Merrienböer, 1994).

**Signaling as a cognitive guide**

Signaling, one of the principles of learning with multimedia that can be applied to video instruction, states that greater transfer of learning occurs when narrations are signaled, reducing cognitive load in working memory by providing cues to the learner about information organization (Mayer & Moreno, 2003). Signals are intended to guide the cognitive processes of the learner without adding new information (Mayer, 2009). Signals for text include stylistic writing devices that depict textual structure.
importance, and organization (Meyer & Poon, 2001). Mayer and Moreno (2003) suggest signaling as a method of reducing cognitive load when one or both channels is in danger of overload due to essential and incidental processing. Examples of explicit signals that are useful in text are provided in Table 1 (Meyer & Ray, 2011).

Table 1

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Much can be learned from the cognitive theory of multimedia learning (Mayer, 1996, 1997; Mayer & Moreno, 2002) that can be applied to video design with respect to signaling. This theory states that narration and graphical images produce verbal and visual mental representations that integrate with prior knowledge to construct new knowledge. Based on Paivio's (1971) dual coding theory, multimedia learning theory assumes a limited-capacity working memory that includes auditory and visual channels for retrieving information. Mayer (2003) posits that learning from multimedia involves
selecting, organizing, and integrating words and images. Learners selectively choose information that is important to a learning task, organize this material into an understandable structure, and integrate this new knowledge with existing knowledge in order to engage in meaningful learning (Mautone & Mayer, 2001; Wittrock, 1989).

Signals are intended to guide the cognitive processes of attention, organization, and integration when learning from visual and verbal representations of information as depicted in Figure 1. An explanation of how signals can affect learner attention, organization, and integration follows, along with related signaling research summaries.

**Figure 1. Cognitive Theory of Multimedia Learning**

![Cognitive Theory of Multimedia Learning Diagram](image)


**Guiding attention or selection.** Signaling is a design principle that has been shown to be especially useful in directing the learner's attention to textual structure and importance, or selection (Mayer, 2009; Meyer, 1985; Morrison, Ross, Kalman, and Kemp, 2011). In learning from expository text, signaling helps the reader discriminate between relevant and non-relevant information (Loman & Mayer, 1983; Lorch, 1989). For complex instruction where extraneous material is still included due to the
complexity of the information, signals are especially useful. Typographical signals
guide the learner’s focus in text-based and graphical presentation. For example, the use
of color, boldface type, and italics can set information apart, guiding the learner’s
attention to visually distinguishable differences (Fleming & Levie, 1978).

In a series of three experiments with college students studying aerodynamics,
signaled instruction resulted in significantly higher performance in generating problem
solutions (Mautone & Mayer, 2001). Signaled text was examined with Experiment 1,
signaled narration was the focus of Experiment 2, and Experiment 3 examined signaled
narrated animation. In all three experiments, researchers tested the knowledge-
construction hypothesis, predicting that signaling would lead to better problem-solving
transfer performance.

Text-only signals in the first experiment consisted of (a) descriptive headings,
(b) a preview summary paragraph added after the introductory paragraph, (c)
connecting words, and (d) boldface and italicized words. Signaling added a total of 109
words to the un-signaled instruction. Experiment 2 used the text from Experiment 1 as a
spoken narration, signaling emphasis with vocal inflection and pauses. The spoken
narration used in Experiment 3 was the same as Experiment 2, and the animation
received additional signals using colors, arrows, and icons.

Verbal signaling, in the form of text and narration, had a positive effect on
problem-solving transfer in all three experiments, with moderate effect sizes. The
experiments supported the transferability of signaling across types of media, and
emphasized the use of signals to improve learner understanding. The study added to the
signaling research on verbal signaling by exploring the effects for audio signals.
However, while significant results were found for transfer problem-solving, learners exhibited little benefit in retention from signaling strategies. A weakness of the study was the additional 109 words of instruction added to the signaled versions. While the preview paragraph was presented as a signaling technique, it could be argued that it represented an additional strategy missing from the non-signaled versions. Additionally, the effect of signaling on retention was small, possibly due to the weakness of the signals chosen. Arrows, used to depict direction of lift and wind over an airplane wing, were included in both signaled and non-signaled instruction, with signals consisting of color only. In this case it could be argued that the arrows alone were sufficient, and color added little to focusing the learner’s attention or providing structure.

**Guiding organization.** Dodd and Antonenko (2012) suggested that signaling through placement of non-content visual and verbal cues aids both selection and organization of material. The organizational structure of material signaled through numbers, headings, and connecting words is especially important when learners possess low or inadequate prior knowledge (Bromage & Mayer, 1981). Signaling is a way to make the conceptual organization more apparent to the learner, encouraging the learner to build a coherent organization of information that is transferable to new situations. An example can be found in two experiments with high school students that resulted in significantly higher recall and problem solving when learners read and listened to signaled expository passages over un-signaled passages (Loman & Mayer, 1983).

The study by Loman and Mayer (1983) focused on signaling techniques to emphasize structure and organization. Published classroom materials were modified to include preview sentences, underlined headings for each major concept, and logical
connective phrases without adding to the original content. Researchers concluded that the signaled group performed better in both recall of concepts and application of the information to new situational problems, suggesting that the signaled structure provided learners with the basic organizational structure to apply the material in creative thinking. Apparently, signaling sequence and relationships within instruction can assist the learner in forming accurate and meaningful organizational structures for difficult material, a necessary step in adequate schema formation.

**Guiding integration.** Integration involves merging the pictorial and verbal mental models held by the learner with relevant prior knowledge (Mayer & Moreno, 2003). An important potential effect of signaling is on the learner’s comprehension of the material that can be observed through problem solving (Lorch, 1989). Problem solving, especially novel problems requiring a new or modified set of steps than the example problems (Catrambone, 1994), requires effective integration of newly formed schema with existing knowledge. Signaling may contribute to this effect by reducing demands on working memory (Mautone & Mayer, 2001). This effect has been observed in improved performance in solving novel problems (Loman & Mayer, 1983) that differ from instructional problems and therefore require a deeper understanding of the solution model (Mautone & Mayer, 2001).

In a series of three experiments, signaling scientific passages tended to enhance recall of conceptual information and creative problem solving performance with college students (Mayer, Dyck, & Cook, 1984). Signals were used in the text of the instruction to emphasize causal relationships and systems in the passages. Specifically, organizational preview statements were added and conceptual headings were inserted to
highlight steps. Assessment questions required learners to apply newly acquired conceptual knowledge to solve problems that were used as examples in the instruction and problems not included in the passages (novel problems). The signaled group consistently recalled more premise information and performed better on problem solving than the control group. The results of these studies suggest that signaling assists learners in building workable mental models, consistent with forming accurate schema.

**Agents and Social Cueing**

An alternative to arrows and typographical signaling in video instruction is the addition of an animated agent that can imitate the instructor in the classroom. Agents may be realistic, closely resembling people, or abstract cartoon-like objects. The job of the agent in multimedia instruction is to facilitate learning (Craig, Gholson, & Driscoll, 2002), much like the role of instructor in the classroom. Learners have been noted to have increased interest and achievement when engaged with a social presence or on-screen agent (Hidi and Baird, 1988).

**Instructor image as an on-screen agent.** Interestingly, advantages associated with computer agents have been equated with attention benefits found with the on-screen presence of the instructor when the instructor is the narrator (Dey et al., 2009). In an experimental study conducted with authentic classes of college students enrolled in an undergraduate physics course, researchers sought to link retention and transfer achievement and the presence or absence of the lecturer's video image (Dey et al., 2009). Multimedia presentations in the form of videos using visual and auditory presentation of material were developed using cognitive design principles for multimedia (Mayer, 2009). One version of the video presentation included the video
image of the lecturer in addition to his voice and slide presentation and the second version included only the voice and slide presentation.

Participants viewed the online video presentations in a setting and at a time of their choosing, as is typical of online instructional delivery. After viewing the presentation, students completed the achievement test and exit questionnaire. Results showed a learner preference for including the instructor’s image on the video (M=2.83 on a 4.0 scale). However, no significant difference was reported for transfer or retention achievement test results.

Results with respect to on-screen agents affecting learning are mixed. Andre, Rist, and Muller (1998) found no effect on student performance when agents were included, but student enjoyment of the presentation increased. Moreno (2001) also found that inclusion of the agent did not improve performance, but personalized messages improved retention and transfer of learning to novel problems (also see Moreno & Mayer, 2004). The instructor-image effect should be explored further, however, since it could increase learner interest through improved learner identification with the instructional agent, and consequently increase learning (Reeves & Nass, 1996; Hidi & Baird, 1988).

Mental Effort

The challenge to the design of video instruction is to maximize the effort expended in learning while minimizing effort needed to make sense of the content. The discussion of signaling strategies to this point has been concerned with reducing extraneous cognitive load inherent in video instruction. Increased mental effort, however, is believed to create greater activation of schema (Cennamo, 1993), and is
therefore a valuable component of learning that can potentially be influenced by signaling.

Mental effort refers to an increase in cognitive resources devoted to processing instructional stimuli (Cennamo, 1993). For example, experienced readers would have to exert little effort in reading this study. Greater effort would be required, however, if those same readers were trying to find contradictory hypothesis or refute arguments in the study (Beentjes, 1989). Measurement of mental effort has been accomplished through learners' self-reports on the amount of invested mental effort (AIME), defined as "the number of non-automatic mental elaborations applied to material" (Salomon, 1984, p. 648). Mental effort may be influenced by the symbol systems employed by the medium, the complexity of the material, program structure, perceived purpose of the task, and individual learner characteristics (Cennamo, 1993).

Research into the effects on mental effort when learning from video has shown mixed results. Several studies indicated that learners invest less mental effort in learning from video due to a perception of television being easier than print (Salomon, 1984; Salomon & Leigh, 1984). However, Thorson, Reeves, and Schleuder (1985) found that more effort was invested in processing videotaped materials that presented information through dual channels than through either channel alone, although learning was not increased.

Perceived purpose of the learning task has also been shown to influence effort in learning from video instruction resulting in increased retention and retrieval (Field & Anderson, 1985; Krendl & Watkins, 1983; Salomon & Leigh, 1984). In another example, Salomon and Leigh (1984) found significantly higher levels of mental effort
were reported when sixth-grade learners were told to learn from film rather than to watch for fun. When students were not instructed to learn, high-ability students reported TV as an "easy" medium and learned significantly less from an instructional television program than low-ability students, suggesting that a conscious application of mental effort affected learning. In a second study, students who received instructions that the material was educational performed better than those who viewed for entertainment, suggesting that perceived demand and consequent mental effort improved encoding (Krendl & Watkins, 1983).

Promising strategies for increasing mental effort in video-based instruction may be derived from similar research with text-based materials. Britton (1980) explored the cognitive capacity (mental effort) used by learners to retain information in text for immediate and delayed recall. Mental effort was measured with a secondary task, as learners responded to random clicks by releasing a previously depressed telegraph key. In two experiments with college students, significantly longer reaction times, indicating increased mental effort being expended on the reading task, were recorded when participants were knowingly reading for a delayed testing condition.

As suggested by Cennamo (1993), research into the link between effort required and effort expended should be investigated to "lend insight into factors that influence learners' cognitive processing of video instruction" (p. 43). Such research could direct the design of instructional video with practical strategies for increasing learner mental effort while minimizing excess cognitive load associated with design, leading to more efficient and effective instruction.
Purpose of Research

The purpose of this study was to extend previous research on signaling strategies with multimedia by examining the effects on adult learners in developmental mathematics courses learning from instructional video. The primary purpose was to determine whether verbal and/or visual signals would improve learning in an instructional video presentation. The study sought to determine effective strategies for designing instructional videos by investigating learner achievement, perceived cognitive load, and learner interest.

Consistent with suggestions by Mayer (2009) for reducing cognitive load and optimizing working memory through signaling multimedia, the following hypothesis was tested:

1. Participants receiving visually and/or verbally signaled video instruction will score higher on immediate and delayed knowledge tests than participants receiving un-signaled video instruction.

Five exploratory research questions were also examined in an attempt to identify which signaling strategy was best for adult novice mathematics learners:

1. Is there a difference in transfer of learning to novel problems with visual, verbal, or visual + verbal signaling of mathematics instruction?
2. Is the perception of required cognitive load affected by the different signaling strategies employed?
3. Is expended mental effort devoted to learning affected by the different signaling strategies employed?
4. Does signaled and instructor-signaled mathematics instruction affect learner interest?

5. Does the ability level of the learner, determined by course entry diagnostic scores, affect the benefits achieved from signaling strategies?
CHAPTER II

METHOD

Design

This study employed a between-subject true experimental design. The method involved instruction and assessment with actual classes of enrolled students. The study compared pre-instruction and post-instruction math knowledge for students randomly assigned to one of four treatments of instruction. Dependent variables were performance on math knowledge posttests, perceived cognitive load, mental effort, and learner interest. The independent variable was the instructional treatments including a controlled implementation of multimedia signaling strategies.

Participants

Participants consisted of 103 students, 50 male and 53 female, enrolled in the same second-level developmental mathematics course at a mid-size southern state college. Ages ranged from 19 to 63, with an average age of 25.62 years. A diagnostic test of mathematical preparedness for algebra placed 29 students as low, 39 as medium, and 35 as high. Seven classes of students enrolled in the same course taught by the researcher were selected for participation in the experiment. All students enrolled in all seven classes agreed to participate in the experiment.

The college student population consisted of approximately 34,000 students enrolled each year in associate’s and bachelor’s degree programs throughout a four county area. There was a college policy of open enrollment to anyone possessing a high school diploma or high school equivalency diploma. Over 70% of the area’s college-bound high school students attended the college following graduation. The student
population was diverse in age, ethnic background, and level of academic achievement. Developmental students, those needing remediation in reading, English, or mathematics, comprised approximately 50% of the enrolling student population. Student enrollment in all courses was by self-selection and academic placement. Placement in developmental mathematics courses was required for a specifically defined set of students testing below college level in math, and highly recommended for all others with low college mathematics placement scores.

Classes chosen for participation in the study were taught by the same developmental math instructor utilizing the same syllabus, supplemental materials, and textbook to teach the classes. Students were asked to voluntarily participate in the study as a part of regular classroom instruction without rewards or remuneration. Participants were randomly assigned within classes to the different treatments and given the assurance that their participation would be completely confidential and anonymous. Volunteers were also given access to all video treatments at the end of the study.

Materials

Instructional materials developed for the study were pilot tested by 20 developmental mathematics students prior to implementation. This process allowed for evaluations of clarity, reliability, and necessary instructional time.

Instruction. The instructional materials consisted of a four equivalent video presentations, each containing the same three examples of graphing linear equations. The presentations were identical in content, but differed in the instructional design strategies employed. A single topic was addressed by the instruction, graphing linear equations, an algebraic procedure frequently confused
by developmental math students and important for students to master in early algebra.

*Treatments.* Four different treatments consisted of: (a) verbal signals only instruction, (b) visual signals only instruction, (c) visual + verbal signals instruction, and (d) instruction with neither visual nor verbal signaling. The image of the instructor narrating the video was included as part of the visual signaling strategies (see Appendix A). Because the purpose of the study was to determine if signaling strategies influenced the success of adult developmental mathematics students, the researcher used a knowledge pretest to establish beginning knowledge (see Appendix B), an immediate knowledge posttest to evaluate math content knowledge learned during the instruction (see Appendix C) and a delayed knowledge posttest to evaluate knowledge retained after five to seven days (see Appendix D). Students were randomly assigned within classes to one of the four instructional treatments with the no-signals instruction counting as the control group.

The instruction was designed to be completed independently by the students in a 45 minute class session. Time was allowed to vary based on prior research that instructional time between groups learning from text was not a factor in learning and retention (Wittrock & Alesandrini, 1990). The worked examples were mathematically the same for all instructional groups; only the design of the signaling treatments differed. Additionally, the narration for all instructional groups was the same. Video instruction was recorded with little to no time differences, using identical wording in the scripts and narrated by the same instructor. The following describes the materials used in each treatment.
Verbal signals only group. The verbal signals received by this group included sequencing numbers and words, headings, labels, and connecting words (e.g., after, then, therefore). Emphasis signals were added to this treatment through the instructor's vocal inflection and significant pauses for emphasis in the narration (see Appendix E); however, the participants did not see the instructor.

Visual signals only group. Emphasis signals were added to the instruction for the visual signals only group (see Appendix F). Color, underlining, arrows, and circles were included to encourage attention and organization. The instructor’s image as narrator was added to this treatment, providing emphasis and attention cues with hand motions (e.g., pointing) and facial expression. The narration for the visual signals only group contained minimal vocal inflection and no significant pauses (see Appendix G). Additionally, the visual signals included fading in and out the information and graphics timed to the narration.

Visual signal + verbal signals group. The visual + verbal signals group received materials combining both the visual and verbal signaling strategies. Participants viewed the instructor in the video, and the narration done by the instructor included vocal inflection and significant pauses for emphasis (see Appendix E).

No-signals group. The no-signals group was the control, and used material that did not include signaling strategies (see Appendix H). The narration for this group was the same as the visual signals only group, containing minimal vocal inflection and no significant pauses (see Appendix G).
**Delivery.** The video instructional treatments were delivered to students through a computer-based system using the Internet. Participants were able to pause, backup, and repeat video instruction as is consistent with learner control of online video instruction. Students viewed the videos independently in a computer lab setting with identical computer displays and headphones.

**Measures**

All assessment instruments designed for the study were paper-based, and are described as follows:

**Achievement tests.** A knowledge pretest was given four weeks prior to the instructional session to determine prior knowledge (see Appendix B). The knowledge pretest consisted of problems similar to the knowledge posttest problems, but employed different numbers.

Immediate and delayed knowledge posttests, consisting of similar and novel problems addressing graphing linear equations knowledge, were given immediately following the instructional session and five to seven days following completion of the instruction, respectively (see Appendix C; see Appendix D). Test items consisted of solving and graphing linear equations using the point-plotting method (see Appendix I).

Fourteen test problems provided 53 individually evaluated achievement points (see Table 2). Similar items, 41 of the 53 achievement points evaluated by the posttests, closely resembled instructional example problems, but differed in the numbers employed. Similar items on the delayed knowledge test were the same as immediate knowledge test items, but used different numbers. Novel problems, 12 of the 53 points evaluated by the posttests, were not identical to instructional problems, and required
application of learned mathematical procedures. Knowledge tests were reviewed by three experts to establish content validity, and internal consistency reliability was established with a piloted test group of 20 enrolled developmental algebra students who had completed instruction on graphing linear equations. The internal consistency reliability for the pilot test was .94 as calculated with Kuder-Richardson Formula 20 (KR-20), with a reliability of .93 for novel problems and .94 for similar problems. The internal consistency reliability in the study was calculated as .96 with the 103 participants taking the immediate posttest. A reliability of .94 for novel problems and .95 for similar problems was calculated for the study posttest.

Table 2

Overview of achievement posttests.

<table>
<thead>
<tr>
<th>Items</th>
<th>Number of items</th>
<th>Number of points</th>
<th>Sample Items with scoring</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Similar</td>
<td>10</td>
<td>41</td>
<td>“Find two points on the line by completing the table. Then graph the line.”</td>
<td>.95</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Scoring: 1 point for each of the 5 steps in the problem.</td>
<td></td>
</tr>
<tr>
<td>Novel</td>
<td>4</td>
<td>12</td>
<td>“Graph the line by finding and plotting the intercepts.”</td>
<td>.94</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Scoring: 1 point for each of the 5 steps in the problem. Steps 4 and 5 (graphing the</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>points and line) were considered similar items.</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td>53</td>
<td></td>
<td>.96</td>
</tr>
</tbody>
</table>

Cognitive load. Participants’ attitudes and opinions concerning the instructional treatments were measured with a modified version of the NASA Taskload (NASA-TLX) questionnaire originally developed by Hart and Staveland
(1988). The questionnaire was administered immediately following the instructional video section with the exception of the mental demand question asked after each instructional problem. Participants were asked to respond to a single mental demand question (How hard did you have to work to understand the instruction?) after viewing each of the three examples in the assignment. Mental demand reported by instructional example was used to evaluate cognitive load based on the assumption that individuals are able to evaluate their own cognitive processes and report on the level of mental demand (Paas et al., 2003).

Participants were instructed to circle a number on a five-point Likert scale for each mental demand question and each item on the questionnaire. Four cognitive load subscales, (a) mental demand, (b) mental effort, (c) perceived performance, and (d) frustration, were included in the questionnaire (see Appendix J; see Table 3). Items for each subscale were rated on a five-point Likert scale ranging from 0 to 100. A mental demand question asked participants to rank demand following each instructional example on a scale ranging from 0 (very easy) to 100 (very difficult). Two mental effort items questioned the effort applied to the instruction from 0 (low effort) to 100 (high effort). Next, two perceived performance items asked participants to rate their success at learning the material on a scale ranging from 0 (unsuccessful) to 100 (very successful). Finally, participants ranked their frustration level while learning from the instruction on a scale of 0 (very low) to 100 (very high).
Table 3  
*Cognitive load questionnaire examples and points.*

<table>
<thead>
<tr>
<th>Measure</th>
<th>Number of items</th>
<th>Total Points Possible</th>
<th>Sample Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mental Demand</td>
<td>3</td>
<td>300</td>
<td>How hard did you have to work to understand the instruction? In other words, how difficult was this instruction?</td>
</tr>
<tr>
<td>Mental Effort</td>
<td>2</td>
<td>200</td>
<td>How much effort did you give to understanding the instruction? In other words, how hard did you try to understand and remember?</td>
</tr>
<tr>
<td>Perceived Performance</td>
<td>2</td>
<td>200</td>
<td>How successful do you think you were in understanding the graphing linear equations material?</td>
</tr>
<tr>
<td>Frustration</td>
<td>1</td>
<td>100</td>
<td>How frustrated were you during the learning task?</td>
</tr>
</tbody>
</table>

**Interest.** An adaptation of the Perceived Interest Questionnaire (Schraw, Bruning, & Svoboda, 1995) was used to measure participant interest in the video instruction. The questionnaire (see Appendix K) consisted of 13 items using a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), and was reviewed by three experts to determine content validity. Participants responded to specific items on the questionnaire based on treatment group (see Table 4). All participants responded to the first five items on the questionnaire, covering general satisfaction questions that applied to all treatments (e.g., “I would like to learn from more instructional videos like these” and “I clearly understand graphing linear equations after completing the instruction.”) The three groups receiving signaled instruction were asked to respond to additional questions specific to the signaling treatments they viewed. For example, participants receiving verbal signals were queried on the usefulness of headings and labels, while participants receiving visual
signals responded to items involving arrows, circles, graphics, and the instructor’s presence in the video. The resultant data provided different numbers of responses for each group: (a) eight items for the verbal signals group, (b) 10 items for the visual signals group, (c) 13 items for the visual + verbal signals group, and (d) five items for the no-signals group. The average score for the items completed in each participant’s response was calculated for the total interest score, yielding an interest score between 0 and 1 for each participant.

Table 4

*Interest questionnaire examples.*

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of items</th>
<th>Sample Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal</td>
<td>8</td>
<td>The headings helped me to understand and remember the instruction.</td>
</tr>
<tr>
<td>Visual</td>
<td>10</td>
<td>The colors helped me understand how to graph linear equations.</td>
</tr>
<tr>
<td>Visual + Verbal</td>
<td>13</td>
<td>Both of the above Verbal and Visual items.</td>
</tr>
<tr>
<td>No-signals</td>
<td>5</td>
<td>It was easy to understand what I needed to remember from the instruction.</td>
</tr>
</tbody>
</table>

**Procedure**

The experiment took place as part of regular classroom instruction with developmental mathematics students enrolled in seven different classes of the same course taught by the same instructor during the same semester at a mid-size southern state college. The content for the study was focused on graphing linear equations and based on content covered in the course. A knowledge pretest with parallel content to the knowledge posttests was administered four weeks prior to the instructional sessions to
provide a beginning knowledge score. Data collection took place in sessions of students' regularly scheduled mathematics classes using classroom computers. Students completed the instruction as part of a normal class assignment used in the course.

**Session 1.** During the first session, students were given an explanation of the study objectives and participant expectations, including regulations involving voluntary participation and protection of participant anonymity. The importance of the content of the instruction was stressed, as well as the assurance that all instructional treatments and results would be shared with participants following the study. Participants were also assured that all materials would be kept confidential and secure. Participants were then randomly assigned within classes to one of four treatment groups and the instruction and achievement tests were loaded into the online delivery system.

**Session 2.** The next session was instructional, and each student was given the randomly assigned treatment for the instructional unit. Students were not limited in time, and all participants completed the unit within the estimated 45 minute timeframe. Time-on-task was supposed to be automatically recorded during the study, but unavoidable technical difficulties with the online learning management system prevented the data capture. Following the completion of the interest questionnaire, participants were given the immediate knowledge posttest.

**Session 3.** A final session was used to administer the delayed knowledge posttest five to seven days after the instructional session. Students were allowed access to all four versions of instructional videos at the completion of this session.
Data Analysis

Following the instructional sessions, collected data was analyzed and evaluated. Achievement posttest results were analyzed with pretest results as the covariate, while questionnaire data was analyzed separately and in combinations as described in Table 5.

Table 5

<table>
<thead>
<tr>
<th>Data analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypotheses/Research Questions</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>HO1 Participants receiving visually and/or verbally signaled video instruction will score higher on immediate and delayed posttests than participants receiving un­signaled video instruction.</td>
</tr>
<tr>
<td>RQ1 Is there a difference in transfer of learning to novel problems with visual, verbal, or visual + verbal signaling of mathematics instruction?</td>
</tr>
<tr>
<td>RQ2 Is the perception of required cognitive load affected by the different signaling strategies employed?</td>
</tr>
<tr>
<td>RQ3 Is expended mental effort devoted to learning affected by the different signaling strategies employed?</td>
</tr>
<tr>
<td>RQ4 Does signaled and instructor-signdaled mathematics instruction affect learner interest?</td>
</tr>
<tr>
<td>RQ5 Does the ability level of the learner, determined by course entry diagnostic scores, affect the benefits achieved from signaling strategies?</td>
</tr>
</tbody>
</table>
CHAPTER III

RESULTS

This chapter presents the results of the analyses used to evaluate the effects of signaling strategies on achievement, cognitive load, and learner interest. Since a pretest was used to determine prior knowledge, a one-way analysis of variance (ANOVA) was conducted to determine if the pretest scores were equivalent across treatment groups. The 103 participants were randomly assigned to treatments groups, and remained assigned to the same treatment groups throughout the experiment: no-signals ($n = 28$), verbal signals ($n = 22$), visual signals ($n = 28$) and visual + verbal signals ($n = 25$).

Preliminary analysis of the pretest revealed a homogeneity of variances, as assessed by Levene's test of homogeneity of variances ($p = .249$). The results of the analysis revealed that the pretest was not statistically significantly different between different treatment groups, $F(3, 99) = .24, p = .868, \omega^2 = 0.023$.

The following statistical results are organized by hypothesis and research questions, beginning with test performance. This is followed by a presentation of the results related to cognitive load and learner interest. Last, results concerning the effect of learner ability between the treatment groups are presented.

Analysis of Test Performance – Hypothesis

An analysis of covariance (ANCOVA) was run to determine the effect of three different signaling treatments and a control (no-signals) on immediate posttest scores after controlling for pretest scores. Preliminary analysis revealed a linear relationship between pre- and immediate posttest scores for each intervention type, as assessed by visual inspection of a scatterplot. There was homogeneity of regression slopes as the
interaction term was not statistically significant, $F(3,95) = .31, p = .82$. A homogeneity of variances was also found using Levene's test of homogeneity of variance ($p = .06$). There were no outliers in the data, as assessed by no cases with standardized residuals greater than $\pm 3$ standard deviations.

The ANCOVA results showed that there were statistically significant differences in immediate posttest scores between the treatments, $F(3,98) = 5.63, p = .001$, partial $\eta^2 = .15$, after adjusting for pretest scores. Post hoc analysis was performed with a Bonferroni adjustment. Table 6 presents means and standard deviations on unadjusted immediate posttest scores and means and standard errors on adjusted immediate posttest scores for the four groups.

Table 6

*Adjusted and unadjusted immediate posttest scores for signaling treatments with pretest scores as a covariate*

<table>
<thead>
<tr>
<th></th>
<th>Unadjusted</th>
<th></th>
<th>Adjusted</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$n$</td>
<td>$M$</td>
<td>$SD$</td>
<td>$M$</td>
</tr>
<tr>
<td>No-signals</td>
<td>28</td>
<td>13.86</td>
<td>8.78</td>
<td>14.06</td>
</tr>
<tr>
<td>Verbal</td>
<td>22</td>
<td>21.45</td>
<td>12.89</td>
<td>22.12</td>
</tr>
<tr>
<td>Visual</td>
<td>28</td>
<td>26.89**</td>
<td>13.09</td>
<td>26.12**</td>
</tr>
<tr>
<td>Visual + Verbal</td>
<td>25</td>
<td>23.76*</td>
<td>13.43</td>
<td>23.81*</td>
</tr>
</tbody>
</table>

*Note:* $n =$ number of participants, $M =$ Mean, $SD =$ Standard Deviation, $SE =$ Standard Error. Single asterisks denote $p<.05$, and double asterisks denote $p<.005$.

Multiple comparisons showed that there were statistically significant differences in achievement between the no-signals group ($n = 28, 13.86 \pm 8.78$) and both the visual treatment ($n = 28, 26.89 \pm 13.09, p = .001$) and the visual + verbal treatment ($n = 25, 23.76 \pm 13.43, p = .017$) (also see Table 6). Both the observed and adjusted means
showed that students in the visual treatment performed best, followed by students in the visual + verbal treatment, verbal treatment, and no-signals group, in that order.

To evaluate potential differences in test performance on delayed posttest scores between the four groups, a second ANCOVA was run, again controlling for pretest scores. Some attrition occurred in the number of participants due to student absences on the day of the delayed posttest, leaving 84 participants: no-signals (n = 20), verbal signals (n = 18), visual signals (n = 25) and visual + verbal signals (n = 21). Preliminary analysis revealed a homogeneity of regression slopes, $F(3,6) = 1.17, p = .33$. However, Levene’s Test of Equality of Error Variances showed a violation of the assumption of homogeneity of variance, $p = .002$; the analysis was continued due to the robust nature of the procedure even when assumptions are not fully met (Sprinthall, 2007).

The variance in delayed posttest scores was significant, $F(3,79) = 3.50, p = .019$, partial $\eta^2 = .117$, indicating that retention of knowledge varied between treatments. Post hoc analysis, using a Bonferroni adjustment, revealed specific differences represented in Table 7 with means and standard deviations on unadjusted delayed posttest scores and means and standard errors on adjusted delayed posttest scores for the four groups.

A single treatment group, visual (n = 25, 20.48 ± 15.81, $p = .049$), achieved significantly higher scores on delayed posttests than the no-signals, or control, group (n = 20, 10.65 ± 8.11) (also see Table 7). The visual + verbal signals treatment had the highest delayed posttest scores mean (n = 21, 20.57 ± 10.36); however, this score was not statistically significantly different from the no-signals group ($p = .053$).
Table 7

*Adjusted and unadjusted delayed posttest scores for signaling treatments with pretest scores as a covariate*

<table>
<thead>
<tr>
<th></th>
<th>Unadjusted</th>
<th>Adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>M</td>
</tr>
<tr>
<td>No-signals</td>
<td>20</td>
<td>10.65</td>
</tr>
<tr>
<td>Verbal</td>
<td>18</td>
<td>14.00</td>
</tr>
<tr>
<td>Visual</td>
<td>25</td>
<td>20.48*</td>
</tr>
<tr>
<td>Visual + Verbal</td>
<td>21</td>
<td>20.57</td>
</tr>
</tbody>
</table>

*Note: n = number of participants, M = Mean, SD = Standard Deviation, SE = Standard Error. Single asterisks denote p < .05.*

**Analysis of Test Performance, Novel Problems – Research Question 1**

Similar ANCOVA analyses were conducted to examine the effect of signaling treatments on immediate and delayed posttest scores with novel problems. For immediate posttest scores, preliminary analysis revealed a homogeneity of regression slopes, $F(1,97) = .56, p = .46$. Levene’s Test of Equality of Error Variance showed a violation of homogeneity, $p < .001$, and further analysis was continued with this in mind.

After adjusting for pretest scores, immediate posttest scores on novel problems were found to be significantly different between treatments, $F(3,98) = 4.90, p = .003$. Partial $\eta^2 = .13$. Post hoc analysis was again performed with a Bonferroni adjustment, with resultant adjusted and unadjusted means represented in Table 8.

A single significant difference was found in achievement indicated by immediate posttest scores on novel problems. Participants receiving the visual signaled treatment performed significantly higher on immediate posttests with novel problems than the no-signals group ($p = .003$) (also see Table 8). Means for the visual treatment
(3.46 ± 3.61) represented the highest achievement scores, followed by visual + verbal (2.40 ± 2.77), verbal (1.41 ± 2.56), and no-signals (.68 ± 1.54), respectively.

Table 8

Adjusted and unadjusted immediate posttest scores on novel problems for signaling treatments with pretest scores as a covariate

<table>
<thead>
<tr>
<th></th>
<th>Unadjusted</th>
<th></th>
<th>Adjusted</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>No-signals</td>
<td>28</td>
<td>.68</td>
<td>1.54</td>
<td>.76</td>
</tr>
<tr>
<td>Verbal</td>
<td>22</td>
<td>1.41</td>
<td>2.56</td>
<td>1.41</td>
</tr>
<tr>
<td>Visual</td>
<td>28</td>
<td>3.46**</td>
<td>3.61</td>
<td>3.32**</td>
</tr>
<tr>
<td>Visual + Verbal</td>
<td>25</td>
<td>2.40</td>
<td>2.77</td>
<td>2.48</td>
</tr>
</tbody>
</table>

Note: n = number of participants, M = Mean, SD = Standard Deviation, SE = Standard Error. Double asterisks denote $p < .005$.

Another ANCOVA was conducted to determine the effect of signaling treatments on delayed posttest scores with novel problems, again controlling for pretest scores. Preliminary tests revealed a homogeneity of regression slopes as the interaction term was not statistically significant, and the term was not estimable. Additionally the assumption of homogeneity of variance was violated, $p < .001$.

Analysis of delayed posttest scores with novel problems did not reveal significant differences between signaling treatments, $F(3,78) = 2.46$, $p = .069$, partial $\eta^2 = .09$. Results of further analysis revealed no statistically significant difference in delayed posttest scores on novel problems between the treatments, $F(3,78) = 2.46$, $p = .069$, partial $\eta^2 = .09$ after adjusting for pretest scores.
Analysis of Mental Demand – Research Question 2

Mental demand during the instructional session was examined using a one-way analysis of variance (ANOVA). Initial analysis did reveal a violation of Levene’s homogeneity of variances ($p = .019$), but analysis was continued due to the robust nature of the ANOVA procedure (Sprinthall, 2007).

Results of the ANOVA showed a statistically significant difference for mental demand between signaling treatments, $F(3, 99) = 8.105, p = .000, \omega^2 = 0.017$. Table 9 presents means, standard deviations, and confidence intervals on mental demand for the four treatment groups.

<table>
<thead>
<tr>
<th>Mean</th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-signals</td>
<td>28</td>
<td>138.39</td>
<td>65.79</td>
<td>112.88</td>
<td>163.90</td>
</tr>
<tr>
<td>Verbal</td>
<td>22</td>
<td>103.41</td>
<td>95.84</td>
<td>60.92</td>
<td>145.90</td>
</tr>
<tr>
<td>Visual</td>
<td>28</td>
<td>67.86**</td>
<td>63.41</td>
<td>43.27</td>
<td>92.45</td>
</tr>
<tr>
<td>Visual + Verbal</td>
<td>25</td>
<td>52.00**</td>
<td>52.99</td>
<td>30.13</td>
<td>73.87</td>
</tr>
</tbody>
</table>

Note: $n =$ number of participants, $M =$ Mean, $SD =$ Standard Deviation. $SE =$ Standard Error. Double asterisks denote $p < .005$.

The mental demand of the instruction increased from the visual + verbal signals group ($n = 25, 52.00 \pm 52.99$), to the visual signals group ($n = 28, 67.86 \pm 63.41$), to the verbal signals group ($n = 22, 103.41 \pm 95.84$), to the no-signals group ($n = 28, 138.39 \pm 65.79$), in that order. Games-Howell post hoc analysis revealed that the increase from visual ($67.86 \pm 63.41$) to no-signals ($138.39 \pm 65.79$) was statistically significant ($p$
Analysis of Mental Effort, Perceived Performance, and Frustration – Research Question 3

To further evaluate potential differences in cognitive load between treatment groups, a one-way multivariate analysis of variance (MANOVA) was conducted. Three measures of cognitive load were assessed: mental effort, perceived performance, and frustration. Four signaling treatment groups were involved.

Preliminary assumption checking revealed there were no univariate or multivariate outliers, as assessed by boxplot; there was no multicollinearity (effort and performance \( r = .610, p = .000 \), effort and frustration \( r = .617, p = .000 \), and performance and frustration \( r = .633, p = .000 \) ); and there was homogeneity of variance-covariance matrices, as assessed by Box’s M test \( p = .008 \).

There was a statistically significant difference between the signaling treatments on the combined dependent variables, \( F(9, 236) = 2.70, p = .005, \text{Wilks’ } \Lambda = .788, \) partial \( \eta^2 = .08 \). Follow-up univariate ANOVAs showed that both perceived performance \( (F(3, 99) = 4.76, p = .004, \text{partial } \eta^2 = .126) \) and frustration \( (F(3, 99) = 6.32, p = .001, \text{partial } \eta^2 = .161) \) were significantly different between the treatments, using a Bonferroni adjusted \( \alpha \) level of .167. Table 10 presents the means and standard deviations on mental effort, perceived performance, and frustration for the four groups.

Results of the analysis revealed that the mental effort for participants increased from the visual \( (66.96 \pm 49.09) \) to visual + verbal \( (83.00 \pm 52.90) \) to no-signals \( (101.79 \pm 54.83) \) to verbal \( (102.27 \pm 54.51) \) treatments, while perceived performance for
participants increased from the no-signals (104.46 ± 59.71) to verbal (121.59 ± 63.29) to visual (145.54 ± 45.16) to visual + verbal (152.00 ± 36.74), and frustration for participants increased from the visual (23.21 ± 37.22) to visual + verbal (34.00 ± 37.42) to verbal (68.18 ± 68.22) to no-signals (80.36 ± 72.44).

Table 10

<table>
<thead>
<tr>
<th></th>
<th>Mental Effort</th>
<th>Perceived Performance</th>
<th>Frustration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>No-signals</td>
<td>28</td>
<td>101.79</td>
<td>54.83</td>
</tr>
<tr>
<td>Verbal</td>
<td>22</td>
<td>102.27</td>
<td>54.51</td>
</tr>
<tr>
<td>Visual</td>
<td>28</td>
<td>66.96</td>
<td>49.09</td>
</tr>
<tr>
<td>Visual + Verbal</td>
<td>25</td>
<td>83.00</td>
<td>52.90</td>
</tr>
</tbody>
</table>

Note: n = number of participants, M = Mean, SD = Standard Deviation. Single asterisks denote *p<.05.

Follow-up comparisons using the Tukey HSD procedure showed that participants in the visual treatment indicated significantly higher perceived performance scores than participants in the no-signals treatment (*p = .020), and that participants in the visual + verbal treatment reported significantly higher perceived performance scores than participants in the no-signals treatment (*p = .007). Reported levels of frustration also showed significant differences. The no-signals group indicated a greater level of frustration than both the visual treatment (*p = .001) and the verbal + visual treatment (*p = .017).

Analysis of Learner Interest – Research Question 4

A one-way ANOVA was conducted to determine if learner interest was different for groups with different signaling strategies. Since the number of questions per
participant varied based on the treatment group, responses to learner interest questions were averaged for each participant.

Preliminary analysis revealed that there were no outliers, as assessed by boxplot; data was normally distributed for each group, as assessed by Shapiro-Wilk test \( p > .05 \). There was, however, a violation of homogeneity of variances, as assessed by Levene's test of homogeneity of variances \( p = .000 \), and analysis was continued with this in mind.

Results of the ANOVA indicated a significant main effect for treatment group, \( F(3, 99) = 8.17, p = .000, \omega^2 = 0.1725 \). Table 11 displays the means and standard deviations for learner interest for the four treatment groups.

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>( n )</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-signals</td>
<td>28</td>
<td>.6027</td>
<td>.2203</td>
<td>.5189</td>
<td>.6864</td>
</tr>
<tr>
<td>Verbal</td>
<td>22</td>
<td>.7091</td>
<td>.2041</td>
<td>.6186</td>
<td>.7996</td>
</tr>
<tr>
<td>Visual</td>
<td>28</td>
<td>.7848**</td>
<td>.0979</td>
<td>.7469</td>
<td>.8228</td>
</tr>
<tr>
<td>Visual + Verbal</td>
<td>25</td>
<td>.8078**</td>
<td>.1237</td>
<td>.7556</td>
<td>.8600</td>
</tr>
</tbody>
</table>

*Note: n = number of participants, M = Mean, SD = Standard Deviation. Double asterisks denote \( p < .005 \).*

The learner interest increased from the no-signals group \( n = 28, .6027 \pm .2203 \), to the verbal signals group \( n = 22, .7091 \pm .2041 \), to the visual signals group \( n = 28, .7848 \pm .0979 \), to the visual + verbal group \( n = 25, .8078 \pm .1237 \). Games-Howell post hoc analysis revealed that the increase from no-signals to visual \( (p = .1821, 95\% CI (.0648 to .2995)) \) was statistically significant \( p = .001 \), as well as the increase from no-
signals to visual + verbal (.2052, 95% CI (.083 to .3274), \( p = .000 \)), but no other group differences were significant.

**Analysis of the Effect of Learner Ability – Research Question 5**

In an effort to determine the influence of the ability level of the learner on the benefits achieved from signaling strategies on the immediate and delayed posttests, a one-way multivariate analysis of variance (MANOVA) was conducted. Participants were given a diagnostic test the first week of class placing them into three ability level groups: low \( (n = 29) \), moderate \( (n = 39) \), and high \( (n = 35) \). Four treatment groups and three diagnostic levels were involved in the analysis.

Preliminary assumption checking revealed that there were no univariate or multivariate outliers, as assessed by boxplot; there were linear relationships, as assessed by scatterplot; no multicollinearity \( (r = .606, \ p = .000) \), and there was homogeneity of variance-covariance matrices, as assessed by Box's M test \( (p = .003) \). However, there was no homogeneity of variances, as assessed by Levene’s \( (p = .002) \), and subsequent analysis was conducted with this in mind.

Results of the MANOVA revealed that there were no statistically significant differences between the signaling treatments on the combined dependent variables.

\[
F(12, 142) = 1.287, \ p = .233; \ Wilks' A = .813; \ partial \eta^2 = .098.
\]

In a further exploration of the effects of ability level, a one-way ANOVA was conducted to determine if the learner interest differed based on learner ability. Preliminary analysis revealed four outliers, as assessed by boxplot, which were left in the data unchanged; data was normally distributed for low \( (p = .366) \) and moderate \( (p = .115) \) groups, as assessed by Shapiro-Wilk test, and not normally distributed for the
high group ($p = .000$); and there was homogeneity of variances, as assessed by Levene's test of homogeneity of variances ($p = .131$).

ANOVA results showed that interest increased from the low ability group ($.2952 \pm .3724$) to the high ability group ($.2811 \pm .3391$) to the moderate ability group ($.3361 \pm .4471$). However, there were no statistically significant differences found in interest between different ability levels. $F(2, 100) = .196, p = .822$. 
CHAPTER IV

DISCUSSION AND CONCLUSIONS

The purpose of this research was to examine the effects of verbal and visual signaling strategies on procedure learning and learner participation in a video-based environment. Participants completed an instructional video assignment on graphing linear equations using the rectangular coordinate system. Participants viewed either (a) an instructional video with verbal signaling, (b) an instructional video with visual signaling, (c) an instructional video with both visual and verbal signaling, or (d) an instructional video without signaling strategies. This chapter explains the results and discusses their implications for future research and practice.

Test Performance

Achievement test results in this study supported signaling strategies for both immediate and delayed posttests, including novel problems. These results were reinforced by the analysis of the pretest revealing no significant differences in prior knowledge between the treatment groups. Additionally, there were no significant differences in test performance based on the ability level of the learner as determined through course entry diagnostic scores. Therefore, the study supports signaling for video instruction of mathematical procedures equally across ability levels.

Posttest achievement. Results of this study provided support for the hypothesis that signaling strategies would improve immediate learning of procedures for novice adult mathematics learners. Participants who received visual or visual + verbal signaling treatments exhibited better performance on the achievement test taken immediately following the instruction as compared to
participants who received no signals or verbal signals only. Visual signals produced
the strongest improvement in immediate learning followed by visual + verbal
signaling. The instructional treatment using verbal signals also produced higher
immediate posttest scores than the no-signals group, but the difference was not
significant. In other words, test performance was influenced more by visual signals
than by verbal signals. Improvement in learning from signaling is consistent with
the advantages attributed to multimodal instruction containing both visuals and
verbal narration (Mayer & Anderson, 1991). Additionally, the results found support
the argument that signaling reduces cognitive load by providing necessary cues
which aid the learner in selecting and organizing critical information (Dodd &
Antonenko, 2012; Mayer & Moreno, 2003). In this study, visual signaling was
found to be more effective than verbal signaling when learning from instructional
videos while also reporting lower levels of mental demand, suggesting a more
efficient organization of critical cognitive resources.

Results also provided support for visual signaling strategies in improving
retention of learning from video instruction, contrasting with findings by Mautone and
Mayer (2001) and Dey et al., (2009) that exhibited little benefit from signaled narrated
video instruction. The strength of the signals employed is one possible explanation to
these mixed results. While Mautone and Mayer (2001) used colors, arrows, and icons as
visual signals, this study also added instructor image and animation in the form of
fading-in information. In this study, delayed test scores showed significant differences
when participants received visual signals only. The visual + verbal treatment and the
verbal signals only treatments were not shown to be significant in delayed posttest
scores; however, delayed posttest scores improved in all signaling treatments suggesting a trend toward improved retention through signaling. Retention in learning is supported through the combined visual and verbal elements in the instruction; however, all treatments, including the no-signals treatment, could be considered multimodal since they contain both audio narration and visual graphics (Paivio, 1971). Ksobiech’s (1976) argument that learners must be made aware of the importance of visual information in dual mode presentations could be used to support visual signaling, and seems to have been effective in this case. Indeed, typographical signals have been recommended to direct the learner’s attention in text-based and graphical presentations (Loman & Mayer, 1983; Lorch, 1989), and selection and organization of key elements is vital in the creation of effective schema needed to improve retention. The deeper impression indicated by increased retention in this study supports the value of visual signals for learning from video instruction, adding to the research on signaling text-based materials and supporting improved schema creation through signaling (Loman & Mayer, 1983).

**Posttest achievement with novel problems.** Learner performance in solving novel problems also improved in immediate testing when visual signaling strategies were applied; however, adding verbal to visual signaling did not show a significance with novel problems and signaling treatments did not change delayed posttest performance on novel problems. Novel problems, or problems differing from the instructional problems, are believed to require a deeper level of learning than similar problems (Catrambone, 1994). Learners must apply learned procedures in a transfer of learning that makes adjustments for differences in previously studied problems. Results found in this study support the argument that greater
transfer of learning occurs when narrations are signaled (Mayer & Moreno, 2003), and support results found in previous research with signaling novel problems (Lowman & Mayer, 1983).

Although a medium effect ($\eta^2 = .13$) was found supporting signaling for novel problems on the immediate posttest, no significance was found between strategies on delayed posttest performance on novel problems. This lack of difference could be explained by the limited number of novel problems contained on the post tests and the difficulty of learning mathematical procedures for novice learners in a single session. Novel problems accounted for less than a fourth of the immediate and delayed posttest problems, yielding a smaller set of data for analysis. Also, the timeframe of the study allowed only one instructional session. Beginning algebra students frequently need multiple session to understand complex procedures (Brecht & Ogilby, 2008). Additional studies focusing on retention of learning could benefit from the expansion of testing with novel problems and the increase of instructional sessions.

**Summary.** Achievement test performance improved with signaling treatments in immediate and delayed posttests, and immediate posttests of novel problems. The visual signaling only strategy showed the greatest achievement test differences, followed by visual + verbal and verbal only, in that order. Visual signals, either alone or combined with verbal signals, proved to be the strongest indicator of test performance overall, while also reporting the lowest level of mental demand. These results support the use of color and type settings in guiding the learner's attention in graphical presentations (Fleming & Levie, 1978). The inclusion of the instructor as narrator of the visual treatments can be credited in part
with aiding retention and transfer of learning by increasing the personalization of the instruction. Moreno and Mayer (2004) found learners benefitted from personalized messages resulting in improved retention and performance in solving novel problems. Visual signals received from the visual image of the instructor included pointing and facial expressions, aiding the learner by directing attention to key elements in the instruction. Visual signals directly impacted both learning from instructional video and retention of learning. This impact could be that the result of learners connecting more with the on-screen presence of the instructor leading to increased attention to the instruction and other signals. Dey et al., (2009) also found a learner preference for instructor images, but no significant difference in retention or learning. One variation that should be explored in future studies is the value of visual signals that do not include instructor image.

**Cognitive Load**

**Mental demand.** Visual signaling, with and without verbal signaling, was found to lessen the mental demand of the instruction when learning mathematical procedures, providing support for the cognitive theory of multimedia learning (Mayer & Moreno, 2002). Signals, especially visual signals in video instruction, positively impacted the creation of new knowledge as indicated by improved posttest performance. This improvement in learning may be explained by the suggestion that effective signaling can reduce cognitive load, allowing for the more effective utilization of working memory for schema creation (Mayer, 2009).

Mental demand questions answered after each instructional problem indicated a strong effect ($\eta^2 = .25$) for signals decreasing cognitive load. Learners reported lower
demand on mental resources with each signaling strategy employed; however, visual +
verbal signaling reported the lowest mental demand with visual only signals reporting
the second lowest mental demand. While verbal only signaling proved effective over
the no-signals treatment, the difference was not significant. Learners therefore indicated
an increased ease of understanding the instruction when visual signals were employed,
indicating an easing of demands on working memory resulting in increased schema
formation as indicated by test performance.

**Mental effort, perceived performance, and frustration.** Three measures of
cognitive load associated with the video instruction were examined in survey questions:
(a) mental effort, (b) perceived performance, and (c) frustration. These learner attitudes
related to cognitive load showed mixed results with signaling strategies. First, the
mental effort the learner applied to the instruction was not significantly affected by the
signaling strategies employed. Although no significant differences were found in mental
effort between signaling groups, it should be noted that visual only and visual + verbal
group participants reported less mental effort than both the no-signals and verbal only
signaling groups. Second, the learner’s perception of their own performance was
improved by visual signaling and by visual + verbal signaling over the no-signals group.
and third, learner frustration associated with the learning task was significantly
decreased by visual signaling and visual + verbal signaling over no signaling.

The reported differences in frustration and perceived performance could be
explained by examining all three attitudes together. Learners with no signaling
strategies or verbal only strategies reported higher levels of frustration, higher mental
effort, and lower perceived performance than participants in visual only and visual +
verbal treatments. These results are consistent with the relationship proposed by Salomon (1981) that suggests learner confidence may decrease as perceived effort required increases.

Other research by Morrison (2013) found support for Salomon’s position that learners may feel less confident in their ability to complete a task that appears to require more effort. In a study on the effects of generative strategies used in learning from simulations, results supported the current study in that participants with the highest reported mental effort reported the lowest levels of performance. Perceived performance in this study indicated that signaling video instruction raised learner confidence levels, with visual signals only and visual + verbal signals showing the greatest improvements. Additionally, this increase in perceived self-efficacy was noted with a decrease in mental effort when visual signals were employed and the lowering of frustration levels reported from the same signaling strategy treatments, visual only and visual + verbal.

Although Bandura (1977) discusses the link between self-efficacy and effort, the relationship found in this study does not support improved self-efficacy increasing learner effort. In fact, the opposite relationship is indicated. Learners confident of their ability to understand the instructional treatments reported lower expended effort in learning the material. Since reported mental effort and frustration levels decreased as signaling moved from no-signals to verbal to visual to visual + verbal, the results indicate that participants reported increased instructional difficulty when signaling strategies were not present. It is interesting to note that both visual signaling treatments reported lower levels of mental demand, mental effort, and frustration, indicating that
participants may have found it necessary to work harder when visual signaling strategies were not present.

**Interest**

Learner interest also showed significant differences when visual signals were employed, with visual and visual + verbal groups exhibiting significantly higher levels of interest than the no-signals group. This finding may support the addition of the instructor image as narrator as an element of visual signaling. On-screen computer agents have been associated with increased learner interest (Hidi & Baird, 1988) and student enjoyment (Andre et al., 1998). Improved learner interest reported in this study supports both increased interest and learning in strategies associated with the instructor's image on the screen. Additional support can be found in participant comments. One learner commented, "I really, really like having a person in the video talking to me," and another wrote, "The video-teacher helped me learn." Again, the ability level of the learner, measured by beginning course diagnostic scores, had no significant effect on learner interest, suggesting the signaling strategies were equally effective regardless of ability level of the learner.

**Limitations**

Several limitations to the current study should be noted. The instructional section conducted in a single class session did not encourage deep learning of complex mathematical procedures or mathematical reasoning. While test results did show significant differences between treatment groups, additional instructional sessions could provide insight into the differences between verbal and visual signals for video when utilized over multiple class sessions. Additionally, this study consisted of a single topic.
while additional topics could add insight into signaling strategies across topic areas.

Other difficulties presented in the study were consistent with authentic research conducted in actual classrooms. For example, initial analysis of data frequently revealed non-homogeneous groups, and learners were asked to self-report on cognitive load and interest variables. These factors could possibly be controlled in a non-classroom experiment with volunteers from a variety of disciplines.

The present study originally planned to measure time-on-task through the institution learning management system (LMS), but technical difficulties internal to the LMS prevented the data capture. This additional piece of data could lend insight into cognitive load required by the different signaling strategies when considering time on task. Another item of interest to research with video instruction is the number of times a learner pauses or repeats the instruction. In this study, participants were asked to contribute the number of pauses and repeats, but few volunteered this information. Automatic capture of this data could add to research examining the effect of signaling on learner interest and mental effort.

**Implications**

This research study indicated that signaling strategies for video instruction can be valuable instructional design considerations. Participants receiving video instruction with visual signaling strategies (visual only and visual + verbal) demonstrated improved performance and learner attitudes. Visual signals proved to be effective in several areas: (a) test achievement in immediate and delayed posttests, and with regular and novel problems, (b) learner perceptions of mental effort, performance, and frustration, and (c)
learner interest. The study yielded interesting implications for both research and practice when learning from instructional video.

Research
While verbal signals have proven to be effective strategies for print-based materials, visual signals provided the greatest measurable differences in all areas of this research study. The strength of visual over verbal signals for video instruction suggests further research to evaluate typographical visual signals without the presence of an instructor image. Additional research is also needed to explore signaling for video instruction across disciplines. Mathematics instruction differs greatly from other subject areas, and is generally not considered to be text oriented. The effect of verbal signals for a more textual subject, such as English, could be a valuable addition to the research on signaling for multimedia. While this study presented the opportunity to conduct research with authentic classrooms of students engaged in learning the material presented, a more controlled study could provide data with fewer variances in homogeneity. Also, a computer-controlled delivery method with real-time capture of time expended on both task and assessment would enrich the data captured and provide for additional analysis.

Practice
The study provides support for the use of visual signaling in the design of instructional video. Several suggestions can be made from examination of the results of the study. Of particular importance is the presence of the instructor as a visual signaling agent, which led to both increases in learning and interest while decreasing frustration. Verbal signals, found to be extremely valuable in text-based instruction, need to be carefully blended with their visual counterparts in order to not overwhelm the learner.
This study found the greatest value in visual signals, including colors, arrows, animation, and instructor image. While these signals can be costly and time consuming to incorporate into video instruction, results suggest their value to the student in reducing cognitive load and aiding schema formation.

**Conclusions**

This study provides a necessary addition to the body of research involving signaling studies with multimedia. Existing studies have primarily focused on print-based materials, while instruction is increasingly moving toward the video format. Strategies that direct attention and assist the learner in improving organization and integration with prior knowledge were examined with a highly complex subject and novice learners, in a media of vital importance to instructional design.

Signaling strategies were also examined in verbal and visual categories to explore the contribution of each to improving learning with video instruction through reducing cognitive load, adding to the research guided by cognitive load theory (Sweller et al., 2011). The effectiveness of visual signaling for video instruction was demonstrated in this study, including test performance, retention, and learner attitude. While verbal signaling strategies showed benefits to learning, differences were small, indicating the value of visual techniques employed with a visual media. Verbal signals have been the focus of print-based research in signaling in the past. This study illustrates the differences in verbal and visual signals for video instruction, using mathematical procedures that may not lend themselves to verbal signaling.
REFERENCES


Journal of Educational Psychology, 76(6), 1089-1105. doi: 10.1037/0022-0663.76.6.1089


Appendix A. Signaled and Un-signaled Video Instruction Sample Screens

Visual + Verbal Treatment

Example 1: \( y = -4x \)

No-signals Treatment

| \( x \) | \( y \) | \( y = -4x \)  
|---|---|---|
| 1  | -4  | \( y = -4(1) \)  
| 0  | 0   | \( y = -4(0) \)  

\( y = -4x \)  
\( \text{Let } x = 1 \)  
\( y = -4(1) \)  
\( y = -4 \)  

\( y = -4x \)  
\( \text{Let } x = 0 \)  
\( y = -4(0) \)  
\( y = 0 \)
Appendix B. Knowledge Pretest Items.

1. The y-axis and x-axis divide the rectangular coordinate system graph into four quadrants. Label the four quadrants on the graph below.

2. The y-intercept is the point where a line crosses the __________.

3. For the x-intercept, _____ will always equal zero.
Use the points to graph the line.

4. \((4,3)\) \((-1, -3)\)

5. \((-4, 5)\) \((4, -2)\)
Complete the ordered pair so that it is a solution of the given linear equation.

6. \( y = -x + 5 \)
   a. \((4, \underline{\quad})\) b. \((7, \underline{\quad})\) c. \((0, \underline{\quad})\)

7. \(3x + y = -9\)
   a. \((-2, \underline{\quad})\) b. \((0, \underline{\quad})\) c. \((1, \underline{\quad})\)

Find two points on the line by completing the table. Then graph the line.

8. \(y = -2x + 4\)

\[
\begin{array}{c|c}
 x & y \\
\hline
 & \\
 & \\
 & \\
\end{array}
\]

9. \(7x + 2y = 0\)

\[
\begin{array}{c|c}
 x & y \\
\hline
 & \\
 & \\
 & \\
\end{array}
\]
Graph the line by finding and plotting its intercepts.

10. \( x + y = -4 \)  
   \( y \)-int = ________  
   \( x \)-int = ________

11. \( x = 3y \)  
   \( y \)-int = ________  
   \( x \)-int = ________
Graph the line.

12. $4x + 6y = 0$

13. $5y = x$

14. $4x = 4 - 8y$
Appendix C. Immediate Knowledge Posttest Items.

1. The y-axis and x-axis divide the rectangular coordinate system graph into four quadrants. Label the four quadrants on the graph below.

2. The y-intercept is the point where a line crosses the _____________.

3. For the x-intercept, ______ will always equal zero.
Find the intercepts for the equation and use them to graph the line.

4. \((3,4)\) \((-2,-2)\)

5. \((-1,5)\) \((4,-3)\)
Complete the ordered pair so that it is a solution of the given linear equation.

6. \( y = -x + 7 \)
   a. \((4, \_\_\_\_\_)\)  
   b. \((7, \_\_\_\_\_)\)  
   c. \((0, \_\_\_\_\_)\)

7. \( 7x + y = -9 \)
   a. \((-2, \_\_\_\_\_)\)  
   b. \((0, \_\_\_\_\_)\)  
   c. \((1, \_\_\_\_\_)\)

Find two points on the line by completing the table. Then graph the line.

8. \( y = -2x + 6 \)

<table>
<thead>
<tr>
<th>( x )</th>
<th>( y )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>


9. \( 7x + 4y = 0 \)

<table>
<thead>
<tr>
<th>( x )</th>
<th>( y )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Graph the line by finding and plotting its intercepts.

10. \( x + y = -6 \)

\[ y \text{-int} = \]

\[ x \text{-int} = \]

11. \( x = -2y \)

\[ y \text{-int} = \]

\[ x \text{-int} = \]
Graph the line.

12. $2x + 3y = 0$

13. $3y = x$

14. $2x = 2 - 4y$
Appendix D. Delayed Knowledge Posttest Items.

1. The y-axis and x-axis divide the rectangular coordinate system graph into four quadrants. Label the four quadrants on the graph below.

2. The y-intercept is the point where a line crosses the ______________.

3. For the x-intercept, ______ will always equal zero.
Use the points to graph the line.

4. \((4,2) \quad (-3, -3)\)

5. \((-4,2) \quad (5, -1)\)
Complete the ordered pair so that it is a solution of the given linear equation.

6. \( y = -x + 6 \)
   a. \((3,\, \_\_\_\_\_\)\)  
   b. \((6,\, \_\_\_\_\_\)\)  
   c. \((0,\, \_\_\_\_\_\)\)

7. \( 2x + y = -9 \)
   a. \((-1,\, \_\_\_\_\_\)\)  
   b. \((0,\, \_\_\_\_\_\)\)  
   c. \((2,\, \_\_\_\_\_\)\)

Find two points on the line by completing the table. Then graph the line.

8. \( y = -3x + 6 \)

\[
\begin{array}{c|c}
\hline
x & y \\
\hline
1 & \\
5 & \\
\hline
\end{array}
\]

9. \( 5x + 3y = 0 \)

\[
\begin{array}{c|c}
\hline
x & y \\
\hline
1 & \\
5 & \\
\hline
\end{array}
\]
Graph the line by finding and plotting its intercepts.

10. $x + y = -3$  
   y-int = ________
   x-int = ________

11. $x = -3y$  
   y-int = ________
   x-int = ________
Graph the line.

12. $2x + 2y = 0$

13. $4y = x$

14. $3x = 3 - 5y$
Appendix E. Visual + Verbal Signaled Video Narration

Narration is numbered to align with the instructional slides. Visual signaling includes the appearance of information to match the words in the narration and pauses for emphasis. Verbal signaling includes vocal inflection emphasis represented by the words in bold print in the narration.

1. This lesson will introduce you to plotting points and graphing straight lines on the Rectangular Coordinate System.

2. Linear equations can be drawn as straight lines on the graph known as the Rectangular Coordinate System. This graph has two numbered lines, the y-axis and the x-axis, that help us identify points and lines.

3. The y-axis and x-axis divide the rectangular coordinate system graph into four quadrants, I, II, III, and IV.

4. Points are identified on the rectangular coordinate system graph by their x and y values as ordered pairs, written (x, y).

5. The x coordinate is always listed first, and it represents the distance from 0 to the left or right, following the x-axis.

6. The y coordinate is always listed second, and it represents the distance from 0 up or down, following the y-axis.

7. For example, beginning at the center of the graph, where the x and y axis cross, is the point (0,0).

8. To locate another point on the graph such as (-1,5) we would start at (0,0) and go left 1 space.

9. Another point, (-2,-2) would be found by going left 2 spaces from (0,0) and then down 3 spaces.

10. A third point, (2, -4) would be found by going right 2 spaces, then down 4 spaces.

11. Remember, when plotting points, always begin at the center (0,0); next follow the first number in the coordinates on the x-axis, going left or right;

12. Last, follow the second number in the coordinates up or down like the y-axis.

13. Now that we know how to plot points on our graph, let’s learn to graph lines. It takes only 2 points to draw a line on the rectangular coordinate system. For example, we’ll plot the points (3.4) and (-2,-2) on the graph below, and then draw a line that goes through both points.

14. (3,4) is found by going right 3 spaces from (0,0) and then up 4 spaces.

15. (-2,-2) is found by going left 2 spaces from (0,0) and then down 2 spaces.
24. After we have the 2 points plotted, we can draw our line.
25. To graph linear equations, we simply need \textbf{2 points} that work for the equation.

\textit{Remember....}

To graph a line by Point-Plotting:

1 - \textbf{Pick a value} for either \textit{x} or \textit{y}.
2 - \textbf{Solve the equation} for the unknown value.
3 - \textbf{Plot the point}, and \textbf{repeat} these steps for another value.

Hint: pick numbers that make the equation easy to solve.
26. Let’s look at this linear equation for an example. \textit{First}, since the equation is \textbf{already solved for \textit{y}}, we’ll \textbf{choose a value for \textit{x}}. This will make our math easier. We’ll let \textit{x} = \textbf{the number 1}.

27. Now we \textbf{replace \textit{x}} in our equation with the \textbf{number 1}, and \textbf{solve for \textit{y}}.
28. We then multiply \(-4\) times \(1\), which gives us \(-4\). \textit{Y}, therefore, is \textbf{equal to} \(-4\), and our point is \((1,-4)\).

29. Let’s find \((1,-4)\) and place it on our graph. \textit{Remember}, we start from \((0,0)\) and move in a \textbf{positive} direction on the \textit{x axis} \(1\) space, then in a negative direction on the \textit{y axis} \(4\) spaces to find \((1,-4)\).

30. \textit{Next}, we’ll choose another value for \textbf{either \textit{x} or \textit{y}} and solve the equation again to find a second point. We’ll let \textit{x} = \textbf{0} for this one.

31. Just like before, we \textbf{replace \textit{x}} in our equation with the \textbf{number 0}, and \textbf{solve for \textit{y}}.

32. We then multiply \(-4\) times \(0\), which gives us \(0\). \textit{Y}, therefore, is \textbf{equal to} \(0\), and our point is \((0,0)\).

33. Again, we’ll find \((0,0)\) and place it on our graph. Since this is where the \textit{x} and \textit{y} axis cross, it is an easy point to find.
34. Now it is just a matter of \textbf{drawing a line} that goes through both points, and we’ve graphed the equation \textit{y} = \(-4x\).

35. A second example, \textit{y} = \(-x+2\), can be solved using the same method. \textit{1st}, \textbf{choose a value for \textbf{either \textit{x} or \textit{y}}}, and \textbf{solve for the other variable}. In this example I’ve decided to let \textit{x} = \(-2\).

36. When I \textbf{replace \textit{x}} in my equation with \textbf{2}, I have \textit{y} = \(-2+2\).
37. Or \textit{y} = \(0\). My \textit{first point}, therefore, is \((2,0)\), which I place on my graph by moving \textit{2} spaces to the \textbf{right} from \((0,0)\) on the \textit{x axis}, and \textbf{zero} spaces for \textit{y}.
Since my \textit{y} coordinate is \(0\), my point is actually \textbf{on} the \textit{x-axis}.

38. Now I need to choose another value for \textit{x} or \textit{y} and solve the equation again to find a second point. I’ll \textbf{let \textit{x} = -2} this time.

39. I’ll \textbf{replace \textit{x}} in my equation with \textbf{-2}, being careful not to lose the \textbf{negative sign} that was \textbf{already} in the equation.
40. This gives me \textit{2 negatives together}, which becomes \textbf{positive}. Remember, it is just like \textbf{distributing the negative} or multiplying \textbf{negative 1 times anything in the parenthesis}. I now have \textit{y} = \(2+2\).

41. Which is \textit{y} = \(4\).
42. Once again, we find our point on the graph by moving in a **negative x direction**, left 2 spaces from (0,0), then **up** 4 spaces for our **positive y** coordinate.

43. Last, **draw a line** that goes through both points, and you’ve graphed y=-x+2 by plotting points.

44. For our last example, let’s graph x+3y=6. This equation is a little more complicated since it is **not already solved for either x or y**. In other words, we don’t have x or y alone on one side of the equation. We still **follow the same steps**, however, and **choose a value** for either x or y.

45. I’ve decided to let y=0 because I think it will make my equation easy to solve.

46. When I **replace y with 0** in the equation, I have x + 3 times 0 = 6.

47. Since 3 times 0 = 0,

48. The solution is simple, and x = 6.

49. I can now **find the point** (6,0) on my graph by moving 6 spaces in a **positive x** direction from (0,0), and **0 spaces** for the y coordinate. This point is also **on** the x axis.

50. For my second point, I’ve chosen to let x=0 this time.

51. For the next step, I replace x with 0 in my equation, giving 0+3y=6.

52. Simplifying, the equation reads **3y=6**.

53. And I can **solve for y** by dividing both sides of the equation by the coefficient of y, or 3. This gives us y=2. So, our second point on the line is **(0,2)**.

54. We can then find our second point on the graph. Since the x coordinate is 0, we **don’t move anywhere** on the x axis, but we do need to **move up 2** spaces on the y axis because of a y coordinate of **positive 2**.

55. Once both points are plotted, we again **draw a line** that goes through both. and we’ve completed our graph of x+3y=6.
### Appendix F. Signaled Video Instruction Examples

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<thead>
<tr>
<th>The Four Quadrants and Plotting Points</th>
<th>The Four Quadrants and Plotting Points</th>
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<tr>
<td><img src="image1" alt="Diagram of the four quadrants" /></td>
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</thead>
<tbody>
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Example 1: \( y = -4x \)

Graphing Lines by Point-Plotting

Example 1: \( y = -4x \)

Graphing Lines by Point-Plotting

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Graphing Lines by Point-Plotting

Example 1: \( y = -4x \)

Graphing Lines by Point-Plotting

Example 1: \( y = -4x \)
Example 1: \( y = -4x \)

Example 2: \( y = -x + 2 \)
Example 2: $y = -x + 2$

Example 3: $x + 3y = 6$

Example 3: $x + 3y = 6$

Example 3: $x + 3y = 6$
**Example 3: \( x + 3y = 6 \)**

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<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>0.66</td>
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**Example 3: \( x + 3y = 6 \)**

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<tbody>
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<td>0</td>
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<td>1.66</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
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**Example 3: \( x + 3y = 6 \)**

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**Example 3: \( x + 3y = 6 \)**

<table>
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<tr>
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<td>1</td>
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**Example 3: \( x + 3y = 6 \)**

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</tr>
<tr>
<td>3</td>
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Appendix G. Visual and No-signals Video Narration

Narration is numbered to align with the instructional slides. Minimal vocal inflection and no significant pauses will be included

1. This lesson will introduce you to plotting points and graphing straight lines on the Rectangular Coordinate System. Linear equations can be drawn as straight lines on the graph known as the Rectangular Coordinate System. This graph has two numbered lines, the y-axis and the x-axis, that help us identify points and lines. The y-axis and x-axis divide the rectangular coordinate system graph into four quadrants, I, II, III, and IV.

2. Points are identified on the rectangular coordinate system graph by their x and y values as ordered pairs, written (x, y). The x coordinate is always listed first, and it represents the distance from 0 to the left or right, following the x-axis. The y coordinate is always listed second, and it represents the distance from 0 up or down, following the y-axis. For example, beginning at the center of the graph, where the x and y axis cross, is the point (0,0). To locate another point on the graph such as (-1,5) we would start at (0,0) and go left 1 space, and up 5 spaces. Another point, (-2,-3) would be found by going left 2 spaces from (0,0) and down 3 spaces. And a third point, (2, -4) would be found by going right 2 spaces, and down 4 spaces. When plotting points, begin at the center (0,0); follow the first number in the coordinates on the x-axis, going left or right; and follow the second number in the coordinates up or down like the y-axis.

3. Now that we know how to plot points on our graph, let’s learn to graph lines. It takes only 2 points to draw a line on the rectangular coordinate system. For example, we’ll plot the points (3,4) and (-2,-2) on the graph below, and then draw a line that goes through both points. (3,4) is found by going right 3 spaces from (0,0) and up 4 spaces. (-2,-2) is found by going left 2 spaces from (0,0) and down 2 spaces. After we have the 2 points plotted, we can draw our line.

To graph linear equations, we simply need 2 points that work for the equation. Remember....

To graph a line by Point-Plotting:
Pick a value for either x or y.
Solve the equation for the unknown value.
Plot the point, and repeat these steps for another value.
Hint: pick numbers that make the equation easy to solve.

4. Let’s look at this linear equation for an example. Since the equation is already solved for y, we’ll choose a value for x. This will make our math easier. We’ll let x = the number 1.
Replace x in our equation with the number 1, and solve for y. We multiply -4 times 1, which gives us -4. Y is equal to -4, and our point is (1,-4). Let’s find
(1,-4) and place it on our graph. Remember, we start from (0,0) and move in a positive direction on the x axis 1 space, then in a negative direction on the y axis 4 spaces to find (1,-4). We’ll choose another value for either x or y and solve the equation again to find a second point. We’ll let x=0 for this one. We replace x in our equation with the number 0, and solve for y. We multiply -4 times 0, which gives us 0. Y is equal to 0, and our point is (0,0). We’ll find (0,0) and place it on our graph. Since this is where the x and y axis cross, it is an easy point to find. Now it is just a matter of drawing a line that goes through both points, and we’ve graphed the equation $y=-4x$.

5. A second example, $y=-x+2$, can be solved using the same method. Choose a value for either x or y, and solve for the other variable. In this example I’ve decided to let x=2. When I replace x in my equation with 2, I have $y=-2+2$, or y=0. My first point, therefore, is (2,0), which I place on my graph by moving 2 spaces to the right from (0,0) on the x axis, and zero spaces for y. Since my y coordinate is 0, my point is actually on the x-axis. I need to choose another value for x or y and solve the equation again to find a second point. I’ll let x=-2. I’ll replace x in my equation with a -2, being careful not to lose the negative sign that was already in the equation. This gives me 2 negatives together, which becomes positive. It is just like distributing the negative or multiplying negative 1 times anything in the parenthesis. I now have $y=2+2$, which is y=4. We find our point on the graph by moving in a negative x direction, left 2 spaces from (0,0), then up 4 spaces for our positive y coordinate. Draw a line that goes through both points, and you’ve graphed $y=-x+2$ by plotting points.

6. For our last example, let’s graph $x+3y=6$. This equation is a little more complicated since it is not already solved for either x or y. In other words, we don’t have x or y alone on one side of the equation. We still follow the same steps, however, and choose a value for either x or y. I’ve decided to let y=0 because I think it will make my equation easy to solve. When I replace y with 0 in the equation, I have $x + 3 \times 0 = 6$. Since 3 times 0 = 0, the solution is simple, and x = 6. I can find the point (6,0) on my graph by moving 6 spaces in a positive x direction from (0,0), and 0 spaces for the y coordinate. This point is on the x axis. For my second point, I’ve chosen to let x=0. I replace x with 0 in my equation, giving $0+3y=6$. Simplifying, the equation reads $3y=6$, and I can solve for y by dividing both sides of the equation by the coefficient of y, or 3. This gives us y=2. Our second point on the line is (0,2). We can find our second point on the graph. Since the x coordinate is 0, we don’t move anywhere on the x axis, but we do need to move up 2 spaces on the y axis because of a y coordinate of positive 2. Once both points are plotted, we again draw a line that goes through both, and we’ve completed our graph of $x+3y=6$. 
Appendix H. Un-signaled Video Instruction Examples

The Four Quadrants and Plotting Points

Graphing Lines by Point-Plotting

Example 1 \( y = -4x \)

Example 2 \( y = -x + 2 \)

Example 3 \( x + 3y = 6 \)
## Appendix I. Blueprint for Knowledge Posttests

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<th>Novel Problems</th>
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<td>4</td>
<td>4</td>
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<tr>
<td>Solve linear equations in two variables.</td>
<td>6</td>
<td>4</td>
<td>10</td>
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<tr>
<td>Graph points and linear equations in two variables by point-plotting.</td>
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<td>14</td>
<td>14</td>
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<tr>
<td>Complete ordered pairs.</td>
<td>13</td>
<td>6</td>
<td>19</td>
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<tr>
<td>Graph linear equations in two variables using intercepts.</td>
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Appendix J. Cognitive Load Questionnaire

Mental Demand – measure repeated for each instructional example:
   a. How hard did you have to work to understand the instruction?
      In other words, how difficult was this instruction?

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   (Very easy)  (Very difficult)

Effort:
   a. How much effort did you give to understanding the instruction? In other words, how hard did you try to understand and remember?

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   (Low effort)  (High effort)

   b. Was the instruction easy or demanding?

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   (Easy)  (Demanding)

Performance:
   a. How satisfied were you with your ability to learn the graphing linear equations material?

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   (Unsuccessful)  (Very successful)

   b. How successful do you think you were in understanding the graphing linear equations material?

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   (Unsuccessful)  (Very successful)

Frustration Level:
   a. How frustrated were you during the learning task?

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   (Very low)  (Very high)
Appendix K. Satisfaction Questionnaire

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<th>Neither agree nor disagree</th>
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</tr>
</thead>
<tbody>
<tr>
<td>I thought the instruction was very interesting.</td>
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<tr>
<td>I enjoyed watching the video instruction.</td>
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<tr>
<td>I would like to learn from more instructional videos like these.</td>
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<tr>
<td>It was easy to understand what I needed to remember from the instruction.</td>
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<tr>
<td>I clearly understand graphing linear equations after completing the instruction.</td>
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<tr>
<td>(Verbal Signals Treatments)</td>
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<tr>
<td>The headings helped me to understand and remember the instruction.</td>
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<tr>
<td>The labels helped me understand how to graph linear equations.</td>
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<tr>
<td>The labels helped me remember important parts of the instruction.</td>
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<tr>
<td>(Visual Signals Treatments)</td>
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<tr>
<td>The colors helped me understand how to graph linear equations.</td>
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<tr>
<td>The arrows and circles helped me understand the instruction.</td>
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<tr>
<td>I enjoyed seeing the image of the instructor on the video.</td>
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<tr>
<td>The instructor on the video helped me understand how to graph linear equations.</td>
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<tr>
<td>The instructor on the video helped me remember important parts of the instruction.</td>
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</tbody>
</table>

**Did you use the replay/rewind feature?**

<table>
<thead>
<tr>
<th>Did not use</th>
<th>Used 1 or 2 times</th>
<th>Used 3 to 5 times</th>
<th>Used quite often</th>
</tr>
</thead>
</table>

**Do you have any suggestions for improving the instruction?**
VITA

Kimberly W. Milner

EDUCATION

Old Dominion University, PhD candidate
Instructional Design and Technology (dissertation defended June 2015)
Dissertation: Signaling instructional video for mathematics

Walden University, M.S.
Education, Educational Technology emphasis (2006)

Troy State University, B.S.
Computer and Information Science (1979)
Graduated magna cum laude

PRESENTATIONS


Milner, K. W. (2013, May). Texting in class: How to turn it to your advantage. Presentation at the International Conference on Teaching and Leadership Excellence, Austin, TX.


Milner, K. W. (2008, April). Supporting faculty and students with one online LMS shell. Presentation at the 19th Annual International Conference on College Teaching and Learning, Jacksonville, FL.

Milner, K. W. (2008, April). SLS1101 Student Success collaborative online shell. Presentation at the FACC Spring Conference for Instructional Innovation, Fort Pierce, FL.


PROFESSIONAL EXPERIENCE

Associate Professor, Developmental Education, Mathematics 2012-Present
Indian River State College, Fort Pierce, Florida

Assistant Professor, Learning Assistance, Mathematics 2009-2012
Indian River State College, Fort Pierce, Florida

Instructor, Learning Assistance, Student Success 2006-2009
Indian River Community College, Fort Pierce, Florida

Program Developer Trainer, Adult Education 2004-2006
Indian River Community College, Fort Pierce, Florida

Adjunct Instructor, Adult Education 1999-2004
Indian River Community College, Fort Pierce, Florida

Senior Systems Analyst 1983-1995
Intermet Corporation, Columbus, Georgia

Systems Analyst Programmer 1979-1983
Champlin Petroleum Company, Fort Worth, Texas

AWARDS AND HONORS

2013 National Institute for Staff and Organizational Development Excellence Award
2012 J. Douglas Stephens Endowed Teaching Chair in Technology, Indian River State College
2011 Indian River State College Faculty of the Month
2011 National Institute for Staff and Organizational Development Excellence Award
2008 Award for Innovative Excellence in Teaching, Learning, and Technology, 19th Annual International Conference on College Teaching and Learning
2008 FACC Excellence in Instructional Innovation Award

PROFESSIONAL ORGANIZATIONS

Association for Educational Communications and Technology (AECT)
Association of Florida Colleges (AFC)
American Association of University Professors (AAUP)