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A comparison of learning outcomes in a traditional lecture-based versus blended course module using a business simulation with high cognitive load

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A COMPARISON OF LEARNING OUTCOMES IN A TRADITIONAL LECTURE-BASED VERSUS BLENDED COURSE MODULE USING A BUSINESS SIMULATION WITH HIGH COGNITIVE LOAD

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Dissertation Abstract

A Comparison of Learning Outcomes in a Traditional Lecture-based versus Blended Course Module Using a Business Simulation with High Cognitive Load

A recent U. S. Department of Education (2009) meta-analysis concluded that blended learning may be better than either online or traditional lecture-based instruction. However, other research has shown that, for technology-enhanced instruction, learning outcomes are, at best, equal to traditional lecture-based instruction. Blended learning, when evaluating learning outcomes, may be no different than previous technology-supplemented instruction. The purpose of this study was to compare blended and traditional lecture instruction in an undergraduate business course.

Ninety four business undergraduate students were randomly assigned to three treatment groups; a traditional lecture-based group, a blended group with one-time access to online curricular materials, and a blended group with unlimited access to online curricular materials. The three groups were given the same curricular materials and teaching method for a supply chain simulation in a required business course. The curricular materials and instruction followed the construct of multimedia learning, including the principles of worked-out examples and guided instruction. The students completed two online supply chain simulations over a period of four and one-half weeks.

Eight dependent variables, measuring both lower- and higher-order achievement, demonstrated only minor differences between the three treatments, and the one

statistically significant difference was explained by changes in study behavior, not better learning outcomes.

In very few cases does technology-enhanced instruction outperform either traditional lecture-based or 100% online instruction when curricular materials, teaching method, and time available for learning are controlled. This study demonstrated that blended learning, like many other educational technologies that preceded it, does not produce positive learning outcomes when compared to traditional lecture-based instruction or 100% online instruction.

This dissertation, written under the direction of the candidate's dissertation committee and approved by the members of the committee, has been presented to and accepted by the Faculty of the School of Education in partial fulfillment of the requirements for the degree of Doctor of Education. The content and research methodologies presented in this work represent the work of the candidate alone.

Stephen K. Morris November 22, 2010

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CHAPTER ONE

STATEMENT OF THE PROBLEM

Many educators embrace new technologies. Whether television or computers, multimedia or the Internet, technology inflames passions and excites educators to try to leverage technology in the pursuit of improving teaching and learning (Bernard, et al., 2004; Kulik, 1994; Kulik, Kulik, & Cohen, 1980; Schramm, 1962).

Online instruction has been one pedagogy that has sparked numerous studies comparing the efficacy of the technology with the traditional classroom. A number of meta-analyses have found that, on average, learning outcomes with online instruction is as good as the traditional lecture-based classroom instruction (Bernard, et al., 2004; Phipps & Merisotis, 1999; Tallent-Runnels et al., 2006; U. S. Department of Education, 2009; Zhao, Lei, Yan, Lai, & Tan, 2005).

An alternative to both traditional and 100% online education is the blended classroom model, also known as the hybrid model (Garnham & Kaleta, 2002; Garrison & Kanuka, 2004), which combines them, thereby complementing and supplementing both. Many universities are turning to the blended model to solve space shortages, offer schedule flexibility and improve the overall learning experience (Young, 2002). Consequently, educators and institutions are interested in combining the best of both models (Lindsay, 2004; Picciano & Dziuba, 2005).

A number of studies have compared online and traditional instruction (Bernard, et al., 2004; Tallent-Runnels, et al., 2006; Zhao, et al., 2005), but few have compared empirically the learning outcomes of traditional and blended courses that have a large online component. One recent meta-analysis (U.S. Department of Education, 2009) examined 99 studies, 20 of which compared traditional classroom-based courses with blended learning, and suggested the blended model was superior. Unfortunately, almost all the research on blended courses in the analysis have methodological flaws.

First, some studies had instructional methods that differed between the traditional and the blended courses. It was not clear that there was a good reason for any of the studies to have instructional method differences. Except for one study (Zacharia, 2007), all of the blended studies appear to have been able to create the same instruction in the classroom as in the blended model but many chose not to, without an explanation as to why the blended instruction should be substantially different. It is not known if the studies would have had similar outcomes had the studies controlled for instructional method.

Zacharia (2007) controlled for both instructional methodology, curricular materials, and time variables and suggests that, for certain applications, blended learning may be better than traditional classroom instruction. Zacharia (2007) investigated whether students could learn more about electrical circuits when combining both real experimentation and virtual experimentation as opposed to real experimentation alone. The software in the Zacharia (2007) study gave feedback to the students in a manner that would be very difficult if not impossible to duplicate in a classroom, suggesting that for certain applications, a blended learning experience is superior to either a traditional approach or a wholly online method.

Second, many studies had curricular content that differed between the courses that were compared. It is not possible to accurately compare learning outcomes when course content is different.

Third, many studies failed to account for time allowed for learning material, where blended course students had much more time to access online course materials than traditional students. It was not evident from any of the studies that the researchers had decided that more time allowed for learning was a goal of the blended learning model. Rather, more time on task was a byproduct of the blended model and most studies with time disparities ignored the issue. Consequently, poor research methodology precludes valid conclusions of blended learning being significantly better than either 100% online learning or traditional lecture-based instruction.

Poorly designed studies of new technologies in education is nothing new. Clark (1983, 1985, 1994, 2001) has argued that studies comparing outcomes between traditional learning and the various forms of electronic learning have confounded the results either because of the differing instructional methodologies used between control and treatment groups, or because of the newness of the medium, which typically has a slight initial advantage that quickly wears off (Clark, 2001). As Clark and Feldon (2005) observed:

> If studies provide a necessary method of instruction in a multimedia condition and do not provide an equivalent form of the method in a compared instructional treatment, the results will appear to favor multimedia when in fact, the method influenced the learning. The key issue is whether any instructional method can be presented in more than one medium. (Clark & Feldon, 2005, p. 99)

The current interest in blended course pedagogy is following a similar path to that taken by earlier electronic technologies in education. It is important to evaluate the efficacy of blended courses on student learning, and determine if it is better than either traditional or 100% online instruction as some studies indicate (U.S. Department of Education, 2009). However, very few comparative studies have controlled for methodology of instruction and curricular materials or time (Clark, 1994, 2001; U.S. Department of Education, 2009), and blended learning may or may not offer the outcome benefits claimed by some researchers.

Purpose of the Study

The purpose of this study was to control for methodology and time in a blended learning module and determine if the medium of blended learning offers a better alternative to either the traditional classroom experience or online education. This study controlled for method of instruction and curricular materials as well as time variables and avoided confounding the methodology of instruction and curricula with the medium of delivery. It controlled for method of instruction by using guided instruction and used the same script in both the lecture and online modules; it controlled for curricular materials by having the same worked-out examples, problem sets, and tasks for all treatments; and it controlled for time by having the online video content run for the same length as the lectures, while limiting one blended treatment group to one viewing to match the lecture-based group's exposure to the material. An evaluation of how time may affect learning outcomes was made by having a second blended treatment group able to view the online videos more than once.

The overarching intent of this study was to create an optimal environment for learning intrinsically difficult material. Under the conditions of an optimal learning environment, based on previous research of multimedia learning, this study compared learning outcomes of a course module presented in a traditional face-to-face classroom setting with learning outcomes of an identical course module presented in a blended learning environment. Both environments had modules that created an instructional experience following the multimedia principles of guided instruction and worked-out examples.

To determine if blended learning is more efficacious than traditional instruction for learners, this study provided a control group and two treatment groups. Ninety four undergraduate business students taking a required Systems in Organizations course participated in the study. The study placed the students into an instructional treatment method by using a three-group, randomized block design: a traditional lecture-based *control* group; a blended treatment group (*blendedsingle*) that had limited classroom participation for the students and who were able to view online materials just once; and a second blended treatment group (*blendedmultiple*), also with limited classroom instruction but with unlimited ability to view online material. The blocking used gender and grade point average (GPA) before randomized placement. Learning outcomes among the groups were measured by scoring questions about forecasting and inventory planning on knowledge and problem-solving posttest, as well as calculated scores derived from two tasks: the playing of two business supply chain game simulations over a 4 ½ week period.

The undergraduate business course is divided into modules that cover the Toyota Production System, just-in-time, quality systems, forecasting, inventory planning, and supply chains. This study encompassed the supply chain module that also incorporated knowledge from the forecasting and inventory planning modules that preceded it. During the supply chain module, the students participated in two tasks that were incorporated into this study: the playing of two business supply chain simulations. During the simulations, the students learned how forecasting and inventory planning were integral parts of running a company's supply chain, from producer to customer. The students learned how to analyze past demand for a product, made a forecast of future demand, decided how much and when to order product from a factory, and determined how much inventory to keep in stock to meet demand. The students learned that making correct decisions, as well as the timing of the decisions, is critical in running an efficient and effective supply chain.

Significance of the Study

This study is important for two reasons. First, historically, few studies that compared traditional classroom instruction with teaching that incorporated technology controlled for instructional method, curricular materials, and time (Clark, 1983, 1985, 1994, 2001). Clark has argued that studies comparing outcomes between traditional learning and the various forms of electronic learning have confounded the results because of the differing instructional methodologies used between control and treatment groups.

Second, the current excitement of educators for blended learning may be based on faulty studies that confounded outcomes. A recent meta-analysis reported that blended learning may result in better outcomes than either the traditional lecture-based model or 100% online instruction (U.S. Department of Education, 2009). An examination of 18 of the 20 blended studies included in the meta-analysis showed, unfortunately, that researchers consistently confounded results by not controlling for methodology of instruction or curricular materials, or for time allowed to view those materials.

To address these two concerns, this study controlled for instructional method, curricular materials, and time in both a traditional classroom and blended learning module and determined if the medium of blended learning offered a better alternative to either the traditional classroom experience or online education.

Through much of the latter half of the 20th century, educators have compared traditional lecture-based classroom instruction with media using technology (Bernard et al., 2004). Whether it be radio or television, computers or online instruction, technology has been unable to deliver on its initial promise of improving learning outcomes compared to classroom instruction (Clark 1983, 1985, 1994, 2001). It has not been possible to conclude that technology-supplemented instruction outperforms classroom instruction. This study tackled a relatively new entrant in the field of technology in education: blended instruction. The conclusion of the recent U. S. Department of Education (2009) meta-analysis that blended learning may be better than either online or traditional lecture-based instruction needed to be addressed. Outcomes from blended learning instruction may not be better. Past research has shown that, for technology-enhanced instruction, learning outcomes are at best, equal to traditional lecture-based instruction. Blended learning, when evaluating learning outcomes, may be no different than previous technology-supplemented instruction.

Theoretical Framework

The theoretical rationale underlying the design of this study is cognitive load theory, which describes how information is processed in the human brain and integrates new information (Sweller & Chandler, 1991; Sweller, 1988, 1994). The theory assumes that there is limited capacity in working memory and a relatively unlimited capacity in long-term memory (Sweller, 2005). Although people can hold as many as seven items simultaneously in working memory (Miller, 1956), it may be possible to manipulate and analyze only two or three novel items in working memory at any one time (Sweller, 2005). Therefore, course designers need to take into account the limited working memory capacity of people when creating instructional material (Paas, Renkl, & Sweller, 2003; Sweller, 1994, 2005; Sweller, Chandler, Tierney, & Cooper, 1990).

Cognitive load theory borrows the theory of dual coding (Paivio, 1986), which posits two separate sensory pathways, visual and auditory, for information entering the brain (Sweller, 1994). Once information reaches working memory, the information in the two pathways are processed by a central executive (Baddeley & Hitch, 1974). If the incoming data are then integrated into existing concepts or organizational patterns in long-term memory, learning can be thought to have taken place (Sweller, 2005). Cognitive load theory postulates that instructional materials should take advantage of the two sensory pathways and present information in a way that does not overload working memory, but allows novice learners to process germane information effectively (Chandler & Sweller, 1991; Sweller, van Merriënboer & Paas, 1998; Tindall-Ford, Chandler & Sweller, 1997). As a consequence, course designers need (a) to understand the inherent difficulty of the material being presented, (b) to control the delivery method of instruction in order for the student to best learn the material effectively, and (c) to eliminate extraneous information from instruction that may interfere with learning (Sweller, 2005).

Cognitive load theory encompasses three categories of cognitive load: extraneous, intrinsic, and germane cognitive load. Extraneous cognitive load is defined as unnecessary information placed in front of the student during instruction that interferes with learning (Chandler & Sweller, 1991). Intrinsic cognitive load refers to the natural complexity of the information to be learned or processed (Ayers, 2006; Paas, et al., 2003; Sweller, 1994, 2005). If new material is inherently difficult to comprehend, or if a task requires several novel ideas to be held in working memory at the same time, the intrinsic cognitive load may be high (Sweller, 2005). “Germane cognitive load is cognitive processing that contributes to learning” (Mayer & Moreno, 2010, p.133). Germane cognitive load is influenced by the designer of instructional materials and can help the learning process (Paas & van Merriënboer, 1994; Paas, et al., 2003). “The manner in which information is presented to learners and the learning activities required of learners are factors relevant to levels of germane cognitive load” (Paas, et al., 2003, p. 2).

The demands on working memory are cumulative: the intrinsic cognitive load is inherent in the difficulty of the material; well-designed instructional materials put a germane cognitive load on the learner and minimize extraneous cognitive load. The course designer needs to understand how much demand is put on working memory by new information and use that demand as a guide for the creation of instructional material (Sweller, et al., 1998). One method of instruction used for material with high intrinsic cognitive load is guided instruction, an approach that was used in this study in order to ameliorate the high cognitive load placed on the novice learner during a business simulation. Guidance was directed at a discovery learning process, such as forecasting demand, and integrated into the simulation learning process. An attempt was also made to eliminate extraneous information that was not relevant to the learning process.

Business simulations are designed as experiential learning environments, the theory of which is defined as "the process whereby knowledge is created through the transformation of experience [and] results from the combination of grasping and transforming experience" (Kolb, Boyatzis, & Mainemelis, 2001, p. 2). Mayer (2004) and others have found that experiential learning, or inquiry-based learning, is often taught as pure discovery learning. However, unguided inquiry-based learning methods have been found to impose undue extraneous cognitive load on the student as the novice learner searches for solutions to problems. Consequently, when presented with a novel situation, students often have no idea where to begin, or how to progress through a series of steps to solve a problem, without help from the instructor. If they are left to their own devices, with little or no guidance, they may spend laborious time searching needlessly for ideas and solutions without tangible results. As a result, incorrect pathways are chosen and working memory time is spent blindly, rather than on schema generation and the incorporation of information into long-term memory (Clark, Yates, Early, & Moulton, 2009; Kirschner, Sweller, & Clark, 2006; Mayer, 2004).

With discovery-based learning, as well as scientific discovery learning, students are given problems to solve and allowed to explore the world and discover solutions (Clark, in press; de Jong, 2005; Kirschner, et al., 2006; Mayer, 2004; Sweller, Kirschner, & Clark, 2007). Discovery-based learning and scientific discovery learning mirror the way experts in the field solve problems (Kirschner, et al., 2006). However, when novice learners are missing basic information of a discipline in their long-term memory, they lack schema in which to parse incoming information, as experts do. The strain on their working memory is high (Mayer, 2004) and results in heavy cognitive overload blocking their ability to learn (Kirschner, et al., 2006).

In order to lessen the cognitive load on the novice learner participating in the two supply chain simulations, multimedia principles served to guide the design of the instructional treatments. These principles have been merged by Mayer (2005) and others into a construct called multimedia learning. Two of the principles, guided instruction and worked-out examples, were used in this study.

Practitioners of discovery-based learning advocate minimal guidance, believing that too much instruction may interfere with performance (Kirschner, et al., 2006); however, empirical research shows that guided instruction for the novice, designed to support the cognitive processing of learning, is more effective and efficient than discovery learning alone (Kirschner, et al., 2006; Mayer, 2004). Business computer simulations are often taught as discovery learning in an experiential environment (Association for Business Simulation and Experiential Learning, http://www.absel.org). In opposition to pure discovery learning, the methodology of guided instruction (Clark, in press; Kirschner, et al., 2006; Mayer, 2004; Sweller, et al., 2007) was used as a road map to introduce new material to help novice learners overcome some of the negative experiential learning aspects of simulations. This study created learning modules of guided discovery which added germane cognitive load to an intrinsically difficult task by having course materials integrate guidance with discovery (de Jong, 2005). An attempt was made to minimize extraneous cognitive load in the learning materials.

This study also used another multimedia principle, worked-out examples. Worked-out examples help novice learners understand a new cognitive domain by showing how to use various problem-solving strategies. Examples help lower extraneous cognitive load by integrating new information into existing knowledge (Chandler & Sweller, 1996; Paas, et al., 2003; Paas & van Merriënboer, 1994; Renkl, 2005; Sweller, 1994).

In a review of the literature by Atkinson, Derry, Renkl, and Wortham in 2000, worked-out examples were found to produce better student learning outcomes. They can also be used in computer-based environments and are ideally suited to multimedia learning, whereby the review material may be played as many times as is needed. Multiple worked-out examples should also be created, since having more than one example can speed up the learning process; however, Sweller and Cooper (1985) found that learners showed improvement only in solving problems that were identical, or very similar, to the worked-out examples. Therefore, course materials for the study were created that followed cognitive load theory and multimedia principles aimed at providing guided instruction and worked-out examples in order to help the students analyze data and create strategies in the supply chain game simulations.

Within the learning environment of guided instruction and worked-out examples, this study had a fair comparison of learning outcomes and determined if teaching method, traditional versus blended, made a difference when students try to learn inherently difficult material.

Background and Need

The use of technology in education is widespread. Research has accumulated over the last six decades with thousands of studies comparing the efficacy of distance education versus traditional classroom instruction. The research suggests that, whenever a new medium is introduced, educators try to find ways of incorporating the technology into instruction (Allen & Seaman, 2003, 2009; Bernard, et al., 2004; Clark, 1983, 1994). As Bernard et al. stated:

> The 1950s and 1960s (saw) the emergence of television as a new medium of instruction (which) initiated a flurry of research that compared it with 'traditional' classroom instruction. Similarly, various forms of computer-based instruction in the1970s and 1980s, multimedia in the1980s and 1990s, teleconferencing in the1990s, and distance education, spanning all of these decades, have been investigated from a comparative perspective in an attempt to judge their relative effectiveness." (Bernard, et al., 2004, p. 379)

Unfortunately, the excitement caused by the new technologies never seems to pan out. One technology that generated initial enthusiasm was educational television. Television promised a new learning medium that might be more effective than the traditional classroom and generated hundreds of studies (Schramm, 1962). However, this fizzled out with the realization that, at best, educational television was not significantly different in educational outcomes – with some televised courses better and some worse than classroom instruction (Chu & Schramm, 2004; Schramm, 1962).

Another example of a new technology that never lived up to the initial hype was computer-based instruction. The introduction of computers in the classroom generated a flurry of research, and Kulik (1994) lists a dozen meta-analyses of the empirical research from the 1970s and 1980s, comparing computer-based outcomes with those of the traditional classroom. After examining them, Kulik noted that each “yielded the conclusion that programs of computer-based instruction have a positive record in the evaluation literature” (p. 11). He went on to state that “students usually learn more in classes in which they receive computer-based instruction” (p. 11). However, when Clark (1985), analyzed a 30% sample of the computer-based instruction studies meta-analyzed by Kulik and Kulik and Cohen (1980), he found the method of instruction or curricular content differed and the medium of delivery was confounded with learning outcomes. Any achievement gains from computer-based instruction would be comparable to instruction delivered by other media if the instruction or curricular content were the same. As a consequence, the hope and promise of computer-based instruction moved from higher achievement gains to that of a more cost effective medium for instruction.

As with other technological innovations in education, multimedia instruction, too, held out the hope and promise of higher achievement outcomes. Multimedia advocates believed the new medium would produce more learning than live instruction, and it could be more motivating than either traditional instructional media or live instructors (Clark & Feldon, 2005). Bernard et al. (2004) examined 167 empirical studies and found a very weak advantage for multimedia instruction. Bernard et al. (2004) attributed the difference to researchers not controlling for instructional methods nor curricular materials between the control and treatment groups. Contrary to expectations that motivated students learn more, Salomon (1984) actually found a negative correlation for students who preferred multimedia. Students in multimedia courses showed lower learning outcomes than those in traditional courses, perhaps due to putting in less time and effort on the assumption that multimedia courses would be easier (Salomon, 1984).

New technology often generates interest in its adoption by educators. As with television, computer-based instruction, and multimedia, blended learning has sparked interest in instructional research. Research was undertaken comparing blended learning with traditional instruction (U.S. Department of Education, 2009) with the expectation that, by using a combination of traditional and pure online instruction, an improvement would be seen in learning outcomes (Picciano & Dziuban, 2007). However, empirical studies of blended learning suffer from the same methodological problems as earlier comparative studies of electronic media and traditional instruction. The recent U.S. Department of Education (2009) meta-analysis included 99 empirical studies comparing traditional instruction with some form of electronic education such as 100% online or blended learning. Of the 99 studies in the meta-analysis, 20 studies compared blended learning outcomes with traditional instruction. An examination of 18 of the 20 blended studies (one was unavailable for review, another did not provide enough information for analysis) showed that 17 of them had one or more methodological problems such as not controlling for method of instruction or curricular materials, or time allowed for review of material, leading to a confounding of learning outcomes.

An example of a study comparing traditional instruction with the blended model, and has been included in two meta-analyses (Bernard et al., 2004; U.S. Department of Education, 2009), but did not control for method of instruction or curricular materials, nor for time, was the study by Maki and Maki (2002). Maki and Maki (2002) recount several studies by other researchers that had students in lecture format courses outperform students in online courses, yet their experience was that students in web-based courses outperformed those in the traditional classroom. The Maki and Maki study compared learning outcomes of students in web-based versus lecture sections of introductory psychology courses in an attempt to settle the issue.

Maki and Maki (2002) compared three kinds of outcomes: learning, performance, and student perceptions. They used a "quasi-experimental nonequivalent-groups pretest-posttest design" (p. 88) and included 184 college students taking either a web-based section or a lecture section of introductory psychology. Both the lecture and web-based sections used the same textbook; what differed was the supplementary material to the textbook, as well as instructional method. The lecture-based sections had thrice-weekly lecture sessions with graduate student-led discussions. Graduate instructors gave handouts reviewing course material and held review sessions. The web-based portion of the courses consisted of activities delivered over the web in addition to one weekly class session. The web-based students were engaged in four different required activities each week, the first three being substantially different than the requirements for their lecture-based counterparts:

1. All were asked to study a chapter outline, reading answers to frequently asked questions, and defining terms related to the chapter;

2. Web-based students were given a weekly quiz and had "interactive multiple-choice mastery quizzes" (Maki & Maki, 2002, pg 88) with questions supplied by the publisher of the text. The computer database gave reasons why an answer was correct or incorrect and students were allowed to take as many quizzes as they wished, with the database providing different questions based on the answers

previously given by the student;

3. All participated in an interactive experimental demonstration or searched the Web for chapter-related material;

4. All were required to attend one class meeting each week.

There was a substantial difference of methodologies for the web-based blended sections compared to the traditional lecture sections in the Maki and Maki (2002) study. Not only was the instructional methodology different, but the curricular materials as reported by Maki and Maki were substantially different, too. Because of the different amount of material presented in the two formats, there is a confounding of variables, eliminating the possibility to conclusively determine if the medium of delivery actually helped learning outcomes or whether the instructional methodology and different curricular materials improved the student learning outcomes in the web-based course.

One study in the U.S. Department of Education (2009) analysis that controlled for time but not for method of instruction was Day, Raven, and Newman (1998). Day et al. (1998) investigated learning outcomes for traditional lecture-based instruction without a laboratory and a web-enabled course with a laboratory in an agricommunication technical writing course. Responding to the interest in the new medium of the web, the authors investigated student achievement and attitudes towards writing, computers, and the Internet when presented with different instructional methods. Day et al. (1998) concluded that "using the combination of WWW-dependent instruction with a practical laboratory was a better method of teaching students technical writing than a traditional classroom approach" (p. 71-72). However, the study substituted a hands-on laboratory experience for one classroom lecture per week for the treatment group and did not offer a comparable instructional methodology for the control group in the traditional classroom. Day et al. confounded the study with different instructional methodologies; it is not possible to conclude that it was the medium of online delivery in the blended model that contributed to better learning outcomes.

The current study was done in the context of business education at the university level. It controlled instructional method, curricular materials, and time in an informed multimedia learning environment while students learned inherently difficult material.

Research Questions

This study investigated the following research questions:

1. Are there differences in the learning outcomes of students in a face-to-face traditional course module and the learning outcomes of students in a blended course module as measured by task outcomes on two supply chain computer simulations?
2. Does time influence learning outcomes as measured by learning outcomes among the students in the traditional, blended with time-limited viewing, and blended with unlimited viewing teaching methods?
3. Are there differences in the learning outcomes of students in a face-to-face traditional course module and the learning outcomes of students in a blended course module as measured by scores on an achievement posttest measuring knowledge and problem solving ability?

Definition of Terms

Traditional face-to-face instruction: refers to instruction in a classroom with the students physically present. In this study, students will learn in the classroom about forecasting, inventory planning, and an online supply chain game simulation.

Online learning: refers to courses delivered completely over the Internet (Tallent-Runnels, et al., 2006). For this study, online learning encompasses all course materials, including videos, graphics, lectures, and text being delivered over the Internet and accessed via computer. Students in the blended learning treatment groups will be dismissed from some of the classroom lectures and instead have online learning modules in forecasting and inventory planning for the online supply chain game simulation.

Blended learning: "integrate(s) online with traditional face-to-face class activities in a planned, pedagogically valuable manner and…a portion…of face-to-face time is replaced by online activity" (Picciano & Dziuban, 2007, p. 9). In this study, students in the blended learning treatment groups will have some lecture-based instruction and some online viewing of material about forecasting and inventory planning for the online supply chain game simulation.

Cognitive load theory: describes how information is processed in the human brain. The theory assumes that there is limited capacity in working memory, although there is relatively unlimited capacity in long-term memory (Chandler & Sweller, 1991; Sweller, 1988; Sweller & Chandler, 1991). The theory also posits that there are two sensory input pathways, visual and auditory, and course design should take advantage of this. In this study, cognitive load theory will guide the creation of online learning materials (Sweller, et al., 1998; Chandler & Sweller, 1991; Tindall-Ford, et al., 1997).

Working memory: refers to the temporary storage of information in connection with the performance of other cognitive tasks, such as reading, problem-solving, or learning (Baddeley, 1983). In this study, limited working memory and cognitive load theory will be used to guide the creation of curricular material.

Extraneous cognitive load: is unnecessary information placed in front of the student during instruction that interferes with learning (Chandler & Sweller, 1991). For this study, multimedia learning principles will be followed to minimize extraneous cognitive load.

Intrinsic cognitive load: is defined as the inherent difficulty of the material to be learned (Sweller, 2005). The online supply chain business simulation in this study is assumed to have a very high intrinsic cognitive load.

Germane cognitive load: is the working memory burden placed on the learner by the instructional materials that will result in new information being learned and integrated into existing concepts or organizational patterns in long-term memory (Sweller, 2005). For this study, the classroom instruction and the online materials will use guided instruction and worked-out examples as proper germane cognitive load for learning.

Multimedia learning: is a construct proposed by Mayer (2001, 2005) based on three assumptions: first, the dual-channel assumption, which postulates that humans process material both visually and aurally through different neural pathways; second, the limited capacity assumption, which postulates that humans are limited to the amount of information they can process simultaneously through either channel; and third, that people actively process information received visually and aurally and try to make sense of the information by integrating that information into existing schemas in long-term memory. This study will use principles of multimedia learning to guide the development of course materials.

Guided discovery learning: is where guidance can be directed at a discovery learning process that can be integrated into the learning environment. Whereas many inquiry learning environments expect learners to discover the domain, guidance can be an effective learning approach for novices to gain conceptual knowledge (de Jong, 2005). In this study, forecasting and inventory planning models will use guided discovery in the supply chain simulations.

Worked-out example principle: states that people “gain a deep understanding of a skill domain when they receive worked-out examples in the beginning of cognitive skill acquisition” in multimedia learning (Renkl, 2005, p. 230). In this study, worked-out examples will form the basis of integrating forecasting and inventory planning into the tasks of the supply chain simulations.

CHAPTER TWO

REVIEW OF THE LITERATURE

The literature review is organized into four sections. The first section describes blended learning studies. The second section presents experiential learning and some of the problems associated in a simulation environment. The third section covers the learning theory of cognitive load. The fourth section presents the multimedia learning construct and the principles of guided instruction and worked-out examples.

Blended Learning

Blended courses recast the traditional classroom model into one that combines both seat time and online instruction. Such courses may take upwards of 50% of classroom activities and converts them to online learning (Garnham & Kaleta, 2002; Mossavar-Rahmani & Larson-Daugherty, 2007). The blended learning model has been touted as having the ability to transform higher education (Bransford, Brown, & Cocking, 2000; Garrison & Kanuka, 2004; McCombs & Vakili, 2005; Vignare, 2005), providing a pedagogy "to enhance both the effectiveness and efficiency of meaningful learning experiences" (Garrison & Kanuka, 2004, p. 95). Blended learning courses offer not only the promise of helping colleges save money while still meeting student’s needs for face-to-face interaction (Young, 2002) but advocates of the blended model also point to increased student satisfaction when taking blended courses (Allen & Seaman, 2003; Koohang & Durante, 2003; Tang & Byrne, 2007).

For years there has been a debate between the efficacy of online education and that of the traditional classroom experience and a number of meta-analyses have attempted to address the debate (Bernard, et al. 2004; Phipps & Merisotis, 1999; Tallent-Runnels, et al. 2006; Zhao, et al., 2005). Bernard, et al. (2004) analyzed 232 research papers that were published between 1985 and 2002. This meta-analysis examined several questions, the most salient being: first, whether or not distance education was as effective as traditional classroom-based instruction in the areas of student achievement, attitudes, and retention; second, what factors helped make distance education more effective; and third, how media and pedagogy influenced student learning in distance education. Bernard, et al. found that because of methodological problems with many of the studies, they were unable to make recommendations to educators and policy makers. Bernard et al. also found the quality of the studies to be weak in terms of design features that would permit definitive interpretation of results and were unwilling to draw conclusions regarding what works best in the classroom or online despite the large body of literature of comparative studies. The meta-analysis showed that, even though the mean effect size was essentially zero comparing student achievement between traditional classroom and online instruction, there was wide variability in student learning outcomes. Some distance education studies in the analysis showed much better achievement than traditional classroom instruction, while other studies showed much poorer learning outcomes for the online courses. Averaging outcomes has the result of specifying comparable learning outcomes between traditional classroom courses and online instruction, as well as hiding the wide variability in learning outcomes for both methods of course delivery. These results were consistent with findings of other meta-analyses (Tallent-Runnels, et al.; 2006; Zhao, et al., 2005).

Bernard et al. (2004) were unable to tease out the factors that might determine how media and pedagogy influence student learning in distance education. The U. S. Department of Education (2009) meta-analysis noted that:

> *instruction combining online and face-to-face elements had a larger advantage relative to purely face-to-face instruction than did purely online instruction* (p. xv)…. (However,) in many of the studies showing an advantage for online learning, *the online and classroom conditions differed in terms of time spent, curriculum, and pedagogy*. It was the *combination* of elements in the treatment conditions (which was likely to have included additional learning time and materials as well as additional opportunities for collaboration) that produced the observed learning advantages. (U. S. Department of Education, 2009, p. xvii)

Blended learning offers the potential to compete effectively with both the traditional and online arenas. Blended courses have been found to increase student motivation (Delialioglu, 2005), to initiate active learning (Gannon, 2004), and to create environments in which students participate both in the classroom and online (Marcus, 2005). They may also improve learning outcomes compared to conventional or online courses alone (U.S. Department of Education, 2009).

The meta-analysis of the U.S. Department of Education (May 2009) reviewed studies with an online component in an attempt to determine if students receiving online learning outperformed their counterparts having face-to-face instruction. The analysis screened over a thousand studies, looking for those that compared online with face-to-face instruction and that empirically measured student learning outcomes. To be included in the meta-analysis, a study had to provide enough information to enable the calculation of an effect size. Included studies were web-based, had random assignment or quasi-experimental designs, and had objective measures of student learning outcomes. After an initial search returned 1,132 studies, the meta-analysis settled on 99 studies for a quantitative analysis, each having at least one form of online instruction and one face-to-face comparison group. An additional 77 studies that did not have a face-to-face component were included in the narrative synthesis of the study. Both 100% online and blended course designs were included. "The meta-analysis found that, on average, students in online learning conditions performed better than those receiving face-to-face instruction" (U. S. Department of Education, 2009, p. ix).

The meta-analysis reported a number of results from the quantitative studies analyzed. The meta-analysis found that:

1. Students enrolled in online or blended classes performed better than students in a face- to-face equivalent course;
2. Blended learning had a more positive effect on student learning outcomes relative to face-to-face instruction compared to purely online instruction;
3. Time on task had a more positive effect for online courses than in face-to-face courses. Effect size was +0.46 for students that spent more time on task in an online course than for students that spent more time in face-to-face courses (+0.19);
4. Only two variables on the implementation of online learning had any significance on affecting student learning outcomes. These included, a) the use of a blended model rather than purely online and, b) the time on task for online learners;
5. Studies with almost identical curricula and materials for both the face-to-face

and online portions showed small effect sizes (+0.20), whereas variability in curricula produced an effect size of +0.42.

The meta-analysis concluded that studies comparing blended instruction with face-to-face instruction showed "blended instruction has been more effective, providing a rationale for the effort required to design and implement blended approaches" (U. S. Department of Education, 2009, p. xvii).

The studies included in the meta-analysis were examined for this literature review for time, curricular, and instructional differences. The studies can be divided into four groups: those with differing instructional methodologies or curricular materials, and different times between the control and treatment groups for viewing material (Al-Jarf 2004; DeBord, Aruguete, & Muhling, 2004; El-Deghaidy, H., & Nouby, A. 2008; Gilliver, Randall, & Pok, 1998; Maki & Maki, 2002; Midmer, Kahan, & Marlow, 2006; Rockman et al., 2007; Schilling, Wiecha, Polineni, & Khalil, 2006; Suter & Perry, 1997); those with different instructional methodologies or curricular materials but controlled for time (Day, et al., 1998; Englert, Zhao, Dunsmore, Collings, & Wolbers, 2007; Frederickson, Reed, & Clifford, 2005; O'Dwyer, Carey, & Kleiman, 2007; Spires, Mason, Crissman, & Jackson, 2001); three that controlled for instructional methodology and curricular materials but not for time viewing materials (Aberson, Berger, Healy, Kyle, & Romero, 2000; Davis, Odell, Abbitt, & Amos, 1999; Urban, 2006); and one that controlled for both instructional methodology, curricular material and time (Zacharia, 2007). One study by Long & Jennings included in the U. S. Department of Education (2009) meta analysis was unattainable and not included in this literature review; another study (Caldwell, 2006) did not supply enough information about instructional methodologies or time allowed in the courses to be included in this review.

Two representative studies in the meta-analysis that had differing methodology and time allowed for studying material are Gilliver, et al., (1998) and Maki and Maki (2002). The Maki and Maki study was also included in the Bernard et al. (2004) meta-analysis. Gilliver, et al., (1998) investigated the effects of information technology on learning outcomes at Ngee Ann Polytechnic in Singapore in a Financial Accounting course. 444 students in 24 classes were in a first-year cohort with six classes comprising 111 students being chosen for the treatment group. All students took Financial Accounting in classrooms and had traditional instruction. However, to support the treatment group, 800 pages of course material was developed and put onto the Internet. The treatment group students also spent at least 15 minutes of each 2-hour class with a special lecture and a tutorial pointing out the relevant resource material on the Internet. The treatment group students were sent email messages pointing out where to find relevant material on the Internet; provided with material beyond the core curriculum with more advanced readings and more difficult questions; and were given multiple-choice questions focusing on basic principles. Each week, Frequently Asked Questions and their answers were posted on the Internet site. Twice weekly tutorials were held by teleconference using Microsoft's NetMeeting for interested students. The additional online materials were not available to the control group students.

Gilliver, et al., (1998) analyzed the end-of-semester 2-hour examinations and compared achievement by students in the treatment group to those in the control group. The examination covered material from the entire course and included computational as well as theoretical questions and were scored by lecturers other than the researchers. A *z* test compared the final exam scores and a test statistic of 4.448 at the 0.1% significance level determined that the learning of the experimental group was superior to that of the control group.

The study clearly states that the two groups had different curricular materials available as well as differing amounts of time spent going over the course material. The superior achievement of the treatment group cannot be ascribed to the blended course being superior to the traditional classroom, but most likely attributable to the additional time and resources afforded the treatment group.

Another study in the meta-analysis that used different instructional methodologies, curricular materials, and time for student learning was by Maki and Maki (2002). Maki and Maki recount several studies by other researchers that had students in lecture format courses outperform students in online courses, yet their experience was that students in web-based courses outperformed those in the traditional classroom. The Maki and Maki study compared learning outcomes of students in web-based versus lecture sections of introductory psychology courses in an attempt to settle the issue.

Maki and Maki (2002) compared three kinds of outcomes: learning, performance, and student perceptions. They used a "quasi-experimental nonequivalent-groups pretest-posttest design" (p. 88) and included 184 college students taking either a web-based section or a lecture section of introductory psychology. Both the lecture and web-based sections used the same textbook; what differed was the supplementary material to the textbook. The lecture-based sections had thrice-weekly lecture sessions with graduate student-led discussions with the graduate instructors giving handouts reviewing course material and holding review sessions.

Unlike the control group material, the web-based portion of the courses consisted of activities delivered over the web in addition to one weekly class session. The students in the treatment group were engaged in four different required activities each week:

1. All were asked to study a chapter outline, reading answers to frequently asked questions, and defining terms related to the chapter;

2. Web-based students were given a weekly quiz and had "interactive multiple-choice mastery quizzes" (Maki & Maki, 2002, pg 88) with questions supplied by the publisher of the text. The computer database gave reasons why an answer was correct or incorrect and students were allowed to take as many quizzes as they wished, with the database providing different questions based on the answers previously given by the student;

3. All participated in an interactive experimental demonstration or searched the Web for chapter-related material;

4. All were required to attend one class meeting each week.

All students in the study took the same examinations based on the textbook on the same days. Questions were supplied by the publisher’s test bank and were chosen by the graduate students and instructor. Maki and Maki (2002) also administered the Multi-Media Comprehension Battery to students who volunteered to come into the laboratory. Maki and Maki reported mean scores, standard deviations, and Cohen’s *d* for both lecture and web-based sections and performed a regression analysis for six dependent variables. They reported a Cohen’s *d* of .367 for examination scores for the web-based course as compared to the lecture course, but also a Cohen’s *d* of .487 for relative workload of the web-based sections as opposed to the lecture sections.

There was a substantial difference of instructional methodologies and curricular materials for the web-based blended sections compared to the traditional lecture sections in the Maki and Maki (2002) study. Not only was the instructional methodology different, but the curricular course load, as reported by Maki and Maki, was substantially different, too. Because of the different amount of material presented in the two conditions, there is a confounding of variables, eliminating the possibility to conclusively determine if the medium of delivery actually helped in learning outcomes or whether the different instructional methodology increased the student learning outcomes. Even with the disparity in course delivery, the meta-analysis' calculated effect size was small, only +0.171.

Some studies in the meta-analysis controlled for time but used different instructional methodologies for the control and treatment groups. Two representative studies in this group are Day et al., (1998) and Englert, et al., (2007). Day et al. (1998) investigated student learning outcomes in an agricommunication technical writing course with: a) traditional instruction without a laboratory and, b) a web-enabled course with a laboratory. Responding to the interest in the new medium of the web, the authors investigated student achievement and attitudes towards writing, computers, and the Internet when presented with different instructional methods.

The study used 58 undergraduate juniors and seniors enrolled in an agricommunication technical writing course at Mississippi State University. Before the first class the students were randomly assigned to two groups, A and B. The treatment level was randomly assigned to one of the two groups with Group A assigned the traditional lecture-based course and Group B the web-enabled course.

Students in the traditional course attended class three times per week for class sessions of 50 minutes. Students used a textbook and a packet of course materials; instruction in the classroom consisted of a chalkboard and overhead transparencies. Students in the web course attended two 50-minute class sessions each week and one 50-minute laboratory. Classroom lectures used computer slides and a projector instead of the chalkboard and transparencies. Students worked on assignments in the laboratory under the supervision of the instructor and had access to material on the web whereas the students in the lecture section did not have the opportunity to work on assignments with instructor supervision.

All students took a midterm and completed a technical report which were used for measures of achievement. The results were analyzed using a MANOVA which found a significant difference in learning outcomes between the two groups, with the students in the blended course section performing better (Wilks' $\lambda = .731$, $F(1,50) = 8.841$).

Day et al. (1998) concluded that "using the combination of WWW-dependent instruction with a practical laboratory was a better method of teaching students technical writing than a traditional classroom approach" (p. 71-72). However, the study substituted a hands-on laboratory experience for one classroom lecture per week for the treatment group and did not offer a comparable instructional methodology for the control group in the traditional classroom. Day et al. confounded the study and it is not possible to conclude that it was the medium of online delivery or the blended model which contributed to better learning outcomes.

Another study that controlled for time but not instructional methodology was by Englert et al., (2007). Englert, et al. investigated the writing quality and length of pieces of students with disabilities who planned and organized ideas for an expository writing exercise. The control group of 20 students used a paper-and-pencil format and the treatment group of 15 students used a web-based environment.

A sample of writing was collected from each student for comparison purposes before the treatment began. A classroom discussion with all participants about farm animals followed. After the discussion, the paper-and-pencil group was presented with a concept map where informational categories were labeled and the students were told to write a paragraph for each category about the animal they had chosen. Verbal instructions were given for each step of the process. The web-based group were given identical instructions, but had concept mapping tools on a computer using TELE-Web software. “The concept map offered a more dynamic interface that allowed students to click to add ideas (details), and then they would drag the details to fill out the animal categories” (Englert, et al., 2007, p. 16).

ANCOVA results, with the pretest scores as covariates, revealed a statistically significant difference between the groups (F(1, 34) = 9.276, p = .005, p^2 = .225) with the web-based group performing better than the paper-and-pencil group.

Englert, et al. suggest that TELE-Web offered cognitive support for the students and “the intellectual work of writing well-formed texts was distributed between the student and the technology” (p. 25). The paper-and-pencil concept map did not offer the same support but may have led to extraneous cognitive load which led to lowered learning outcomes. In this instance, a web-based tool helped the students perform better. However, technology can be designed “to prompt routines and processes in a timely way just as a tutor might prompt students to employ particular writing processes and actions”

(Englert et al., p. 11). Apparently the TELE-Web software acted as a tutor for the web-based students, tutors that the control group were not offered. The two instructional methodologies are not comparable and it is not known whether the performance of the paper-and-pencil group would have improved to the level of the TELE-Web group if the students had been given a tutor that prompted writing as did the TELE-Web software.

Two representative studies in the meta-analysis that attempted to control for curricular material but did not control for time viewing that material were Aberson, et al. (2000) and Davis, et al. (1999). Aberson, et al. (2000) investigated how an interactive online tutorial compared with a classroom demonstration of the central limit theorem. All students were given a problem statement: they will investigate life satisfaction as measured by a scale with a reported mean of 0.50 and a standard deviation of 0.20. Students using the online tutorial simulated the drawing of a sample of 100 scores, then recorded the sample mean and noted whether it fell within 0.05 points of the population mean. This process of drawing 100 samples was repeated nine more times. Each student examined the sampling distribution of means and estimated the proportion falling within 0.05 of the population mean. By using *z*-score formulas, the students calculated the proportion of sample means expected to fall within 0.05 of the population mean. The students then started the process all over again by using samples of 25 scores, then samples of 5 scores.

Instead of the online tutorial, the students in the classroom group attended a lecture and a demonstration on sampling distributions. The demonstration consisted of having a population of between 20 and 35 exam scores written on slips of paper and put into a paper bag. Students drew various numbers of slips out of the bag as samples and they examined how closely the sample means approximated the population mean. They also calculated the proportion of sample means falling within a certain distance of the mean compared to the proportion that would be expected to fall within that range.

The authors found that students in both groups learned comparable amounts ($F(1,109) = 148.5$, $p < .001$, $\eta^2 = .58$) and that the online "tutorial was comparable in effectiveness to a good lecture or demonstration" (p. 291).

Though the curricular material was similar for the two groups, the time allowed to learn the concepts differed as did the instructional methods. Aberson et al. (2000) state "the interactive tutorial gives students substantial control over the learning process. The student can access the tutorial any time, proceed at any desired pace, stop at any time, redo portions of the module, and so on" (pg 291). Because of the time differences to access the material, it cannot be determined that the blended model would have led to better outcomes had the classroom group had more time and control over the learning process.

Another study that attempted to control for instructional methodology but not for time was by Davis, et al. (1999). Three sections of a preservice educational technology course were offered in three modalities: traditional, online, and integrated (blended). Each section required the students to become proficient in the use of word processing, spreadsheet, presentation, and database programs. Though the study was not clear how the traditional course was offered, Davis et al. made a point to stress that all three sections had similar instructional methodologies. The online course had hypermedia instruction and it is not known how that may have differed from the traditional instruction, nor how the two methodologies were integrated into a blended course. Even assuming that the instructional methodologies were similar, it was clear that the time allowed for learning the curricular material differed. The students in the online and blended sections were not limited on how much time they spent on the materials as seemed to be the case for the traditional lecture sections. An ANOVA test indicated that there was no difference among the three groups ($F(2, 27) = 2.218$, $p > .05$).

One study (Zacharia, 2007) in the meta-analysis controlled for both instructional methodology, curricular materials, and time variables and suggests that, for certain applications, blended learning may be better than traditional classroom instruction alone. Zacharia (2007) investigated whether students could learn more about electrical circuits when combining both real experimentation and virtual experimentation as opposed to real experimentation alone. The study design used 90 undergraduate students, all pre-service elementary school teachers, who were enrolled in an introductory physics course. Zacharia (2007) made “a conscious effort…to preserve the same teaching method and associated curriculum materials for both the control and the experimental group” (p. 122). The students used the “method of inquiry and followed the curriculum *Physics by Inquiry*” (p. 122) for the electric circuits module in the study.

The materials for the real experimentation had a real apparatus and materials consisting of batteries and resistive elements such as light bulbs. The virtual experimentation had virtual materials and apparatus on a computer and used the software *Virtual Laboratories Electricity*. The students in the control group could build circuits and use instruments (e.g. voltmeter and ammeter) to measure the circuit’s behavior. The experimental group could create circuit parts and move them to various positions in the software environment. Zacharia (2007) states:

> the software evaluated the circuit whenever parts were added to, or removed from it, and offered feedback….After completion of the circuit, the software's feedback concerned the circuit's behavior (e.g. bulbs' brightness, charges' flow). In addition, feedback could be offered throughout the construction of the circuit through the use of the software's measuring instruments….This feedback concerned the current passing through any circuit element, the voltage across any circuit element and the resistance of any circuit element. (Zacharia, 2007, p. 123)

A pre-post comparison study design was used to assess students' conceptual understanding of electrical circuits before and after the module. Zacharia evaluated pre- to post-electrical circuit test gain scores and a one-way ANCOVA comparison of the post-test scores of the two groups. A *t*-test showed that both groups improved their conceptual understanding of electrical circuits. The experimental group had significantly higher post-test scores than the students in the control group, suggesting that virtual experimentation, in conjunction with real experimentation, was better than real experimentation alone in understanding electrical circuits. Students in the experimental group not only had their scientific conceptions increased, but also had non-scientific conceptions reduced.

There are times when it may not be feasible for classroom instruction to be as effective or as immediate as learning with a computer. The *Virtual Laboratories Electricity* software gave feedback to the students in a manner that would be very difficult if not impossible to duplicate in a classroom, suggesting that for certain applications, a blended learning experience is superior to either a traditional approach or a wholly online method. Zacharia (2007) states:

> it could be that V(irtual) E(xperimentation): (i) made phenomena more visible to learners…; (ii) allowed students to perform and repeat an experiment more easily and thus experience it more; (iii) enabled easier and faster manipulation of variables than R(eal) E(xperimentation); and (iv) provided immediate feedback (e.g. about errors) throughout the process of construction of any circuit by the students. (p. 129)

The examination of 18 of the 20 blended learning studies cited in the U. S. Department of Education (2009) meta-analysis revealed, in almost all of the studies, differences in instructional method, curricular material and time viewing material between blended and traditional courses, leading to a confounding of method with outcomes. Only Zacharia's 2007 study clearly showed the effectiveness and potential of blended learning when similar classroom instruction was not possible.

Experiential Learning

Operational simulations, such as the supply chain business simulation in this study, are experiential learning experiences with little or no guidance for the learner (de Jong & van Joolingen, 1998; Gosen & Washbush, 2004; Haapasalo & Hyvönen, 2001; Petranek, 1994). Kolb (1984) has defined the characteristics of experiential learning as "the process whereby knowledge is created through the transformation of experience" (p. 38). Kolb (1984) built upon the work of John Dewey and Jean Piaget, that people do learn from their experience (p.6) and that intelligence is shaped by experience (p. 12). Experiential learning is pedagogically similar to constructivism, inquiry learning, discovery learning, and problem-based learning, all of which can be put under the umbrella term of discovery learning (Kirschner, Sweller, & Clark, 2006). Discovery learning pedagogies expect minimal guidance for the learner (Mayer, 2004), as opposed to direct instruction, as a better way for the learner "to get deep and lasting understanding" (Klahr & Nigam, 2004, p. 661).

A major goal of a learner in discovery learning is to find the properties of a given domain (van Joolingen & de Jong, 1997). "A widely accepted claim in the science and mathematics education community is the constructivist idea that discovery learning, as opposed to direct instruction, is the best way to get deep and lasting understanding of scientific phenomena and procedures" (Klahr & Nigam, 2004, p. 661). But empirical evidence suggests that most of what students, as well as teachers and scientists, know about science was taught rather than discovered by them (Klahr & Nigam, 2004). Rather than having students pursue learning in an undirected manner with minimal guidance, Mayer (2004) suggests that "learning may be best supported by methods of instruction that involve cognitive activity rather than behavioral activity, instructional guidance rather than pure discovery, and curricular focus rather than unstructured exploration" (p. 14).

The business supply chain simulation used in this study, as an experiential learning experience, was designed as a discovery learning experience, with the expectation of prior knowledge of the domain with almost no guidance given the learner. Understanding how the students interact with the educational technology of the simulation has helped in designing the treatment materials. Orlikowski (2000) states that the structurational model of technology:

> posit(s) technology as embodying structures (built in by designers during

> technology development), which are then appropriated by users during their use of the technology. Human action is a central aspect of these models, in particular, the actions associated with embedding structures within a technology during its development, and the actions associated with appropriating those structures during use of technology. (p. 405)

The simulation, as designed, places a high cognitive load on the learner with virtually no guidance on how to proceed and is to the detriment of an optimal learning experience. It is important to use the simulation to promote positive learning outcomes (Ruben, 1999). Cognitive load theory and the construct of multimedia principles guided the development of the treatment curricular materials to counteract the high cognitive load of the simulation and to provide a more positive learning outcome.

Cognitive Load Theory

Sweller (1988) describes cognitive load as a theory that explains how information is processed in the brain (Chandler & Sweller, 1991; Sweller, 1988; Sweller & Chandler, 1991, 1994). Sweller (2005) theorizes that everything in long-term memory has been acquired to help humans survive in their environment. He states that learning occurs when there are changes in long-term memory, and furthermore, that long-term memory has organized information into schemas which frees up working memory (Baddeley, 1983; Paas, et al., 2003). Sweller points to evidence of a very large long-term memory capacity, citing two studies: De Groot (1965) and Chase and Simon (1973). De Groot (1965) performed a study, later replicated by Chase and Simon (1973), that found that master chess players could hold thousands of board configurations in long-term memory, but not random board configurations. The difference between master chess players and novices appears to be what has been stored in long-term memory, not in how much information they each can hold in working memory (Chase & Simon, 1973).

Working memory is where the current processing of mental activity takes place (Baddeley, 1983; Chandler & Sweller, 1991; Sweller, 1994; Sweller & Chandler, 1991). There is a limited amount of information that can be held in working memory - perhaps only seven different items (Miller, 1956), and perhaps only three or four different ideas can be manipulated or combined simultaneously (Sweller, 2005). In fact, it is possible that only two or three novel interacting elements can be held in working memory (Paas, et al., 2003) and it has been demonstrated that people have difficulty retaining more than this in working memory. Sweller (2005) contends that four items in working memory have an evolutionary basis - any more than that and early humans would have had too many combinations to ponder, taking too much time to analyze each permutation, while struggling to survive.

Cognitive load theory ascribes to the idea that people process information both visually and verbally, a concept that was proposed in Paivio's dual-coding theory (Clark & Paivio, 1991; Paivio, 1986) and Baddeley's (1983) working memory model. The assumption in dual-coding theory is that there are two separate processing channels for verbal and non-verbal systems (Clark & Paivio, 1991). Working memory can be expanded by using both modalities. Baddeley (1983) proposed that there is a central executive that moderates storage and processing from the two channels, a visual/spatial channel and an auditory channel, or phonological loop. Baddeley suggested that information is taken from working memory and is processed into long-term memory using a central executive.

Cognitive load theory postulates that in order to increase learning, that is, to effectively move information from working memory into schemas in long-term memory, course designers need to use both visual and auditory channels while decreasing extraneous cognitive load (Chandler & Sweller, 1991; Sweller, 1994; Sweller, et al., 1998). It is important to take into consideration the limitations of working memory when designing instruction (Chandler & Sweller, 1991; Sweller, et al., 1998; Tindall-Ford, et al., 1997). When an individual can process multiple items in working memory, bringing up relevant material from long-term memory and incorporate new material, understanding occurs (Sweller, 2005). The information is processed into existing schemas that have been formed in long-term memory (Sweller 2005).

Evidence for cognitive load theory is suggested in a number of studies. Chandler and Sweller (1991) performed a series of experiments detailed in a seminal study on cognitive load theory when they investigated whether split-source or integrated information had an effect on learning outcomes in electrical engineering and biology materials. Experiments 1 and 2 were carried out over a three month period with 28 first-year electrical apprentices. Experiment 1 investigated whether integrated materials were better than conventional, split-source instructional materials in the area of installation testing. Two handbooks that covered the 1-week module of installation testing, one with conventional instructions and another with integrated instructions, were given to the participants. The handbook with the conventional materials had electrical diagrams with text instructions on installation testing in a different part of the page. The handbook for the treatment group had the same information but integrated the material by putting text information next to relevant parts of the diagram.

The apprentices were tested after the one-week course, again one week after completing the wiring section of the course, and a third time 12 weeks after the completion of the wiring section of the course. An ANOVA with repeated measures indicated a significant main effect for the treatment group at the .05 level of significance ($F(1, 26) = 8.60$, $MS_e = 553.14$). Chandler and Sweller (1991) hypothesized that the "integrated format imposed a lower cognitive load than conventional instructions" (p. 302). The significance of the outcome is strengthened in that the effects persisted over the 3 months of the study. Chandler and Sweller (1991) state:

> the results indicated that this knowledge continued to affect performance over a relatively long period and, based on the final tests, may have assisted in the acquisition of further skill. Conversely,…the conventional split-source format, which required numerous mental integrations, misdirected attention and imposed a relatively heavy cognitive load, (left) fewer cognitive resources available for acquisition of the installation testing principles. (p. 303)

Experiment 2 examined the differences between conventional and integrated instructions when it is not necessary to integrate diagrams and text in order to comprehend the material. Experiment 2 used the same subjects and was carried out during the same time period as Experiment 1 and was done as part of the electrical training program. The conventional instructions, discussing the principles of wiring electrical circuits, had the diagrams and the text physically separated, whereas the integrated materials had the text located throughout the diagram near the relevant area. It was not necessary to have the written instructions to understand the diagram which could be understood by itself.

A test was administered after the week-long course was completed, and two follow up tests were given; the first one week after the completion of the wiring course, the second follow up test 12 weeks after completion of the wiring course. Results showed no significant difference between the groups with an ANOVA with repeated measures ($F(1, 26) = 1.76$, $MS_e = 64.29$).

Experiments 3, 4, and 5 showed that introducing nonessential, though seemingly useful, information could have negative effects in an integrated environment. For Experiment 3, 20 first-year apprentices were used. Conventional instructions for a direct on-line starter control circuit contained an internal wiring diagram of the circuit as well as textual information describing the circuit. One group was asked to study the instructions for the circuit (implicit group), the other to study not only the circuit, but also make sure the textual information was read and related to the diagram (explicit group).

A test phase followed the instructional phase with three problems presented one at a time. A *t*-test was performed on the results and showed that the group that was asked to read and integrate the text with the diagram spent considerably more time on the material: $t(18) = 3.28$. The group that was not asked to read and integrate the text scored significantly higher on the first problem, $t(18) = 1.81$. The second and third problems showed no significant difference. Chandler and Sweller (1991) state that:

> despite spending substantially less time on the instructional material, this group performed significantly better than the explicit instruction group on the first test problem….The findings of the study are consistent with the view that apprentices from the implicit instruction group…rapidly identified the nature of the

> instructional material, abandoned attempts at unnecessary mental integrations, and instead directed attention and mental resources solely to the diagram….(I)t is possible that the explicit instruction group…unnecessarily directed attention and cognitive resources to this task. (p. 313)

Experiments 4 and 5 were variations on the theme of extraneous cognitive load interfering with learning and had similar results to Experiment 3. Experiment 6 confirmed what Chandler and Sweller found in Experiment 1; that integrating text with a diagram improved learning outcomes over diagrams that had text physically apart when the textual information was essential for understanding the diagram. Students that had to spend more cognitive resources mentally integrating the information had lower outcomes, further validating cognitive load theory.

Extraneous Cognitive Load

Cognitive load theory encompasses three categories of cognitive load: extraneous, intrinsic, and germane cognitive load. Extraneous cognitive load is defined as unnecessary information placed in front of the student during instruction that interferes with learning (Chandler & Sweller, 1991). Cognitive load theory posits limited working memory and that instructional materials that include both visual information and visual text can overload the working memory of the novice, reducing the amount of information that the central executive can process into long-term memory (Sweller, 2005). Course designers who understand cognitive load theory try to minimize extraneous cognitive load in instructional material (Chandler & Sweller, 1991; Sweller, 1994; Sweller, et al., 1998).

An example of extraneous cognitive load is having text separated physically from a diagram in a visual presentation (Chandler & Sweller, 1991, 1992). The learner has to keep moving their attention from the text to the diagram unnecessarily in what has been described as the split-attention effect (Ayres & Sweller, 2005; Chandler & Sweller, 1992; Mayer & Moreno, 1998). If the text information is placed in proximity to the parts of the diagram that it is referring to, students are better able to integrate the information more efficiently (Chandler & Sweller, 1991; Ayres & Sweller, 2005). Extraneous cognitive load can also occur when there are too many multiple inputs of information into working memory: visual materials, an auditory explanation, and text that repeats the auditory material is one example (Fletcher & Tobias, 2005; Mayer, 2005; Mousavi, Low, & Sweller, 1995; Schnotz, 2005).

Mayer and Moreno (1998) showed that students presented with both visual and auditory material learn better than students who are presented the same visual material but, instead of narration, have text that contains the same information. Including text in material puts additional strain on working memory as the students switch between graphics and text, adding to extraneous cognitive load, and resulting in reduced learning (Mayer & Moreno, 1998).

One experiment described in the study by Mayer and Moreno (1998) had students either viewing an animation showing the process of lightning with concurrent narration or with concurrent on-screen text. After viewing the animation, the students took a retention test, a matching test, and a four page transfer test. “According to the dual-processing hypothesis, students should remember more of the verbal material when it is presented as narration than when it is presented as text” (Mayer & Moreno, 1998, p. 315). The results showed that the students who heard the narration did significantly better than those who had the concurrent text. The retention score was $F(1, 76) = 15.987$, MSE = 2.187, $p < .001$, matching scores were $F(1, 76) = 7.805$, $MSE = 2.380$, $p < .01$, and the transfer scores were $F(1,76) = 44.797$, MSE = 1.683, $p < .001$.

Intrinsic Cognitive Load

Intrinsic cognitive load refers to the natural complexity of the information to be learned or processed (Ayers, 2006; Paas, et al., 2003; Sweller, 1994, 2005). "The number of elements that are to be integrated into a to-be-learned schema and therefore have to be processed in working memory simultaneously is referred to as intrinsic cognitive load" (Gerjets, Scheiter, & Catrambone, 2004, p. 39). If new material is inherently difficult to comprehend, or if a task requires several novel ideas to be held in working memory at the same time, the intrinsic cognitive load may be high (Sweller, 2005). An example in the literature of intrinsic cognitive load is the learning of a foreign language (Sweller, 2005). Vocabulary words have a low intrinsic cognitive load as it is not necessary to understand grammar or have a large vocabulary to learn an individual word. The learner merely needs to know the equivalent word in the native language. Learning grammar and syntax of a foreign language, however, adds considerable complexity to the learning process and has a much higher intrinsic cognitive load as the learner must hold multiple items in working memory - vocabulary, grammar, and syntax (Sweller, 2005).

Course design should take material complexity into account (Chandler & Sweller, 1991; Sweller, 1994; Sweller, et al., 1998). If it is possible to sequence the learning into discrete tasks that are simpler than the whole task, the instructional design can lessen the intrinsic cognitive load by creating simpler tasks that are then combined into a learned task. However, some tasks may need the complex interactivity which cannot be simplified in order to be learned and those tasks will unavoidably have a high intrinsic load (Paas, et al., 2003; Sweller, 1994, 2005).

Gerjets, et al. (2004) attempted to lower the intrinsic cognitive load on learners by designing instruction in a modular format “where complex solutions are broken down into smaller meaningful solution elements that can be conveyed separately” (p. 33). In one experiment, “learners had to acquire *multiple problem categories* by using a nonlinear hypertext learning environment” (p. 47). Learners could study two example problems in six different problem categories relating to event probabilities. One group was presented worked-out examples and solutions in a ‘molar’ view, a technique “that focuses on problem categories and their associated overall solution procedures” (p.33). The other group was presented with examples and solutions broken down into a modular format. In a separate paper presenting the results, Gerjets, P., Scheiter, K., and Catrambone (2006) showed that even though the molar group spent more time on the material ($F(1, 90) = 48.24$, MSE = 31.14, $p < .001$, $f = .73$), the modular group performed better at problem-solving ($F(1, 90) = 12.82$, MSE = 1169.73, $p = .001$, $f = .38$).

Germane Cognitive Load

Germane cognitive load is influenced by the designer of instructional materials and can help the learning process (Paas & van Merriënboer, 1994; Paas, et al., 2003). Extraneous cognitive load may interfere with learning but germane cognitive load enhances learning (Paas, et al., 2003). “The manner in which information is presented to learners and the learning activities required of learners are factors relevant to levels of germane cognitive load.” (Paas, et al., 2003, p. 2) For example, an instructional design can add worked-out examples into the curriculum, and although that increases the cognitive load on the learner, the examples ultimately are germane to the process of understanding and help in integrating the material into long-term memory schema.

Multimedia Learning

Mayer (2001, 2005) has proposed a construct of multimedia learning that encompasses three assumptions: first, the dual-channel assumption postulates that humans process material both visually and aurally through different neural pathways; second, the limited capacity assumption - that humans are limited to the amount of information that can be processed simultaneously through either channel; and third, the active processing assumption - that people actively process information received visually and aurally and try to make sense of the information by integrating that information into existing schemas in long-term memory.

Mayer (2005) outlines five cognitive processes in order for learning to take place in a multimedia environment: selecting relevant words; selecting relevant images; organizing selected words; organizing selected images; and integrating word-based and image-based representations. Designers of multimedia presentations should be cognizant of these processes to optimize learning.

In order to exploit these cognitive processes, multimedia learning encompasses a number of basic and advanced principles (Mayer, 2005). This study will follow the principles of guided discovery and worked-out examples.

Guided Discovery

Guidance for the learner can take many forms (de Jong, 2005). de Jong & Ngoo (1992) describe two types of support in guided discovery: directive and non-directive support (de Jong & Ngoo, 1992). Directive support guides learners in the exploration of a domain. It can take the form of what kinds of questions to ask or actions to perform and may give hints to the learner. “Non-directive support does not steer the learner in a certain direction, but helps with accomplishing what s/he would have done in a completely free exploratory environment” (de Jong & Njoo, 1992, p. 422).

Examples of directive and non-directive support include scaffolding and cognitive tools (de Jong, 2005). Scaffolding can include worked-out examples, checklists, and hints as to what directions learners should go in a domain. Examples of non-directive cognitive tools would be a hypothesis scratchpad or a monitoring tool. A hypothesis scratchpad allows the learner to generate ideas in a work space but does not give directions. A monitoring tool may simply help the learner keep track of where they are in a process or what has already been done in an exploration, off-loading some memory tasks to lessen the burden on working memory.

This study gave students directive support through scaffolding. The supply chain simulations are designed for discovery learning to take place. Students need to figure out what data are relevant to download, determine what to do with it, and analyze and interpret it. The multiple tasks in the supply chain simulations have proven in the past to be difficult for students. Worked-out examples similar to the simulation’s requirements were shown in both the classroom and in the online materials. In addition, forms were provided that asked students to go through a series of steps designed to help them remember what to do for the supply chain simulations. Steps included which data to download and analyze, and asked for forecasting methods and values and capacity and inventory planning values. The forms reminded students of the steps required for analysis in the simulation in an attempt to offload some of the extraneous cognitive load.

Worked-out Examples

Worked-out examples help the learner gain understanding in the cognitive domain at the beginning of skill acquisition (Renkl, 2005). Worked-out examples are what they sound like - examples of how to work through a problem using various strategies and coming up with a solution with the steps explicitly shown (Sweller & Chandler, 1994; Paas, et al., 2003; Paas, van Merriënboer, 1994; Renkl, 2002, 2005). Showing the novice learner how to solve problems helps integrate new information into existing knowledge (Renkl, 2005). Worked-out examples lower the extraneous cognitive load on the learner in a new cognitive domain, allowing working memory to be utilized for gaining understanding and integrating new knowledge into existing schema rather than being overloaded by trying various strategies to solve the problem (Sweller & Chandler, 1994; Paas, et al., 2003; Sweller, 1994). Worked-out examples can be used in computer-based environments and are ideally suited to multimedia learning as the novice learner can replay the media as many times as needed to review the material (Renkl, 2005). Worked-out examples have been shown to produce better student learning outcomes in a review of the literature by Atkinson, et al. (2000). Multiple examples should be created since having more than one worked-out example can help novice learners learn more rapidly in a new cognitive domain (Sweller & Cooper, 1985); however, the learners showed improvement only in solving problems that were identical or very similar to the worked examples.

The value of worked-out examples lessens as the learner becomes more proficient in a cognitive domain. At a certain level of proficiency, problem solving becomes more effective than using worked-out examples (Kalyuga, Chandler, Tuovinen, & Sweller, 2001). Learning can actually be hindered by worked-out examples when students have attained a certain level of proficiency in what is known as the expert-reversal effect (Kalyuga, Ayers, Chandler, & Sweller, 2003; Leahy & Sweller, 2005). With the expert-reversal effect, the worked-out examples become extraneous cognitive load, interfering with problem solving and schema generation.

Using worked-out examples has been found to be more effective when paired with problem solving or when using a series of worked-out examples (Sweller & Cooper, 1985). In a series of experiments, Sweller and Cooper (1985) had students try to solve algebra manipulation problems after viewing worked-out examples. It was shown that students who were exposed to the worked-out examples required less time to process the examples than conventional problems and were able to solve problems more quickly. Experiment 2, in a series of five experiments, had 20 Year 9 students participate from a second-level mathematics high school class. All subjects were given a piece of paper that had two worked-out examples for two types of problems used in the experiment. Eight problems were given to the participants and each problem had to be solved for *a*. There were two groups of 10 students – one group was told to solve the problems using paper and pencil. The worked-out example group, in addition to being given the same eight problems, had worked-out problems that were similar to the worked-out problem example sheet. The students were told to study the worked-out examples until they understood it because the following problem would be similar.

Six test problems, identical for both groups were administered. The problems came from the same two categories of equations as the preceding problems. During the test phase the students did not have access to the previous problems or examples.

Completion time and number of mathematical errors during both the acquisition and test periods were reported. A Mann-Whitney U-test indicated that worked-out example group required significantly less time during acquisition than the conventional problem group, U (10, 10) = 25.

Additional experiments were carried out by Sweller and Cooper (1985). The experiments determined that, with worked-out examples, “problem solvers required less time to study worked examples than to solve the equivalent problems, [and] they subsequently also required less time to solve conventional test problems” (p. 77).

Summary

The review of the literature on blended learning poses the challenge of discerning the effect a technology has on learning outcomes. Reviewing cognitive load theory and the construct of multimedia learning prepares a model on which to create effective instructional materials.

Blended learning has recently been touted as being better than either traditional or online instruction (U. S. Department of Education, 2009). Many educators embrace new technologies in the hope that learning experiences can be enhanced (Bernard, et al., 2004; Kulik, 1994; Kulik, Kulik, & Cohen, 1980; Schramm, 1962). Historically, though, it has been difficult to separate how the medium of delivery affects learning outcomes (Clark, 1983, 1985, 1994, 2001). Questions remain about the efficacy of blended learning as compared to traditional classroom or pure online instruction and if the medium of blended learning actually improves learning outcomes (Bernard, et al., 2004; U. S. Department of Education, 2009).

When designing a blended learning environment, it is necessary to understand how learners acquire and process information to create an effective learning environment. Cognitive load theory not only provides a theoretical rationale of working memory and understanding, but it also presents a theoretical basis for designing effective instruction (Chandler & Sweller, 1991; Sweller, ,1988, 1994, 2005; Sweller & Chandler, 1991, 1994; Sweller, et al. 1990; Sweller, van Merriënboer, & Paas, 1998).

Multimedia learning bridges the gap between cognitive load theory and instructional design. The experiential supply chain simulation module, traditionally presented in a discovery learning context, places a high cognitive load on the learner. Empirical evidence has shown that novice learners in a new cognitive domain learn more with guided discovery than pure discovery learning (Mayer, 2004). The materials in this study followed the multimedia principles of guided instruction and worked-out examples to lessen the cognitive load of the simulation and provide a more optimal learning environment. It was expected that a better learning environment for an experiential simulation module enhanced the comparison of traditional and blended learning.

CHAPTER THREE

METHODOLOGY

This chapter presents the study methodology, addressing research design, sample, protection of human subjects, instrumentation, treatment description, procedures, and preliminary data analysis.

The purpose of this study was to compare the learning outcomes of students in a traditional lecture-based classroom setting with those in two types of blended learning environments. The study controlled methodology of instruction, curricular materials, and time allowed to view the materials. The methodology of instruction was controlled by using guided instruction and the same script was used in both classroom lectures and online videos. The curricular materials were controlled by using the same data sets, spreadsheets, and worked-out examples for all three teaching methods. Time was controlled by having the online videos be the same length as the lecture-based classroom setting and allowing one of the blended groups to view the materials only once. The second blended group was allowed to view the online videos an unlimited number of times. The actual number of times students accessed the instructional videos was recorded by the course management system Blackboard®.

All students participated in two simulation tasks during the study instruction and took a posttest measuring knowledge and problem-solving skills for forecasting and inventory planning after instruction. The tasks were two business supply chain simulations that took place over four of the six weeks of the study; both tasks required the applied problem solving skills of forecasting and inventory planning based on statistical analysis of data. The simulations placed high cognitive loads on the learners; curricular materials that followed the multimedia principles of guided instruction and worked-out examples were used to lower extraneous cognitive load and promote learning. What differed between the three treatment groups was how the treatment materials were delivered to the students: either via lecture or with online videos.

This study investigated the following research questions:

1. Are there differences in the learning outcomes of students in a face-to-face traditional course module and the learning outcomes of students in a blended course module as measured by task outcomes on two supply chain computer simulations?
2. Does time influence learning outcomes as measured by learning outcomes among the students in the traditional, blended with time-limited viewing, and blended with unlimited viewing teaching methods?
3. Are there differences in the learning outcomes of students in a face-to-face traditional course module and the learning outcomes of students in a blended course module as measured by scores on an achievement posttest measuring knowledge and problem solving ability?

Research Design

This six-week study was conducted in three university sections of a class taught by the researcher. The study used a three-group, randomized block design to investigate the efficacy of blended learning compared to traditional lecture-based classroom learning. The study included one independent variable, teaching method, with three levels: a) blended learning limited to one time viewing online materials (*blendedsingle*, n = 33); b) blended learning with unlimited number of times viewing online materials (*blendedmultiple*, n = 30); and c) traditional lecture-based instruction (*control*, n = 31). There were two control variables in this study: gender and grade point average (GPA). These were controlled in the study by using a randomized block design; students were matched on these two variables and then randomly assigned to one of the three treatment groups as explained later. Because all of the subjects were undergraduate business students in their early to mid-20's, it was assumed that age would not be a factor. The study had one 11-item pretest variable. The pretest included five knowledge questions, two for forecasting and three for inventory planning and six problem-solving questions, three on forecasting and three on inventory planning.

There were nine dependent variables: the two simulation tasks generated six dependent variables, two on the first simulation and four on the second simulation; the seventh and eighth dependent variables were time on curriculum variables; the ninth dependent variable was an achievement posttest.

Students in *blendedsingle* had some of the study material presented by lectures in the classroom and had other material presented online which they were allowed to view once. Students in *blendedmultiple* also had some of the study material presented by lectures in the classroom and other material presented online. Students in *blendedmultiple,* however, were allowed to view the online material multiple times. Students in the *control* group had all of the study material presented by lecture in the classroom.

Table 1 outlines the variables of the study.

Table 1

Research Design

Control variables	Pretest variable	Treatment Groups	Dependent variables
Gender	5 knowledge questions	*Blendedsingle* – limited online viewing n=30	1) Capacity parameter - simulation 1 *Sim1a – Achievement* 2) Reorder point *Sim1b - Strategy* 3) Forecasting accuracy-simulation 2 *Sim2a – Achievement*
GPA	6 problem-solving questions	*Blendedmultiple* - unlimited online viewing n=33	4) Continent capacity - simulation 2 *Sim2b – Achievement* 5) Island capacity parameter simulation 2: *Sim2c – Achievement* 6) Strategy parameter - simulation 2 *Sim2d – Strategy* 7) Blackboard Access – simulation 1 *Blackboard – Sim1* 8) Blackboard Access – simulation 2 *Blackboard – Sim2*
		Control – (lecture-based) n=31	9) *Posttest*

Sample

A convenience sample was used comprising 100 undergraduate business students at a medium-sized private university in the San Francisco Bay Area. Four students opted out of the study and two turned in incomplete data, resulting in 94 students included in the data analysis. Students were enrolled in three sections of a required business course, *Systems in Organizations*. Each of the course sections included in this study were taught by the researcher.

The sample included 51 males and 43 females with a mix of 87% seniors and 13% juniors. Student’s ages ranged from 20-26 years old. The sample population male/female ratio approximately mirrored the student population in the business school, but not the undergraduate population at the university which is closer to a 32/68 male/female ratio. Fifty-six students were from the U.S. (45% European-American, 30% Asian-American, 18% Latino-American, and 7% African-American), 13 were from mainland China, four students were from Taiwan, three were from the Philippines, two from Hong Kong and two from Japan, and one student from each of the following countries: Argentina, Brazil, Britain, Columbia, India, Indonesia, Israel, Kuwait, Korea, Malaysia, Mexico, Norway, Singapore, and Spain. All of the students had taken two prerequisite courses or the equivalents that taught the students spreadsheet modeling and some forecasting tools.

Protection of Human Subjects

An application to undertake this study was submitted to the university's Institutional Review Board for the Protection of Human Subjects (IRBPHS). After approval from the university's IRBPHS, participants were informed that their participation was voluntary and would in no way affect their grade (see Appendix A). Four students opted out of participating in the study and did not sign consent forms, though they participated in the simulations and were given the same learning materials as the other students as the study encompassed required coursework. Individual scores, GPA, and all research measures were kept confidential and in a secure location.

There were no anticipated risks to students participating in this study. The treatments used instructional methodologies and curricular materials well accepted at the university as normal for teaching this course. It was anticipated that students would learn equally with each treatment method with little or no significant differences and no one would be harmed academically.

Instrumentation

There were two control variables, one pretest variable, and nine dependent variables in this study.

Control Variables

The two control variables, gender and grade point average (GPA), were controlled by using a randomized block design. Students' gender and GPA were obtained from university records, blocked on the two control variables in triples, and then each member of the triplet was randomly assigned to a treatment group by using the random number generator formula =RAND().

Pretest Variable

The pretest was part of a scheduled midterm that took place during the 10^{th} week of the semester. The midterm was a 65-minute exam that covered the topics of the course, including forecasting and inventory planning. There were two lower-order and three higher-order items for forecasting and three lower-order and three higher-order items for inventory planning. The exam questions were similar to test items the researcher has used in the past, based on Bloom's revised taxonomy (Anderson et al., 2001), and that had produced adequate score variance in past classes (see Appendix B). A value of '1' was used for each correct answer and '0' for an incorrect answer. Item scores were used to calculate the *pretest* variable. Cronbach's α for the *pretest* was .565.

Dependent Variables

The nine dependent variables were labeled *Sim1a – Achievement, Sim1b – Strategy, Sim2a – Achievement, Sim2b - Achievement, Sim2c - Achievement, Sim2d – Strategy, Blackboard – Sim1, Blackboard – Sim2,* and *posttest.* The first six dependent variables were scores from the two simulation tasks, with the first two being scores from the first simulation, and the remaining four scores from the second simulation. The seventh and eighth variables were time variables reflecting the number of mouse clicks the students made on the course management system Blackboard® during the study. The last dependent variable was from items from the course final examination.

Sim1a – Achievement. Students were scored on the accuracy of their factory capacity planning in the first simulation. Proper factory capacity is intimately tied to forecasted demand in the simulation; the students needed to adjust factory capacity according to the product demand forecasted. To determine *Sim1a – Achievement*, the researcher accessed the simulation online and recorded the initial strategy used by the students. Each student was graded on whether or not capacity was chosen within an acceptable range based on the forecasted demand. The acceptable range was between 39 to 45 units of capacity. Students who set up their factory capacity within this range were scored with a '1'; values outside this range were scored a '0' for the dependent variable *Sim1a – Achievement.* Because *Sim1a – Achievement* was measured by a single item, no reliability was estimated.

Sim1b – Strategy. A proper reorder point for manufacturing and shipping additional product in the simulation is essential for optimizing inventory planning. A score for the dependent variable *Sim1b - Strategy* was awarded on a '0' or '1' basis with '0' indicating a reorder point that was too low to keep the factory running properly (i.e.

24/7 for almost two years); a ‘1’ indicated a reorder point high enough to keep the factory running 24/7. The computer that hosts the simulation keeps a record of all factory operations; at the end of the simulation, the researcher checked each student’s factory operation and assigned reorder point scores.

Only two students of the 94 in the study correctly analyzed the data and understood the complexities of the problem to set the reorder point properly. The setting of the reorder point required applied problem solving and could not be solved using textbook problem solving and standard formulas. Due to the lack of differentiation of scores among the students, the *Sim1b - Achievement* variable was deemed unusable and was not included in the data analysis.

Sim2a – Achievement. Prior to the second simulation, students made demand forecasts for five regions. One region’s forecast (Calopeia) was determined using two years of past demand data; the other four regions had 90 days of past demand data for the students to analyze. A weighted forecast score for the dependent variable *Sim2a - Achievement* was created using the true demand percentages for all regions multiplied by the forecasted demand the students calculated. The following formula was used: (each region in the simulation has a different made-up name: Calopeia, Sorange, Entworpe, Tyran, and Fardo)

Sim2a - Achievement = (Calopeia forecast * .245) + (Sorange forecast * .45) + (Entworpe forecast * .1) + (Tyran forecast * .102) + (Fardo forecast * .103) . Because *Sim2a – Achievement* was measured by a single item, no reliability was estimated.

Sim2b – Achievement. As the second simulation began, students set production capacity in factories on the continent (in the regions of Calopeia, Sorange, Entworpe, and

Tyran) where most of the product demand occurred. The production capacity chosen was recorded by the simulation and a score was determined for the dependent variable *Sim2b - Achievement*.

The capacity score was created using a range of values near the ideal capacity. After examining a frequency distribution of the scores, it was determined that students that calculated a combined continent capacity within 8% of the ideal capacity were correct in their analysis and were scored a '1' for being within that range, students outside that range were scored a '0'. The 8% value was determined after examining score distributions. The 8% value was arbitrarily set because of a score gap in the student score distribution close to or at the correct amount and because 8% was within a range that made sense given the simulation task. Because *Sim2b – Achievement* was measured by a single item, no reliability was estimated.

Sim2c – Achievement. As the second simulation began, students could create a factory and set production capacity on the island of Fardo. Since the costs and calculations for building a factory on the island were different than building factories on the continent, a separate dependent variable for island capacity was deemed appropriate. The production capacity chosen for the island was recorded by the simulation and a score was determined for the dependent variable *Sim2c - Achievement*. The capacity score was created using a range of values near the ideal capacity. Using the same procedure and rationale as was used for *Sim2b – Achievement*, students that calculated an island capacity within 12% of the ideal capacity were scored a '1' for being within that range and students outside that range were scored a '0'. Because *Sim2c – Achievement* was measured by a single item, no reliability was estimated

Sim2d – Strategy. Students needed to determine one of four strategies for each of four regions as one region, Calopeia, already had strategy set by default in the simulation: a) do not sell product at all in the region; b) sell product in one region from another region's warehouse; c) build a regional warehouse to meet demand; or d) build a factory and warehouse to meet regional demand. The proper choice is determined by the overall demand of that region and implementing the most economical way to meet that demand. The regions can have demand met economically with the following analysis: if demand is less than 4000, sell from another region's warehouse; if demand is greater than 4000 but less than 12,000, build a warehouse; if demand is greater than 12,000, build a warehouse and factory. Scores for the dependent variable *Sim2d – Strategy* were assigned a '1' for choosing the correct strategy in a region and a '0' for choosing an incorrect strategy in a region. Scores were summed across the four regions producing a range from 0-4. Cronbach's α for the *Sim1d - Achievement* was .375.

Blackboard – Sim1 and Sim2. There were two time variables associated with the two blended groups. Students in *blendedsingle* and *blendedmultiple* received a score based on the number of times they clicked on Blackboard® to access the curricular material videos. Students in the *control* group attended a lecture of the first simulation learning material and received a baseline score of 5 since the minimum number of mouse clicks to access and watch the two relevant videos on Blackboard® was 5. Students in the *control* group also attended a lecture of the second simulation learning material and received a baseline score of 16 since the minimum number of mouse clicks to access and watch the five second simulation videos on Blackboard® was 16.

One hundred percent of the students in the *control* group were present in the classroom for both the first and second simulation lectures. Thus, it was feasible to assign scores of 5 and 16 for the two simulation tasks to the *control* group students. However, unlike the two blended conditions, there was no variance on either variable for the *control* group.

The actual number of times the students clicked on Blackboard® was used as an estimate of the number of times *blendedsingle* and *blendedmultiple* students watched the videos for the first simulation and determined the dependent variable *Blackboard – Sim1*. The same procedure was done after the second simulation task for *Blackboard – Sim2*.

Posttest

The final dependent variable, *posttest*, was derived from 11 items that were part of the scheduled final examination for the course. The posttest questions were identical to the pretest questions except for the use of different numerical values for each question. The students were given a 65-minute test which included items on forecasting and inventory planning. A value of ‘1’ was used for each correct answer and ‘0’ for an incorrect answer. Cronbach’s α for the *posttest* was .679.

Table 2 summarizes the nine dependent variables, what they are and how they were scored.

Table 2
Description of Variables

	Variable	What it is	How score was computed
1	Pretest	11 items on the midterm exam that asked textbook knowledge and problem solving questions on forecasting and inventory.	Questions answered correctly were scored a '1'; incorrect answers were scored a '0'.
2	Sim1a - Achievement	The factory capacity in Calopeia needs to be expanded to meet future demand. This variable measures whether the student calculated the correct capacity within a range bounding the ideal capacity of 42.	A correct answer was between 39-45 units of capacity. Students were scored a '1' for calculating a value within this range, a '0' for outside this range.
3	Sim2a – Achievement	Students analyze two years of past demand data and make demand forecasts for five regions for the next two years. This variable measures the accuracy of the forecasts.	A weighted forecast was calculated : Forecast = (f_2C * .245) + (f_2S * .45) + (f_2E * .1) + (f_2T * .102) + (f_2F * .103) where Forecast is the weighted forecast of the two-year demand of product in the simulation, fij is the forecast for each region multiplied by the true demand of the region expressed as a percentage of all of the demand in the simulation.
4	Sim2b – Achievement	Using the forecasted demand of the four regions on the fictional continent, students set factory capacity for the continent. This variable measures how accurate the continental factory capacity is compared to the ideal capacity.	After examining a frequency distribution of responses, it was determined that students that calculated a combined continent capacity within 8% of the ideal capacity were scored a '1', students outside that range were scored a '0'.
5	Sim2c – Achievement	Using the forecasted demand of the island region, students set factory capacity for the island. This variable measures how accurate the continental factory capacity is compared to the ideal capacity.	After examining a frequency distribution, it was determined that students that calculated a combined continent capacity within 12% of the ideal capacity were scored a '1', students outside that range were scored a '0'.

Table 2 (continues)
Description of Variables

	Variable	What it is	How computed
6	Sim2d - Strategy	Students needed to determine one of four strategies for each of four regions: a) don't sell product at all in the region; b) sell product in one region from another region's warehouse; c) build a regional warehouse to meet demand; or d) build a regional factory and warehouse to meet regional demand. The proper choice is determined by the overall demand of that region and implementing the most economical way to meet that demand.	Scoring of the strategy parameter was as follows: 1 for choosing the correct strategy, 0 for choosing an incorrect strategy. A cumulative score was determined with scores ranging from 0-4.
7	Blackboard – Sim1	A score for how many times the treatment materials were viewed/accessed for the first simulation.	Students in treatment group 3, those who attended the lecture-based portion of the learning material, received a baseline score of 5 because the minimum number of clicks to access the two treatment videos on Blackboard® was 5. Students in treatment groups 1 and 2 received a score based on the number of times they clicked on Blackboard® to access the videos.
8	Blackboard – Sim2	A score for how many times the treatment materials were viewed/accessed for the second simulation.	Students in treatment group 3, those who attended the lecture-based portion of the learning material, received a baseline score of 16 because the minimum number of clicks to access the five videos on Blackboard® was 16. Students in treatment groups 1 and 2 received a score based on the number of times they clicked on Blackboard® to access the videos.
9	Posttest	11 items on the final exam that asked textbook knowledge and problem solving questions on forecasting and inventory.	Questions answered correctly were scored a '1'; incorrect answers were scored a '0'.

Treatment Description

The study took place in the researcher's 16-week *Systems in Organizations* undergraduate business course. The students attended either two or three 65-minute classes each week. The course was a combined operations management and information systems course comprised of six modules. The course is structured to use the Toyota production system as an overarching system that has many components to it. The components are taught as modules during the semester in a logical way where each concept builds on previous ones. The modules and their order in the course were: the Toyota production system, just-in-time, quality, forecasting, inventory planning, and supply chain management.

Early in the semester, all students in the study were in the classroom for forecasting and inventory planning modules. There were lectures, textbook chapters assigned, and worked-out examples in class to help the students understand forecasting and inventory concepts. The students worked in groups of threes on two case studies that required the students to apply their knowledge of forecasting and inventory planning. These modules and case studies helped provide a foundation of knowledge for all of the students for the supply chain simulations but were not included in this study.

After completion of the forecasting and inventory planning modules there was a midterm examination during week 10. Eleven of the midterm questions served as the *pretest* of knowledge and problem-solving ability about forecasting and inventory planning, material that was referenced in the supply chain module.

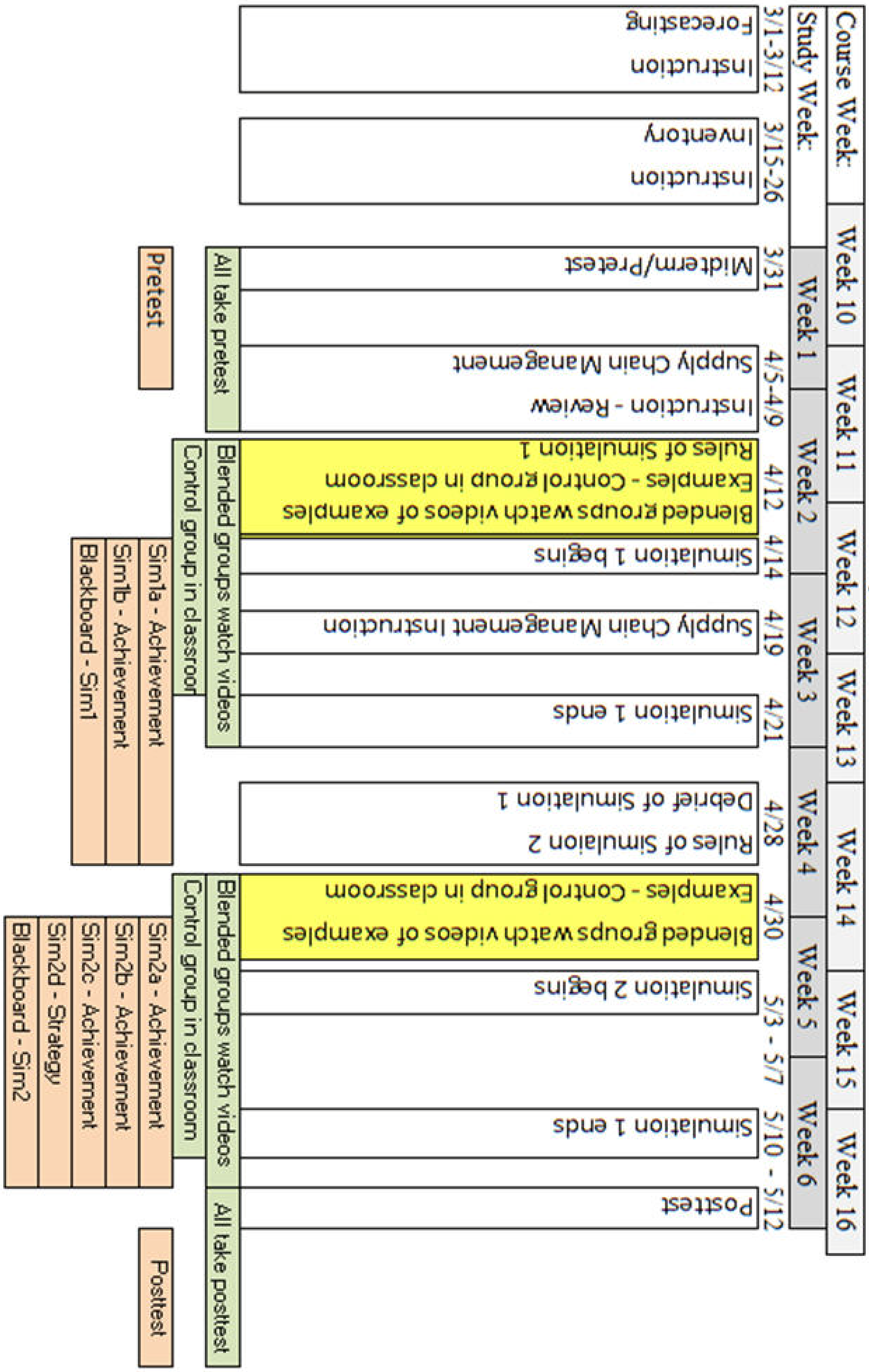
The study was conducted over the final six weeks of the course following the midterm; the course material during the study encompassed supply chain management, the final module taught in the course. The study began with the pretest in the 10th week of the semester. During week 11 the course material reviewed forecasting and inventory planning. Forecasting review included seasonality and trend analysis, while the inventory planning review included demand patterns, cumulative demand and production planning. The three treatment groups were formed in week 12 and lasted for five weeks. The two simulation tasks occurred during the 12th through the 16th weeks of the semester and primarily focused on supply chain management. The final examination occurred during the 16th week of the course.

Students in the *control* group received traditional lecture-based classroom instruction throughout the study period. The students assigned to the two blended treatment conditions, *blendedsingle* and *blendedmultiple*, were not in the classroom during classes designated as treatment lectures. During the four weeks of the two simulation tasks, there were nine classroom sessions, two which were treatment lectures. The *control* group was expected to be in class for the treatment lectures and 100% of the *control* group students attended the two treatment lectures. During the two designated treatment lectures, one for each simulation task, the blended treatment groups were not present in the classroom. Instead of the classroom lectures, the blended treatment students were expected to watch several videos online. The blended treatment students were encouraged but not required to watch the videos during the designated class period, but actually could watch the videos anytime before the simulation task.

Before the start of the simulations, the *blendedsingle* and *blendedmultiple* students were in the classroom with the *control* group and the researcher went over the rules for the two simulations.

Figure 1 provides an overview of the study.

Figure 1
Study Timeline



The simulation tasks placed a high cognitive load on the students. It was expected that the guided instruction and worked-out examples of the treatment materials would reduce the cognitive load and lead to improved learning. The students were asked to analyze the data sets and come up with a cost-effective strategy that would make the most money for their company; that is, increase revenue by capturing more demand and reduce the costs of producing and shipping product. An optimal strategy in the first simulation task required the students to increase factory capacity and increase the factory reorder point. An optimal strategy in the second simulation would result in the students building at least one additional factory, two additional warehouses, increase overall factory capacity, change to the most cost-effective shipping method, and change how often the factories produced the product. The strategies that the students designed were used in scoring the analysis for this study.

Simulation 1

The treatment instruction used applied forecasting concepts and worked-out examples presented by the instructor. There was a spreadsheet with a contrived data set that had demand data for one year that exhibited a seasonal pattern. The instructor demonstrated how to create a graph of the data and how to construct a forecast using the method of trend analysis and a trend line. Included in the demonstration was a comparison of the trend line with the weekly average of the data. The students were shown how either trend analysis with a trend line or computing a weekly average could be used for this particular data set. The demonstration included the creation of a scatter diagram and trend line justifying the use of an average weekly value to forecast future demand. Next, another forecast was created using a data set that had a seasonal pattern but with a slight increase in demand over time. Again, a comparison of a trend line made with trend analysis with the weekly average of the data was made. It was demonstrated that the average demand cannot be used to forecast future demand in this instance. The students were shown how to calculate cumulative demand for future time periods when demand is increasing and shown how the calculated future demand can be translated into factory production to meet that demand. After the demonstration using worked-out examples, the students were given a similar problem to work out on their own.

The goal of the simulation was to properly forecast demand for a fictional product, increase factory capacity if necessary, and have the factory make and ship the product in a timely and cost-effective manner to meet demand. A warehouse keeps inventory of the product and the students needed to calculate how much inventory should be held to optimize sales.

The students were shown two years of past demand data for the simulation which included: factory production, inventory levels, customer demand, lost sales, factory capacity, shipments from the factory to the warehouse, shipping method, inventory reorder points, shipping costs from the warehouse to customers, and shipping costs from the factory to the warehouse.

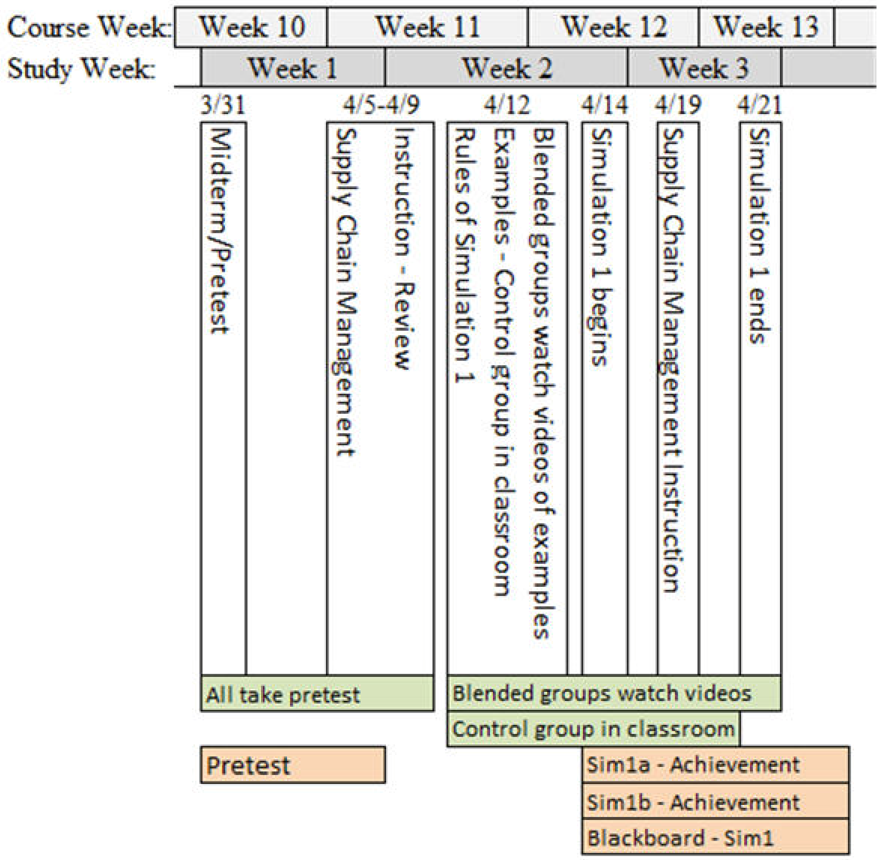
The simulation presented the students with the fictional region of Calopeia which had one factory producing a fictional air-foam product. The product was shipped to a warehouse in Calopeia and then sold to customers. The initial simulation parameters had several problems: the product was shipped from the factory to the warehouse using a too-expensive transportation method; the factory did not have enough capacity to meet customer demand; the factory did not run often enough to meet demand. The students were expected to analyze the data and come up with a cost-effective strategy that would make the most money for their company. Though the students did not know what strategy to use, the optimal strategy was to increase factory capacity to 42 units per day, change to the most cost-effective shipping method (ship by truck rather than mail), and change how often the factory produced the product (run the factory 24/7 rather than periodically). The capacity level that the students chose was used in scoring the analysis.

The one-week long simulation began during the middle of the third week of the study. During the week the simulation ran, the course covered supply chain management principles. After the simulation ended in the middle of week four, there was a debriefing lecture for all the students on what was the optimal strategy for the simulation. During this period, *control* students received four lectures and the blended students attended three in-class lectures and were out of the classroom for part of the one treatment lecture.

Figure 2 provides an overview of the study during the first simulation.

Figure 2

Simulation 1 Timeline



Simulation 2

At the end of week four of the study all of the students were presented in class with the second task of the study: playing the second supply chain simulation. The rules and data sets for the second supply chain simulation were shown to the students. During week five, the students were again divided into the three treatment groups. Students in the *control* group saw a lecture on calculating demand from all five regions of the simulation, and how to turn that strategy into building factories, warehouses, and adding factory capacity. Students in *blendedsingle* and *blendedmultiple* were able to watch virtually identical material online. The online material used the same script and data sets as the classroom lecture. The second supply chain simulation began at the end of the fifth week of the study and lasted one week.

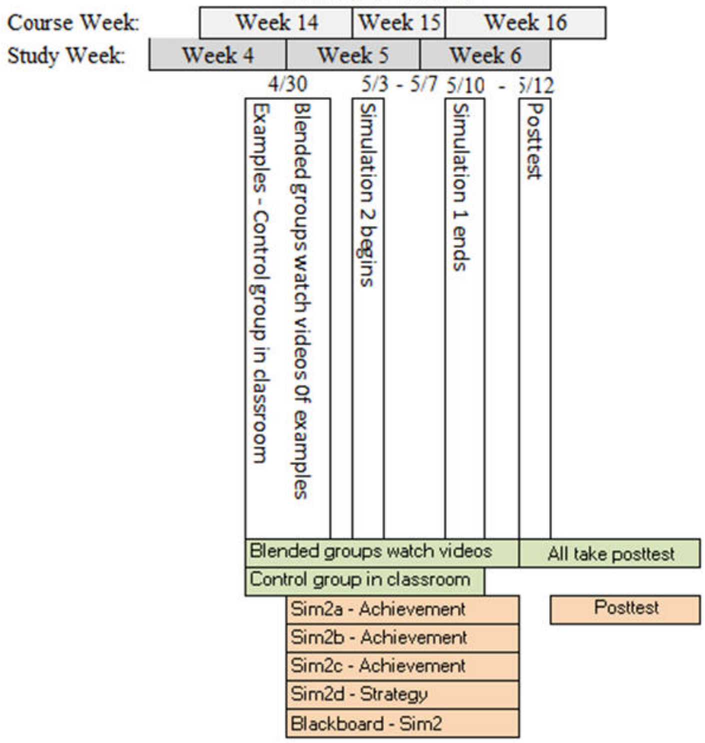
The second supply chain simulation with its five regions was much more complex than the first game which had only one region's data to analyze. The students were presented with five fictional regions: Calopeia, Sorange, Entworpe, Tyran, and Fardo. Each region had different customer demand for the same air-foam product as was used in the first simulation. When the second simulation started, there was one factory and one warehouse, both located in the region of Calopeia, but with a different initial capacity and inventory level than in the first simulation. There was not enough factory capacity to meet all of the customer demand from the four regions on the continent, nor was shipping to all of the customers on the continent from the warehouse in Calopeia the most cost-effective solution. The students were faced with the task of deciding whether to build additional factories and warehouses in the other four regions, how much factory capacity to implement, what shipping method to use, and what the factory production schedules should be. The students were given two years of past demand data for Calopeia, but only 90 days of past customer demand data for the other four regions (Sorange, Entworpe, Tyran, and Fardo).

Data was provided for factory production, inventory levels, customer demand, lost sales, factory capacity, shipments from the factory to the warehouse, shipping method, inventory reorder points, shipping costs from the warehouse to customers, and shipping costs from the factory to the warehouse.

During the week of the second simulation, all of the students continued to receive lecture material in the classroom on supply chain management principles. The second simulation was completed by the middle of the sixth week of the study. Both simulation tasks covered three and one-half weeks of the semester. During the second simulation, the *control* students attended four lectures in the classroom, while the blended students attended three, with the students expected to watch the online videos for the treatment lecture.

Figure 3 provides an overview of the study during the second simulation.

Figure 3
Simulation 2 Timeline



Posttest

Two days after the second simulation ended, the posttest was administered to all of the students. The posttest, an 11-item 65-minute in-class test, was the first part of the course final examination. The final exam included an in-class portion that comprised the *posttest*, as well as a one-week take-home case study analysis about supply chains. The case study was not included in the study. The posttest questions are in Appendix C.

Procedures

All students took the midterm examination which included the *pretest*. The study began following the midterm examination during the 10th week of the course. This is designated Week 1 of the study in Figure 1. During the second week of the study, the students had the study explained to them. The students were requested to sign an informed consent form to grant permission to use data collected in the study. Refusal to participate in the study did not affect the student's grade or standing in the course as the researcher did not know who had opted out of the study until after all of the grades were submitted.

Of the 100 students enrolled in the three sections of the course, four opted out of the study and did not sign permission forms. Two other students did not complete the assignments and were not included in the study. Thus, a total of 94 students were included in the study. During the second week of the study, the researcher accessed the registration system used by the university and recorded GPA and gender, both used as blocking variables to place students into one of the treatment conditions. The information was put into a spreadsheet; the columns of students were first sorted by gender, then sorted by GPA. The students were put into triplets based on gender and GPA. For example, the three women with the highest grade point averages were placed into the first triplet, the next three highest scoring women went into the second triplet, and so on. The men were placed into triplets in the same manner.

The students in the triplets were randomly assigned to one of the three treatment conditions. First, using a random number generator in a spreadsheet the researcher determined which person in the triplet was to be chosen first for assignment. The random number generator was then used a second time to place the chosen student into one of the treatment conditions. The random number generator was used a third time to choose which of the remaining two students of the triplet was to be assigned next. The random number generator was used a fourth time to assign the chosen student to one of the two remaining conditions, with the third triplet being assigned to the remaining condition.

At the beginning of week two of the study, the students were given a lecture reviewing forecasting and inventory planning. In the middle of the second week of the study, all the students received a 30-minute classroom lecture on the rules of the first simulation which were explained both verbally and in a handout. The students were shown how to download the simulation data and were given a form that provided guided instruction on what to download and analyze in an attempt to reduce the cognitive load of the simulation. All of the students had two days to download and analyze the data and submit their strategy.

After the 30-minute lecture in which students from all three treatment groups participated, the students assigned to the two blended treatment conditions were instructed on how to log onto the course management system Blackboard® and watch two curricular material videos prior to the first simulation. The students in the two blended groups were then dismissed from the classroom. The *control* group remained in the classroom and were shown worked-out examples using data similar to that which would be available in the simulation.

The videos were created by the instructor using the software Camtasia® and reproduced the classroom worked-out examples as closely as possible by using the same script. The students in *blendedsingle* were assigned to a Blackboard® course module that limited viewing of the videos to one time only; students in *blendedmultiple* were assigned to a Blackboard® course module that allowed viewing of the videos an unlimited number of times. The number of mouse clicks the students made to access the videos was recorded by Blackboard®. The students needed to 'click' on several links for a total of five clicks to access the two videos available for the first simulation.

By the end of week two of the study, the first simulation began, lasting a full seven days and simulating two years of customer demand, factory production, shipping of product to warehouses, and the sale of product to customers. The Supply Chain Game simulation was created by Responsive Learning Technologies of San Jose (http://www.responsive.net). (See Appendix D for simulation 1).

Changes in strategy could be made to the simulation 24/7 during the week the simulation ran, though only the initial analysis and strategy chosen by the students were used in this study. It was expected that there would be sufficient motivation for the students to do well in creating an optimal strategy as they competed against each other in the simulation, with grades based on how well the students performed in the simulation in relation to the others in their treatment group. The simulation grades comprised 9% of the students' overall grade in the course. The simulation allowed students 24/7 access to compare how they ranked in relation to everyone else in the simulation based on total cash accumulated, but the students could not see each other's strategy. The students only competed against other students in the same treatment conditions in an effort to make the competition and grading fair.

At the beginning of the fourth week of the study, after the simulation was completed, students from all three treatment groups returned to the classroom for a debriefing. Optimal strategies for the first simulation were discussed, and at the end of study week four, the rules for the second simulation were covered both verbally and in a handout.

At the beginning of study week five, the treatment groups were again separated in the same manner as before. The *control* group had a 45-minute classroom lecture on calculating demand for the five regions of the second simulation, and how to turn that analysis into a strategy of building factories, warehouses, and adding factory capacity (see Appendix E for simulation 2). Students in *blendedsingle* and *blendedmultiple*, who were not present in the classroom, were expected to log onto Blackboard® and watch five videos that covered the same curricular material. Again, the students in *blendedsingle* were only able to watch the videos once while the students in *blendedmultiple* were able to watch the videos multiple times. Access to the videos was recorded by Blackboard®.

All students had five days to download and analyze the data for the second simulation and submit their strategy. The instructor gave the students forms that provided guided instruction on what to download and analyze in an attempt to reduce the cognitive load of the simulation. The second simulation started at the end of week five and was played by the students for the next seven days. The students were able to modify their game playing strategy 24/7 during the seven days of the simulation, but only the initial supply chain simulation strategy employed by the students was used in the study. During study week six the *posttest* as part of the final examination was administered.

The *pretest* and *posttest* were collected from student exam papers, scored and entered into Excel® and later transferred into SPSS®. Data for *Sim1a – Achievement*, *Sim1b – Strategy*, *Sim2b – Achievement*, *Sim2c – Achievement*, and *Sim2d – Strategy* were collected by the researcher accessing the simulations and recording the building of factories, warehouses, and capacities set by the students. The information was initially put into Excel® and then transferred to SPSS®. The data for *Sim2a – Achievement* were collected from sheets turned in by the students that listed their forecasts for the five regions. The data were initially put into Excel® and later transferred into SPSS®. Data for *Blackboard – Sim1* and *Blackboard – Sim2* were collected by accessing Blackboard® and recording into Excel® the number of clicks made by the students. The data were later transferred into SPSS®.

Preliminary Data Analysis

Descriptive Statistics for All Variables

SPSS® was used to obtain frequency distributions for the *pretest* and all nine dependent variables. As mentioned earlier, *Sim1b – Strategy* was dropped from analysis due to lack of variability. Table 3 gives the correlations among the remaining eight dependent variables and the *pretest*. Small to medium correlations exist among the pretest and posttest measures. The *pretest* and *posttest* were virtually identical and therefore the moderate correlation between the two was expected ($r = .49$, $p < .01$). There is a small correlation between *Sim1a – Achievement* and *Sim2b – Achievement* ($r = .24$, $p < .05$). These two variables are both measuring the ability to choose factory capacities. The low correlation can probably be accounted for by having worked-out examples in the classroom and in the videos very similar to the *Sim1a* capacity calculations, but the *Sim2b* capacity calculations were much more difficult to calculate and were not shown directly to the students.

The accuracy of student forecasting *(Sim1a – Achievement)* was correlated ($r = .32$, $p < .01$) with capacity calculations for the factories on the continent (*Sim2b – Achievement*) and with the overall strategy (*Sim2d – Strategy*) of the second simulation ($r = 0.25$, $p < 0.05$). It would be expected that the accuracy of the demand forecasts would lead to a corresponding accuracy in strategy and factory capacity calculations. Similarly, the total factory capacity on the continent (*Sim2b – Achievement*) and the island (*Sim2c – Achievement*) has a small to medium correlation ($r = 0.31$, $p < 0.01$ and $r = .49$, $p < 0.01$) with the strategy of whether or not to build factories and warehouses that the students incorporated into the game (*Sim2d – Strategy*).

There was a small correlation ($r = .40$, $p < 0.01$) between how well the students performed on the *posttest* and the number of times the students saw the treatment curricular materials for the first simulation (*Blackboard – Sim1*) but not the second simulation ($r = .18$, n.s.). These two correlations, along with all the other intercorrelations of the two time variables, are attenuated because all *control* group students received a score of 5 on simulation 1 and 16 on simulation 2. When the *control* students are dropped from the analysis, the correlation between the *posttest* and *Blackboard – Sim1* increased to .45 ($p < 0.01$) but the correlation between the *posttest* and *Blackboard – Sim2* remained almost the same ($r = .17$, n.s.).

Table 3

Correlations Among All Dependent Variables Across Three Treatment Groups

	Variable	Mean	SD	1	2	3	4	5	6	7	8	9
1	Pretest	7.04	2.06	1								
2	Sim1a - Achievement	0.36	0.48	0.01	1							
3	Sim2a - Achievement	0.77	0.17	0.05	0.10	1						
4	Sim2b - Achievement	0.40	0.49	0.09	0.24*	0.32**	1					
5	Sim2c - Achievement	0.22	0.42	0.15	0.18	0.04	0.03	1				
6	Sim2d - Strategy	2.07	1.13	0.20	0.13	0.25*	0.31**	0.49**	1			
7	Blackboard - Sim1	4.77	2.38	0.18	0.08	-0.07	0.06	0.02	0.14	1		
8	Blackboard - Sim2	11.72	6.36	0.06	-0.26*	0.02	0.08	0.06	0.20	0.17	1	
9	Posttest	8.62	2.13	0.49**	-0.02	0.13	0.20	-0.01	0.20	0.40**	0.18	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Comparability of Treatment Groups

The control variables of gender and GPA were used to assign students into the three treatment groups by using a randomized block design. A pretest was administered to confirm the equality of the three groups. The pretest was divided into knowledge and problem-solving questions. As shown in Table 4, the means and standard deviations among the three groups were very similar for the knowledge questions and almost identical for the problem solving questions. One-way analysis of variances, shown in Tables 5 and 6, confirmed that the three treatment groups were similar in composition (F = 0.99 for the pretest knowledge and F = 0.07 for pretest problem solving, neither statistically significant). Because of the similarity of the pretest means among the three groups, it was determined that it was unnecessary to use analysis of covariance, with the pretest as a covariate, in the analysis of this study.

Table 4

Means and Standard Deviations (SD) for Pretest Knowledge and Problem Solving

		Pretest Knowledge		Pretest Problem Solving	
	N	Mean	SD	Mean	SD
Blendedsingle	33	3.67	1.05	3.39	1.52
Blendedmultiple	30	3.57	1.14	3.27	1.48
Control	31	3.94	1.00	3.29	1.42
Total	94	3.72	1.06	3.32	1.46

Table 5
Pretest-Knowledge Univariate Analysis of Variance (ANOVA)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.24	2	1.12	0.99	0.37	3.10
Within Groups	102.57	91	1.13			
Total	104.81	93				

Table 6
Pretest-Problem-Solving Univariate Analysis of Variance (ANOVA)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.29	2	0.15	0.07	0.93	3.10
Within Groups	198.13	91	2.18			
Total	198.43	93				

Achievement Change

Although this study was not designed to look for improvement between the *pretest* and *posttest*, the data showed that there was improvement. The *posttest* was virtually identical in content to the *pretest* except for numerical differences in the questions. Though the differences of means between the *pretest* and *posttest* were not statistically significant, the change scores shown in Table 7 indicate that scores improved from the pretest to the posttest by 1.60 points for *blendedsingle*, 1.40 points for *blendedmultiple*, and 1.64 points for the *control* group.

The level of learning, based on a strict percentage, is average and similar to student learning outcomes from previous classes. The mean scores on the *pretest* and *posttest*, as well as the scores on the dependent variables, indicate average learning took place.

Table 7

Pretest - Posttest Comparison of Means and Standard Deviations (SD)

	Pretest		Posttest		Change	
	Mean	SD	Mean	SD	Mean	SD
Blendedsingle	7.06	0.37	8.66	0.31	1.60	-0.06
Blendedmultiple	6.83	0.35	8.23	0.49	1.40	0.14
Control	7.23	0.39	8.87	0.32	1.64	-0.07

In summary, students were randomly assigned to three groups. Group one, *blendedsingle*, received the treatment lectures online and could view the videos only once. Group two, *blendedmultiple*, received the treatment lectures online and could view the videos multiple times. Group three, *control*, received the treatment material in the classroom via traditional lecture. A *pretest* and nine dependent variables were administered. Of the nine dependent variables, two were related to simulation 1 (one of which was dropped), four were related to simulation 2, two were time measures, and there was a *posttest*. A total of eight dependent variables were used in the results.

CHAPTER 4

RESULTS

This study used an experimental design to compare learning outcomes of undergraduate business students in the traditional classroom setting and in two variations of a blended learning environment. In this chapter, data are presented in three sections. First, data resulting from the two simulation tasks are presented to address the first research question. In the second section, data from the accessing of videos are presented to address the second research question. In the third section, data from the posttest are presented to address the third research question.

The independent variable, learning method, included three levels: a) classroom instruction (*control* group), b) blended learning with watching of videos once (*blendedsingle* group), and c) blended learning watching videos multiple times (*blendedmultiple* group). The research questions were answered using one-way, fixed-effects analysis of variance of eight dependent variables: *Sim1a - Achievement; Sim2a - Achievement*; *Sim2b - Achievement*; *Sim2c - Achievement*; and *Sim2d – Strategy* that were derived from the two simulation tasks; the sixth and seventh dependent variables, *Blackboard – Sim1* and *Blackboard – Sim2,* were determined from the viewing of the curricular materials; the eighth dependent variable was the *posttest.* As described in the previous chapter, one of the original dependent variables, *Sim1b – Strategy*, was dropped from analyses because of lack of variability. All statistical tests were run at the 0.05 level of significance.

Analysis Related to Research Question 1

Research question one, "Are there differences in the learning outcomes of students in a face-to-face traditional course module and the learning outcomes of students in a blended course module as measured by task outcomes on two supply chain computer simulations?" was analyzed using a one-way, fixed-effects analysis of variance (ANOVA) on scores from each of the five simulation dependent variables. As shown in Table 8, of the five dependent variables, one dependent variable showed a statistically significant difference among the treatment groups: *Sim1a – Achievement* (F = 6.22, p = .003) at the 0.05 level. *Sim2a – Achievement* was borderline statistically significant (F = 2.90, p = 0.06)

Table 8
Means, Standard Deviations (SD), *F*-values (*F*), and *p* values (*p*)
for Each of the Five Dependent Variables from the Simulation Tasks

	Blendedsingle		Blendedmultiple		Control			
	Mean	SD	Mean	SD	Mean	SD	*F*	*p*
Sim1a - Achievement	0.52	0.51	0.43	0.50	0.13	0.34	6.22	0.00
Sim2a - Achievement	0.80	0.15	0.80	0.16	0.71	0.19	2.90	0.06
Sim2b - Achievement	0.45	0.51	0.40	0.50	0.35	0.49	0.32	0.73
Sim2c - Achievement	0.24	0.43	0.13	0.35	0.29	0.46	1.13	0.33
Sim2d - Strategy	2.12	1.19	1.73	1.02	2.35	1.11	2.43	0.09

Using the Tukey post hoc procedure to identify statistically different means, Table 9 shows both of the blended learning treatment groups scored better than the lecture-based group. One reason for this finding may be due to the timing of the viewing of the materials. Students in the *control* group were taught the capacity material in class two days prior to applying the information to the simulation. The lecture was on a Monday and the information being entered into the simulation was on Wednesday. Both blended treatment groups had the online videos available to view for the three day period (Monday, Tuesday, and Wednesday) prior to the simulation task.

Table 9
Tukey Post Hoc Results for Sim1a - Achievement

Variable	(I) Group	(J) Group	Mean Difference (I-J)	*p*
Sim1a - Achievement	Blendedsingle	Blendedmultiple	0.08	0.76
		Control	0.39	0.00
	Blendedmultiple	Blendedsingle	-0.08	0.76
		Control	0.30	0.03
	Control	Blendedsingle	-0.39	0.00
		Blendedmultiple	-0.30	0.03

It was possible to identify the day that students in the two blended conditions viewed the videos covering the material in the simulation. Table 10 shows the number of students watching the videos two days, one day, and the same day prior to the task. A majority of students in the blended treatments watched the videos closer to the time that the capacity strategy information was entered into the simulation.

Table 10
Number of Students Watching the Video Material Two Days Before, One Day Before, and Same Day as Simulation Task

	Two days	One day	Same day	Did not watch
Blended	12	20	24	7
Lecture	31	0	0	0

Because the curricular material and pedagogy were identical for all treatment groups, it is reasonable to hypothesize that the timing of the curricular material may have affected performance.

Supporting this hypothesis are the data for *Sim2a – Achievement*. While this dependent variable was not statistically significant (borderline at $p = 0.06$), the Tukey post hoc analysis showed exactly the same pattern as for *Sim1a – Achievement* and the timing of the curricular viewing showed the same pattern. Table 11 shows the number of students viewing the videos up to five days prior to their use in the simulation. Again, the majority of students in the blended groups viewed the materials on the same day as the simulation tasks were entered.

Table 11

Number of Students Watching the Video Material Five Days Before, Four Days Before, Three Days Before, Two Days Before, One Day Before, and Same Day as Simulation Task

	Five days	Four days	Three days	Two days	One day	Same day	Did not watch
Blended	0	7	2	1	9	35	9
Lecture	31	0	0	0	0	0	0

Analysis Related to Research Question 2

The second research question addressed whether time looking at the video materials influenced learning outcomes among the students in the *blendedsingle*, *blendedmultiple* and *control* groups. The two time variables measured the number of clicks on Blackboard® the *blendedsingle* and *blendedmultiple* students made to access the videos as recorded by Blackboard® and classroom attendance for the *control* group.

The researcher examined the log output of Blackboard® and determined the number of mouse clicks the students in *blendedsingle* and *blendedmultiple* made to access the learning material videos. As shown in Table 12, a *t*-test comparing *blendedsingle* and *blendedmultiple* in the two simulations showed no significant difference among viewing videos for the first simulation. There was a borderline significant difference between *blendedsingle* and *blendedmultiple* for viewing the videos for the second simulation task (t = 1.85, p = .07).

Because students in the *control* group listened to lectures and did not view videos, their attendance in class could be viewed as a baseline measure. During this period, all students attended all classes and therefore each student was assigned a baseline value that equaled the number of clicks necessary to view all of the videos.

Table 12
Means, Standard Deviations (SD), *t*-value, and *p* value (*p*)
for Blackboard Access by the Blended Groups

	Blendedsingle		Blendedmultiple			
Variable	Mean	SD	Mean	SD	t-value	*p*
Blackboard - Sim1	4.55	2.58	4.77	3.29	0.30	0.77
Blackboard - Sim2	8.12	5.15	11.27	8.11	1.85	0.07

The researcher compared total mouse clicks on Blackboard® made by students in *blendedsingle* and *blendedmultiple* with the baseline number assigned *control* students. The baseline number for the first simulation task was five clicks and 16 clicks for the second simulation task. As shown in Table 13, no significant differences were found among the three treatment groups for viewing the videos for the first simulation.

Table 13
Means, Standard Deviations (SD), *F*-value, and *p* value (*p*)
for Blackboard - Sim1 by Groups

	blendedsingle		blendedmultiple		control			
Variable	Mean	SD	Mean	SD	Mean	SD	*F*-value	*p*
Blackboard - Sim1	4.55	2.58	4.77	3.29	5.00	0	0.29	0.75

As shown in Tables 14 and 15, significant differences were found between the *control* group and the two blended learning groups for the second simulation (*t*-value = 8.52, $p = 0.00$; *t*-value = 3.25, $p = 0.00$).

Table 14
Means, Standard Deviations (SD), *t*-value, and *p* value (*p*)
Between Blendedsingle and Control Group

	Blendedsingle		Control			
Variable	Mean	SD	Mean	SD	*t*-value	*p*
Blackboard - Sim2	8.12	5.15	16	0	8.52	0.00

Table 15
Means, Standard Deviations (SD), *t*-value, and *p* value (*p*)
Between Blendedmultiple and Control Group

	Blendedmultiple		Control			
Variable	Mean	SD	Mean	SD	*t*-value	*p*
Blackboard - Sim2	11.27	8.11	16	0	3.25	0.00

Analyzing the raw data revealed two trends. First, only a handful of people (four) in *blendedmultiple* that had unlimited access to the videos actually watched the videos more than once. This resulted in the loss of a separate treatment group; instead, *blendedmultiple* mirrored *blendedsingle* which only had access to one viewing of each video. Second, many students in both video groups did not watch all of the videos even once (13 in *blendedsingle* and 20 in *blendedmultiple*).

To explore the possibility that the length of time between viewing the treatment material by the blended students and entering the data in the simulation tasks influenced the score on the simulation tasks, a correlation analysis was run. The analysis was between the number of days the curricular material was viewed and performance was computed for the two dependent variables that were either statistically or borderline statistically significant. As shown in Table 16, there was a small correlation in the first simulation (r = -0.28, $p < 0.01$) between the interval of days watching the curricular material and *Sim1a – Achievement*. There was a small correlation in the second simulation (r = -0.29, $p < 0.01$) between the interval of days watching the curricular material and *Sim2d – Strategy*. The analysis was also run after eliminating those students who had not watched the videos. The second analysis did not change the statistically significant differences among the groups.

Table 16
Correlations Between Interval of Days Between Viewing
Curricular Material and Accuracy of Data Entered Into Simulations

	Sim1a - Achievement	Sim2d - Strategy
Interval of Days - Simulation 1	-0.28	
Interval of Days - Simulation 2		-0.29

Analysis Related to Research Question 3

Research question three, "Are there differences in the learning outcomes of students in a face-to-face traditional course module and the learning outcomes of students in a blended course module as measured by scores on an achievement posttest measuring knowledge and problem-solving skills?" was analyzed using the scores of the *posttest* dependent variable in a one-way, fixed-effects ANOVA. As shown in Table 17, no statistically significant differences were found among the three treatment groups.

Table 17
Means, Standard Deviations (SD), *F*-values (*F*), and *p* values (*p*)
for the Posttest by Treatment Group

	Blendedsingle		Blendedmultiple		Control			
Variable	Mean	SD	Mean	SD	Mean	SD	*F*	*p*
Posttest	8.67	1.83	8.23	2.70	8.94	1.79	0.84	0.44

Summary

A review of the data analysis revealed three findings. First, the dependent variable *Sim1a – Achievement* was statistically significant and *Sim2a – Achievement* was borderline statistically significant, with the students in *blendedsingle* and *blendedmultiple* performing better than the *control* group for both variables. Second, the time variable *Blackboard – Sim2* was statistically significant, with the control group scoring higher than either *blendedsingle* or *blendedmultiple*. Third, there was no difference among the groups as measured by the *posttest*.

CHAPTER 5

SUMMARY, LIMITATIONS, DISCUSSION, AND IMPLICATIONS

This chapter presents a summary and conclusion in four parts. First, the study is summarized with an overview of the problem, purpose, theoretical framework, research questions, and methods. Next, the limitations of the study are presented. The third section discusses the results, and the final section discusses the implications for research and practice.

Summary of Study

Online instruction has been one of many teaching methods that have sparked numerous studies comparing the efficacy of using technology with traditional classroom instruction. A number of recent meta-analyses have found that, on average, learning outcomes with online instruction is as good as the traditional lecture-based classroom instruction (Bernard, et al., 2004; Phipps & Merisotis, 1999; Tallent-Runnels et al., 2006; U. S. Department of Education, 2009; Zhao, Lei, Yan, Lai, & Tan, 2005).

An alternative to both traditional and 100% online education is the blended classroom model, also known as the hybrid model (Garnham & Kaleta, 2002; Garrison & Kanuka, 2004), which combines elements of both. More than just a model to solve space shortages, offer schedule flexibility and improve the overall learning experience (Young, 2002), educators and institutions are interested in combining the best of both models (Lindsay, 2004; Picciano & Dziuba, 2005).

Background

A number of studies have compared online and traditional instruction (Bernard, et al., 2004; Tallent-Runnels, et al., 2006; Zhao, et al., 2005), but few have compared empirically the learning outcomes of traditional and blended courses that have a large online component. One recent meta-analysis (U.S. Department of Education, 2009) examined 99 studies, 20 of which compared traditional classroom-based courses with blended learning, and suggested the blended model was superior. Unfortunately, almost all the research on blended courses in the analysis have methodological flaws.

The purpose of this study, therefore, was to determine if the medium of blended learning offers a better alternative to either the traditional classroom experience or online education while controlling for methodology and time in a blended learning module. This study controlled for method of instruction and curricular materials as well as time to view those materials and avoided confounding the methodology of instruction and curricula with the medium of delivery. It controlled for method of instruction by using guided instruction and the same script in both the lecture and online modules; it controlled for curricular materials by having the same worked-out examples, problem sets, and tasks for all treatments; and it controlled for time by having the online video content run for the same length as the classroom lectures. The intent of this study was to create an optimal environment for learning intrinsically difficult material while comparing learning outcomes of students in both blended and classroom instruction.

This study is important for two reasons. First, historically, few studies that compared traditional classroom instruction with teaching that incorporated technology controlled for instructional method, curricular materials, and time (Clark, 1983, 1985, 1994, 2001). Second, the current excitement among educators for blended learning may be based on faulty studies that confounded outcomes. A recent meta-analysis reported that blended learning may result in better outcomes than either the traditional lecture-based model or 100% online instruction (U.S. Department of Education, 2009). However, an examination of 18 of the 20 blended studies included in the meta-analysis showed that researchers consistently confounded results by not controlling for methodology of instruction or curricular materials, or for time allowed to view those materials.

To address these two concerns, this study controlled for instructional method, curricular materials, and time in both a traditional classroom and blended learning module and determined whether the medium of blended learning offered a better alternative to either the traditional classroom experience or online education.

The theoretical framework underlying this study is cognitive load theory, which describes how information is processed in the human brain and integrates new information (Sweller & Chandler, 1991; Sweller, 1988, 1994). The theory assumes that there is limited capacity in working memory and a relatively unlimited capacity in long-term memory (Sweller, 2005). Course designers need to take into account the limited working memory capacity of people when creating instructional material (Paas, Renkl, & Sweller, 2003; Sweller, 1994, 2005; Sweller, Chandler, Tierney, & Cooper, 1990).

Cognitive load theory borrows the theory of dual coding (Paivio, 1986), which posits two separate sensory pathways, visual and auditory, for information entering the brain (Sweller, 1994). Cognitive load theory postulates that instructional materials should take advantage of the two sensory pathways and present information in a way that does not overload working memory, but allows novice learners to process germane information effectively (Chandler & Sweller, 1991; Sweller, van Merriënboer & Paas, 1998; Tindall-Ford, Chandler & Sweller, 1997). As a consequence, course designers need

(a) to understand the inherent difficulty of the material being presented, (b) to control the delivery method of instruction in order for the student to best learn the material effectively, and (c) to eliminate extraneous information from instruction that may interfere with learning (Sweller, 2005).

Methodology

In order to lessen the cognitive load on the novice learner participating in the two supply chain simulations, multimedia principles served to guide the design of the instructional treatments. These principles have been merged by Mayer (2005) and others into a construct called multimedia learning. Several of the principles, including the modality, redundancy, and contiguity principles, as well as guided instruction and worked-out examples, were used in this study.

With discovery-based learning, students are given problems to solve and allowed to explore the world and discover solutions (Clark, in press; de Jong, 2005; Kirschner, et al., 2006; Mayer, 2004; Sweller, Kirschner, & Clark, 2007). Discovery-based learning and scientific discovery learning mirror the way experts in the field solve problems (Kirschner, et al., 2006). However, when novice learners are missing basic information of a discipline in their long-term memory, they lack schema in which to parse incoming information, as experts do. The strain on their working memory is high (Mayer, 2004) and results in heavy cognitive overload blocking their ability to learn (Kirschner, et al., 2006).

In opposition to pure discovery learning, the methodology of guided instruction (Clark, in press; Kirschner, et al., 2006; Mayer, 2004; Sweller, et al., 2007) was used as a road map to introduce new material to help novice learners overcome some of the negative experiential learning aspects of simulations. This study used learning modules of guided discovery which added germane cognitive load to an intrinsically difficult task by having course materials integrate guidance with discovery (de Jong, 2005). An attempt was made to minimize extraneous cognitive load during the simulation by presenting only germane material in the classroom and in the videos. Guidance was directed at analyzing data, forecasting demand, and making factory and inventory decisions for the simulation.

The study also used another multimedia principle, worked-out examples. Worked-out examples help novice learners understand a new cognitive domain by showing how to use various problem-solving strategies. Examples help lower extraneous cognitive load by integrating new information into existing knowledge (Chandler & Sweller, 1996; Paas, et al., 2003; Paas & van Merriënboer, 1994; Renkl, 2005; Sweller, 1994).

Within the learning environment of guided instruction and worked-out examples, this study attempted to have a fair comparison of learning outcomes and tried to determine if teaching method, a traditional lecture-based model versus a blended model that combined both lecture and online portions, makes a difference when students try to learn inherently difficult material.

This study investigated the following research questions:

1. Are there differences in the learning outcomes of students in a face-to-face traditional course module and the learning outcomes of students in a blended course module as measured by task outcomes on two supply chain computer simulations?

2. Does time influence learning outcomes as measured by learning outcomes

among the students in the traditional, blended with time-limited viewing, and blended with unlimited viewing teaching methods?

3. Are there differences in the learning outcomes of students in a face-to-face traditional course module and the learning outcomes of students in a blended course module as measured by scores on an achievement posttest measuring knowledge and problem solving ability?

The study used a three-group, randomized block design to investigate the efficacy of blended learning compared to traditional lecture-based classroom learning. The study included one independent variable, teaching method, with three levels: a) traditional lecture-based instruction (*control* group); b) blended learning with limited time viewing online materials (*blendedsingle*); and c) blended learning with unlimited time viewing online materials (*blendedmultiple*). There were two control variables in this study: gender and grade point average (GPA). These were controlled in the sample population by using a randomized block design; students were blocked on these two variables and then randomly assigned to one of the three treatment groups. It was assumed, since all of the subjects are undergraduate business students in their early 20's, that age would not be a factor. The study had one pretest variable. The *pretest* included questions for forecasting and inventory planning.

The undergraduate business course was divided into modules that covered the Toyota Production System, just-in-time, quality systems, forecasting, inventory planning, and supply chains. This study encompassed the supply chain module that also incorporated knowledge from the forecasting and inventory planning modules that preceded it. During the supply chain module, the students participated in two tasks that were used for this study: the playing of two business supply chain simulations. During the simulations, the students learned how forecasting and inventory planning were integral parts of running a company's supply chain, from producer to customer. The students learned how to analyze past demand for a product, were asked to make a forecast of future demand, needed to decide how much and when to order product from a factory, and analyzed the data to determine how much inventory to keep in stock to meet future demand. The module presented the students the opportunity to learn that making correct decisions, as well as the timing of those decisions, was critical in running an efficient and effective supply chain.

The students in this study were taught the supply chain module either in a blended format (*blendedsingle* and *blendedmultiple*) that had video instruction for some learning materials or 100% lecture-based classroom instruction (*control* group). The students participated in two supply chain simulations over a period of three and one-half weeks. Learning materials were created using the principles of guided instruction and the students were shown worked-out examples. They were expected to download and analyze data and form strategies for the simulation tasks. The analysis and strategies the students employed in the simulation tasks were used to score five dependent variables: *Sim1a - Achievement; Sim2a - Achievement*; *Sim2b - Achievement*; *Sim2c - Achievement*; and *Sim2d – Strategy*. (A sixth variable from the simulation tasks, *Sim1b – Strategy*, was dropped from the analysis due to lack of variability). The sixth and seventh dependent variables, *Blackboard – Sim1* and *Blackboard – Sim2*, were determined using the number of times that students clicked on Blackboard® to access the learning materials. The eighth dependent variable was the *posttest.*

Following the collection of data from the students, the data were analyzed in SPSS®. Descriptive statistics and correlations were obtained and a one-way, fixed-effects analysis of variance (ANOVA) was performed on the dependent variables to determine if student outcomes were dependent on learning method.

Findings

The dependent variable *Sim1a – Achievement* from the first simulation task measured whether students calculated the correct factory capacity within a range bounding the ideal capacity of 42. Both blended groups performed statistically significantly better than the lecture *control* group on *Sim1a – Achievement*.

The dependent variable *Sim1b – Strategy* expected the students to calculate factory reorder point settings for inventory planning. The variable was eliminated from the study as there was not enough variability in the scores, as only two of 94 students were correct in their analysis.

Sim2a – Achievement from the second simulation task was borderline statistically significant. Students analyzed two years of past demand data and made demand forecasts for five regions for the following two years of the simulation. This variable measured the accuracy of the student demand forecasts. Both blended groups performed better than the lecture *control* group on *Sim2a – Achievement*.

The dependent variables *Sim2b – Achievement, Sim2c – Achievement,* and *Sim2d – Strategy* showed no statistically significant differences. *Sim2b – Achievement* measured accuracy of the factory capacity on the fictional continent of Pangea, and *Sim2c – Achievement* measured accuracy of the factory capacity on the fictional island of Fardo. *Sim2d – Strategy* measured the accuracy of the strategy of which factories and warehouses were built in the simulation.

The timing for when the curricular materials for simulation 1 and simulation 2 were viewed by the students was available for analysis. The *control* group received the curricular material lecture for simulation 1 48 hours before the simulation capacity was set. Two-thirds of the students in the blended groups watched the curricular videos within 24 hours of the setting of the simulation capacity, with more than a third of the blended students watching on the day the capacity was set. A similar pattern was observed for the viewing of the curricular materials in simulation 2. The *control* group received the treatment instruction five days before simulation 2 began and the parameters were set. Seventy percent of the blended treatment students watched the simulation 2 treatment videos with 24 hours of the simulation; 55% watched on the same day the simulation started.

The first time variable, *Blackboard – Sim1*, which measured how many times the groups accessed the curricular materials for simulation 1, did not show a statistically significant difference among the three treatment groups. There were only two short videos to watch and almost all of the students did so. However, a number of students did not watch all of the videos for simulation 2. There were five videos for the second simulation that, when combined, were about three times longer than the videos in simulation 1. It is possible that many of the students became bored with watching the longer videos or did not have enough time set aside to watch all of them. Since 35 students waited until the day simulation 2 started before watching the videos, with many waiting until the 65-minute class session began, it is likely that many simply did not have the time to watch the entire set of videos.

All of the students in the *control* group were present in the classroom for the simulation 2 treatment lecture and were assigned a baseline score, but a number of the blended students did not watch all of the videos. As a result, the time variable *Blackboard – Sim2* showed a significant difference between the *control* group and both blended groups. This variable measured how many times the treatment materials were accessed for the second simulation based on the number of mouse clicks for the blended groups and a baseline number for the lecture group. The *control* group value was statistically significantly higher than either blended group value.

The *control* group was given a baseline number of 16 *for Blackboard – Sim2* as that value corresponded to the number of mouse clicks needed by the students in the blended groups to watch all five curricular videos. Analyzing the raw data revealed two trends. First, only a handful of people (four) in *blendedmultiple* that had unlimited access to the videos actually watched the videos more than once. This resulted in the loss of a separate treatment group; instead, *blendedmultiple* mirrored *blendedsingle* which only had access to one viewing of each video. Second, many students in both video groups did not watch all of the videos even once (13 in *blendedsingle* and 20 in *blendedmultiple*). All of the control group students attended the curricular lecture and were given a score of 16.

There were no significant differences among the three treatment groups on the *posttest*. The *posttest* measured textbook knowledge and problem solving, while the treatments emphasized applied problem solving.

Limitations

This study was designed as an experiment, and as such, there were no internal validity concerns. By using a randomized block design, with blocking controlling for gender and grade point average, the treatment groups were considered equal. The *pretest* showed no significant differences among the groups. There was random assignment, no selection bias, and internal validity was good.

One possible threat to external validity was the interaction of setting and treatment. The study took place at a private Jesuit institution with undergraduate business majors representing a wide variety of cultures with the participants being generally good students. It may be that students attending a private university may differ from those in public schools, and it may not be possible to generalize the findings to public schools, other undergraduate majors, or to students in the K-12 environment. However, because of the multicultural mixture of students, it is possible to relate the study population to other populations. The setting was a real course in a college classroom and not in a laboratory setting, and the study occurred over a period of six weeks. It is possible to generalize the outcomes of this study to other courses and settings.

Another limitation to the study was the low reliability of the *posttest* and the dependent variables. This study's simulation tasks required complex applied problem-solving skills and the curricular materials were designed to enhance that effort. The *posttest*, consisting of questions supplied by the textbook publisher, measured the textbook knowledge and problem-solving of forecasting and inventory planning problems, whereas the dependent variables were designed to measure the construct of applied problem-solving.

Discussion

This section describes the motivation for the study; cognitive load theory and multimedia principles guiding the creation of the curricular materials; the recency effect to explain two findings; unintended consequences, including procrastination, which explains the finding of one of the time variables; and thoughts about priming and complex learning.

There have been many studies over the years comparing learning outcomes of educational technologies versus classroom instruction. Historically, many educators have believed that enhancing instruction with technology would result in improved learning outcomes, whether it be radio, television, computers, or multimedia. A number of meta-analyses have compared online and traditional instruction and found that, generally, the two methodologies are comparable for student learning outcomes (Bernard, et al., 2004; Tallent-Runnels, et al., 2006; Zhao, et al., 2005).

Motivation

This study was developed in response to the U.S. Department of Education's meta-analysis (2009) that found that blended learning might offer improved learning outcomes compared to 100% online or traditional face-to-face instruction. The meta-analysis noted that:

> *instruction combining online and face-to-face elements had a larger advantage relative to purely face-to-face instruction than did purely online instruction* (p. xv)…. (However,) in many of the studies showing an advantage for online learning, *the online and classroom conditions differed in terms of time spent, curriculum, and pedagogy*. It was the *combination* of elements in the treatment

> conditions (which was likely to have included additional learning time and materials as well as additional opportunities for collaboration) that produced the observed learning advantages. (p. xvii)

Clark (1983) has stated that almost all studies comparing media and classroom instruction are confounded since the studies do not control for curricular materials, teaching methodology, or time for viewing materials. Clark (1985) analyzed the meta-analysis by Kulik et al. (1980) that claimed achievement gains using computer-based instruction and found that almost all of the studies were confounded due to differences in instructional methods.

An analysis of 18 of the 20 blended learning studies included in the U. S. Department of Education’s 2009 meta-analysis revealed that there was confounding in 17 of the studies. Researchers had not controlled for curricular material or teaching method or time spent on the material, or a combination of these confounding factors. Only one study, Zacharia (2007), controlled for instructional methodology, curricular materials, and time variables and suggests that, for certain applications, blended learning may be better than traditional classroom instruction. Zacharia (2007) investigated whether students could learn more about electrical circuits when combining both real experimentation and virtual experimentation as opposed to real experimentation alone. The software in the Zacharia (2007) study gave feedback to the students in a manner that would be very difficult if not impossible to duplicate in a classroom, suggesting that for certain applications, a blended learning experience can be superior to either a traditional lecture-based curriculum or 100% online material.

This dissertation assumed that if curricular material, teaching methodology, and time viewing materials were kept equal, then blended learning would provide no advantage over face-to-face instruction (Clark, 1983, 1985, 1994, 2001). The three treatment groups either had a lecture (*control* group) or videos (*blendedsingle* and *blendedmultiple* groups) that contained identical curricular material and were presented for the same length of time.

Cognitive Load and Multimedia Learning

The study materials for this dissertation were developed using cognitive load theory (Chandler & Sweller, 1991; Sweller, 1988, 1994, 2005) and the construct of multimedia learning (Mayer, 2005). Cognitive load theory draws upon Paivio's (1986) dual-coding theory of a visual and auditory learning pathway, which Baddeley (1983) terms the phonological loop and visuo-spatial sketchpad as part of a working-memory schema. The theory holds that there is limited capacity in working-memory and can be expanded using both pathways which this study addressed.

According to Sweller, van Merriënboer, and Paas (1998), there are three types of cognitive load: intrinsic, extraneous, and germane. Intrinsic cognitive load reflects the inherent difficulty of the material to be learned; extraneous cognitive load is caused by factors not central to the learning material; germane cognitive load pertains to the instructional methods and materials used for schema acquisition. The instructional methods and materials used to present information, the germane cognitive load, if developed well, can mitigate the intrinsic cognitive load of the treatment materials.

The course materials for this study attempted, through the multimedia principles of worked-out examples and guided instruction, to create germane cognitive load that would lessen the intrinsically high cognitive load placed on the learner in the business simulation (de Jong, 2005; Renkl, 2005). It was hoped that the simulation’s intrinsically high cognitive load would be mitigated by allowing the students to work through similar problems that were expected during the simulation tasks. It was also expected that extraneous cognitive load would be lessened by giving guided instruction through the process of forecasting, inventory planning, and strategy formation during the simulation tasks.

Attempts to minimize extraneous cognitive load were made by following the modality and redundancy principles of multimedia learning (Kalyuga, Chandler, & Sweller, 1999; Leahy, Chandler, & Sweller, 2003). According to the construct of multimedia, the modality effect or principle leads to improved learning if both the audio and visual information pathways are used as working-memory can be expanded by using both modalities (Low & Sweller, 2005).

A practical application of the modality effect can be demonstrated by showing a visual such as a diagram and include an audio explanation, but not both audio and text. Using text that is similar or identical to the audio adds unnecessary cognitive load to the visuospatial pathway, whereas using the auditory phonological loop with the visual expands working-memory and allows for greater processing of the material leading to improved learning. This study had an audio narrative accompanying the videos and did not include duplicating text.

This study attempted to use curricular materials that took into account cognitive load theory and used several principles of multimedia. The study encompassed a business simulation with high cognitive load that strained working-memory. In an effort to expand working-memory capacity, the modality principle was followed by having treatment materials presented both visually and aurally. The curricular materials were designed to avoid extraneous cognitive load (the presentation of unnecessary material). For example, following the redundancy principle, audio was used in the videos of curricular materials, but accompanying written text that duplicated the audio portion was avoided. In addition, the audio was presented simultaneously with the corresponding video material in what is known as temporal contiguity.

The study aimed to minimize extraneous cognitive load and contribute properly to germane cognitive load, the working-memory burden placed on the learner by the instructional materials. The germane cognitive load was tempered by following the multimedia principles of worked-out examples and guided instruction.

Recency

No significant differences among the three treatment groups were the result of this study, as the dependent variables that did have significant differences can be readily explained. The recency effect can explain the statistically significant difference found for the two achievement variables.

1) The dependent variable *Sim1a – Achievement* from the first simulation task measured whether students calculated the correct factory capacity within a range bounding the ideal capacity of 42. Both blended groups performed statistically significantly better than the lecture *control* group on *Sim1a – Achievement*.

2) *Sim2a – Achievement* from the second simulation task was borderline statistically significant. Students analyzed two years of past demand data and made demand forecasts for five regions for the following two years of the simulation. This variable measured the accuracy of the student demand forecasts.

Both blended groups performed better than the lecture *control* group on *Sim2a – Achievement*.

The differences found for *Sim1a – Achievement* and *Sim2a – Achievement* can be explained by how soon before setting the factory capacity the curricular materials were viewed. It is possible that the more recent viewing of the material by the students in the blended groups led to a more positive result of the dependent variables. The recency effect (Bjork & Whitten, 1974; Brown, 1860; Calkins, 1896; Crowder, 1976) "refers to the observation that memories of recent experiences come to mind more easily than memories from the distant past" (Sederberg, Howard, Kahana, 2008; p. 893).

Glanzer (1972) researched the recency effect with the idea that short term-memory was the primary memory store. Efforts were aimed at trying to understand the primary memory store of short-term memory by conducting experiments of recency with free-recall as well as recency with distracting activities. Items that were presented early in a series and later in a series were found to be recalled with the most frequency. It was hypothesized that the early items were recalled "from a long-term memory advantage enjoyed by the first few items in a list owing to the greater rehearsal or mnemonic activities devoted to those items" (Bjork & Whitten, 1974, p. 173).

Glanzer (1972) used the results of experiments of the recency effect on recall to theorize that primary memory store and short-term memory were the same. Baddeley and Hitch (1974), however, proposed a different theoretical underpinning of short-term memory – working-memory. Baddeley and Hitch theorized that working-memory maintains and stores information in the short term. Within working-memory is a central executive that processes information from two sources of information, audio and visual, and processes and stores that information in what is termed the phonological loop and the visuospatial sketchpad. The theory of working-memory and cognitive load forms the theoretical underpinnings of this study.

In a 1993 paper, Baddeley and Hitch theorized that, instead of recency supporting Glanzer's (1972) concept of short-term memory as the primary memory store, recency supports their concept of a multicomponent working-memory model. They suggest that recency is tied to a retrieval process as part of working-memory. The analogy given by Baddeley and Hitch (1993) to describe the retrieval mechanism for recency is one of light nodes, each node being lit up in a series as more information is acquired. Earlier lights go out as new ones are lit up. After the series of information has ended, the last of the lights go out, with the last ones lit remaining the warmest. If a current is slowly applied to the darkened bank of lights, the warmest ones, those that were last lit, are the first to light up again. The priming of the lights leads to the most recent ones lit being the first ones recalled – a priming effect.

The blended treatment groups outperformed the control group on *Sim1a - Achievement* and *Sim2a – Achievement*. The treatment material illustrated worked-out examples on calculating factory capacity for simulation 1 and calculating forecasts for the five regions in simulation 2. Twenty four of 63 blended students watched the simulation 1 video material on the same day the calculations were made, as opposed to all 31 students in the *control* group receiving a lecture two days prior. Similarly, 35 of the 63 blended students watched the simulation 2 curricular material videos on the same day as the calculations were made, as opposed to a lecture five days prior for the *control* group students. The students in the blended groups were primed to perform better on the simulation tasks, having the received the material more recently than the *control* group students.

Ironically, the procrastination of the students in the blended groups can explain the difference found in the time variable, *Blackboard – Sim2*. One hundred percent of the *control* group watched the treatment lecture and were given a baseline score that was equivalent to the mouse clicks needed if they had watched all of the videos. With so many blended group students waiting until the same day as the calculations for the second simulation were submitted, many did not have time to watch all five videos, resulting in the statistical quirk of the *control* group having a statistically significant difference over *blendedsingle* and *blendedmultiple*.

Unintended Consequences

Procrastination towards viewing the curricular materials by the blended group students was one unintended consequence of this study; it had been expected that the students would view the videos in a timely manner. The recency effect led the blended students to outperform the *control* group as measured by two dependent variables. Another unintended consequence of the study was the lack of multiple times viewing the online curricular material by the *blendedmultiple* group, turning it into a treatment group similar to *blendedsingle*. The possibility of performing better on a task by watching the curricular material multiple times was not incentive enough for the undergraduate students in the study.

I started this dissertation wondering about the influence of technology in education. Technological solutions to educational problems is a tantalizing but continually elusive goal. This study attempted to show that media does not affect learning and was designed to control for differing methodologies of instruction and differing curricular material that has confounded learning outcomes of past studies (Clark, 1983, 1985, 1994, 2001). Clark and Estes state in a 1998 article "that well-designed research and evaluation does not provide evidence for expected educational technology results" (p. 5). Much of the problem stems from what Clark and Estes (1998) describe as confusion by educators between craft and technology.

According to Clark and Estes (1998), craft "draws on fortunate accidents, personal experience, insight and the expertise of others to fashion a solution and revise it through trial and error. Craft is then passed on through a system of expert-based instruction and practice-based apprenticeships" (p. 6). Teaching is mostly a craft-based activity, as are instructional design and development strategies. Clark and Estes state that problems with craft include:

> solutions (that) have indeterminate causes. We do not know why they work. Craft solutions are seldom linked to a larger body of knowledge where established scientific principle and causes are explained. While people who develop craft have explanations for why they work, closer scrutiny indicates that these explanations are seldom correct. (p. 7)

Clark and Estes state that craft solutions are situated and "seldom transferrable to new settings and/or people" (p. 7). Craft solutions are also unconnected to a systematic knowledge base and lack a scientific theory about the problems being addressed.

Technology is often applied to craft solutions and what educators call technology is really craft. Instead, educational technology should be a process where problems are identified and solved with techniques based on sound scientific theory, principles, and measurement (Clark and Estes, 1998). The theories and principles need to be validated through systematic experimentation.

Clark & Estes (1998) identify three barriers to developing educational technology. First, many people think only people who are trained and functioning as scientists can participate in technology development and therefore do not participate in their development. Second, it takes much longer to develop a technology than a craft solution. “Extra time is often required at the beginning of the process in order to insure that the real problem has been identified and that the science used for the solution is connected to the problem in prior research and theory” (p. 10). Third, there is an inadequate “system for connecting basic research, practical problems and the constraints” for developing educational technologies in educational organizations.

Clark and Estes (1998) maintain that educational technologies are implemented before the real problem is identified and science from prior research and theory is often not used. Technological solutions are inadequately selected and implemented, and “careful evaluation of the results is a rare event” (p.9). Unintended consequences and not addressing problems properly is often the result.

The confusion of producing craft and calling it technology results in research reporting on the lack of effectiveness of many technologies. “While craft is valuable and, in the absence of technology, the only alternative solution to problems, confusing the two approaches is deadly. Even worse, our craft has too often been targeted on the wrong problems and solutions” (p. 6). Clark and Estes (1998) state:

> there is an engineering component to all social and educational technologies. Engineering strategies are the bridge between the problem, the science

> representing our knowledge about the causes and operation of the problem, and the intervention that is expected to solve the problem. (p. 8)

Unfortunately, engineering strategies in creating technologies can lead to unintended consequences for a variety of reasons. One reason is how people perceive and use the technology.

Orlikowski and Gash (1994) use the term *technological frame* to describe “the assumptions, expectations, and knowledge (the member) use(s) to understand technology in organizations. This includes not only the nature and role of the technology itself, but the specific conditions, applications, and consequences of that technology in particular contexts.” Individuals in organizations “have assumptions about and expectations of technology,” their understanding of “the purpose, context, importance, and role of technology” will influence the use of the technology (pp. 178 & 179). When the technological frames are significantly different among groups, unintended uses may arise from the technology.

Different groups in an organization have different technological frames. “Technologists may…have an engineering perspective of technology, treating it as a tool to be designed, manipulated, and deployed to accomplish a particular task…(whereas) users may…(expect) immediate…task-specific benefits” (Orlikowski & Gash, 1994, p. 179). However, “technologies are social artifacts, their material form and function will embody their…developer’s objectives…and knowledge of that technology” (pp. 179-180). Orlikowski (2000) states that “the empirical evidence (is) that people can (and do) redefine and modify the meaning, properties, and applications of technology after development” (p. 406).

Understanding how users interact with educational technology may reduce consequences unintended by the developers of educational technology. There are a number of structurational models of technology, where behavior and the structure of the technology are intertwined. Orlikowski (2000) states that:

> these models posit technology as embodying structures (built in by designers during technology development), which are then appropriated by users during their use of the technology. Human action is a central aspect of these models, in particular, the actions associated with embedding structures within a technology during its development, and the actions associated with appropriating those structures during use of technology (p. 405).

The structurational perspective of technology may explain "the consequences associated with the use of…information technologies" (Orlikowski, 2000, p. 405).

I introduced educational technology into this study without fully realizing the unintended consequences. Robert Merton (1936) discusses factors as to why there can be unintended consequences to actions. He lists the factors as 1) lack of information in the current state of knowledge; 2) making errors, such as assuming that what happened in the past will happen in the future, or in neglecting to thoroughly examine the problem; 3) the factor of immediacy of interest, in that the person is so interested in a desired outcome that he/she fails to consider other outcomes; 4) the factor of basic values that guides certain actions.

Summary

The unintended consequence of procrastination by the blended students led to a recency effect that resulted in the *blendedsingle* and *blendedmultiple* groups performing better than the *control* group on two achievement variables. Procrastination also led to the inability of the blended group students to watch all of the videos for the second simulation, accounting for the nonsensical result of the *control* group having a statistically significant difference in the time variable *Blackboard – Sim2*. With the differences of these three dependent variables accounted for, the study confirmed that there is no statistically significant difference of learning outcomes between a traditional face-to-face group and a blended learning group, once curricular materials, methodology of instruction, and time variables are equal.

Implications

For Practice

Blended learning can be used to shift more student learning to outside the classroom without sacrificing quality. The time shifting of material could be used strategically in preparing a course design and would be a conscious decision by the instructor. Blended learning can be a pedagogically excellent way to present curricular material to students. It needs to be understood by educators that material presented in a blended environment will not increase positive learning outcomes when compared to traditional lecture-based classroom material when controlled for curricular material and time spent viewing the material. If the blended learning environment is designed to require more time and effort by the student, then well-designed online curricular materials may lead to better learning outcomes. As there was no difference in learning outcomes as shown by this study, educators may opt for putting material online without lowering learning outcomes.

Blended learning can be implemented by universities to free up classroom space and utilize their facilities more efficiently, while maintaining the face-to-face classroom experience that so many students (and parents) expect from institutions of higher learning. It can also be used to allow the coverage of different or additional material in the classroom. Blended learning can free up instructors from having to cover in class the topics on the syllabus, and instead, have activities other than lectures in the classroom.

The introduction of online technology in this study had the unintended consequence of procrastination benefiting those who procrastinated. It is important for course designers to include instructional safeguards for online learning to minimize procrastination. It should be a course design decision as to when curricular material is viewed and when an activity based on that material is completed. The time shifting of material (and resulting procrastination in this study) may help with the execution of short-term and near-transfer tasks, but not necessarily in long-term knowledge acquisition. How short-term tasks and the recency effect affect implicit learning and long-term memory can be part of the course designer's pedagogical arsenal.

For Research

More research needs to be conducted on blended courses. This study sought to show that if curricular materials, instructional methodology, and time constraints were equal, learning outcomes from traditional or blended learning environments are equal. But it may not always be possible to duplicate curricular materials, instructional methodology, or time constraints across lecture-based, 100% online, and blended learning environments. Often, educators are restricted to one environment to teach. Sometimes blended learning may be the best possible environment for positive learning outcomes.

Of the 18 studies on blended learning that were part of the U.S. Department of Education's meta-analysis (2009) and were evaluated in this dissertation, only Zacharia's 2007 study produced a blended learning environment that would very difficult, if not impossible, to recreate in a classroom. Zacharia compared the learning outcomes of students building and testing electrical circuits in a real-world environment with outcomes of students who used both a real-world and virtual environment. The virtual environment had software that gave immediate feedback to the student that would have been very time consuming in a real environment. Feedback in a classroom could not have been given to the students nearly as quickly, efficiently, or accurately as that provided by the virtual environment. "The software evaluated the circuit whenever parts were added to, or removed from it, and offered feedback. The feedback varied according to the stage of construction of the circuit." (p. 123) The Zacharia study is an indication that there are areas of educational technology where blended learning is truly better than any other alternative.

Zacharia's 2007 study clearly showed that technology can be used in ways that cannot be replicated in the classroom. We need to understand what can be done online and not in the classroom. Clark and Estes (1998) present an argument that educational craft is too often mistaken for educational technology. Educators need to properly identify the problem, use scientific principles, and create educational technologies based on science. More research needs to be done on what specific problems students face in learning and integrating knowledge into schema, and how an educational technology can help.

This study attempted to provide good quality instruction by following principles that other studies have shown to be effective. Materials were developed with worked-out examples, guided instruction, and followed other principles of multimedia instruction. It is not possible to know the quality of instruction for this study, but the researcher has taught this course for over 10 years and has used the supply chain simulation for five years. The researcher consistently receives above-average course evaluations and was twice voted “Outstanding Teacher of the Year” by undergraduate students.

It may be assumed that this study provided good instruction. It may be the case that it does not matter through what medium good or excellent instruction is delivered, whether it be traditional lecture-based or blended. But it is unknown if mediocre or poor instruction would have provided a difference among the treatment groups. It may be that with mediocre or poor instruction, the students in the blended groups would need to view the videos multiple times, but with good or excellent instruction, multiple viewing may be unnecessary. Research needs to be conducted comparing learning outcomes between traditional and blended courses while accounting for quality of instruction.

The business simulations in this study required complex analytical thinking and problem-solving. It is unknown if, by watching the videos just before the simulations started, there was priming by the students and whether or not the dependent variables, therefore, were measuring a complex learning activity or not. Baddeley and Hitch (1993) showed that the recency effect can aid in implicit learning. More research can be done on whether blended learning can improve implicit learning in complex tasks with high cognitive load.

Blended learning has been touted as a way for educational institutions to better utilize scarce resources such as classroom space and faculty. For institutions to better understand how resources are actually used in blended learning, research on cost/benefit analyses is also needed.

In summary, this study showed that student learning outcomes in both a blended learning environment and traditional lecture-based classroom for a course module with high cognitive load are equal. However, we have had glimpses that educational technology, including blended learning, if researched and used properly, may provide improved learning outcomes for students.

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APPENDIX A

INFORMED CONSENT FORM
UNIVERSITY OF SAN FRANCISCO

CONSENT TO BE A RESEARCH SUBJECT

Purpose and Background

Assistant Professor Stephen Morris at the University of San Francisco's School of Business and Professional Studies is doing a study on comparing learning outcomes of undergraduate business students in a traditional face-to-face course module with those of students in a blended course module which combines elements of both online and traditional teaching methods.

More and more students are taking online courses and universities are interested in combining elements from online and traditional courses to determine if a better teaching model may emerge. The professor is interested if there are any differences between the two methods of instruction.

I am being asked to participate as I am an enrolled student in one of Professor Morris' *Systems in Organization* sections.

Procedures

If I agree to be a participant in this study, the following will happen:

1. I will complete a short survey on my attitudes towards technology and personal motivation.
2. I agree to have my scores in the course from assignments and tests used in the study for comparison purposes only. Absolutely no personal identifying information will ever be used in this study.
3. I give permission to use my GPA: Yes ☐ No ☐

Risks and/or Discomforts

1. It is possible that some of the questions in the survey on attitude towards technology and motivation may make me feel uncomfortable, but I am free to decline to answer any questions I do not wish to answer or to stop participation at any time.
2. Participation in research may mean a loss of confidentiality. Study records will be kept as confidential as is possible. No individual identities will be used in any reports or publications resulting from the study. Study information will be coded and kept in locked files at all times. Only study personnel will have access to the files.

Benefits

There will be no direct benefit to me from participating in this study. The anticipated benefit of this study is a better understanding of the differences between a traditional and a hybrid/blended course offering.

Costs/Financial Considerations

There will be no financial costs to me as a participant to the study

Reimbursement/Compensation

I understand that there will be no monetary reimbursement for participating in this study.

Questions

If I have any questions or comments about the study, I should talk to Professor Morris at 415-422-6964. If I have any questions or comments about my participation in this study, I should first talk to Professor Morris. If for some reason I do not wish to do this, I may contact the IRBPHS (Institutional Review Board for the Protection of Human Subjects), which is concerned with the protection of volunteers in research projects. I may reach the IRBPHS office by calling (415) 422-6091 and leaving a voicemail message, by emailing IRBPHS@usfca.edu, or by writing to the IRBPHS, Department of Counseling Psychology, Education Building, University of San Francisco, 2130 Fulton Street, San Francisco, CA 94117-1080.

Consent

I have been given a copy of the "Research Subject's Bill of Rights" and I have been given a copy of this consent form to keep. PARTICIPATION IN RESEARCH IS VOLUNTARY. I am free to decline to be in this study, or to withdraw from it at any point. My decision as to whether or not to participate in this study will have no influence on my present or future status as a student or employee at USF, nor will it influence my grade in this course. Professor Morris will not know if I have declined or consented to be part of this study until after grades have been posted at the end of the semester. My signature below indicates that I agree to participate in this study.

____ ____________________

Signature Date

RESEARCH SUBJECTS' BILL OF RIGHTS

The rights below are the rights of every person who is asked to be in a research study. As a research subject, I have the following rights:

(1) To be told what the study is trying to find out;
(2) To be told what will happen to me and whether any of the procedures, drugs, or devices are different from what would be used in standard practice;
(3) To be told about the frequent and/or important risks, side effects, or discomforts of the things that will happen to me for research purposes;
(4) To be told if I can expect any benefit from participating, and, if so, what the benefit might be;
(5) To be told of the other choices I have and how they may be better or worse than being in the study;
(6) To be allowed to ask any questions concerning the study both before agreeing to be involved and during the course of the study;
(7) To be told what sort of medical or psychological treatment is available if any complications arise;
(8) To refuse to participate at all or to change my mind about participation after the study is started; if I were to make such a decision, it will not affect my right to receive the care or privileges I would receive if I were not in the study;
(9) To receive a copy of the signed and dated consent form; and
(10) To be free of pressure when considering whether I wish to agree to be in the study.

If I have other questions, I should ask the researcher or the research assistant. In addition, I may contact the Institutional Review Board for the Protection of Human Subjects (IRBPHS), which is concerned with protection of volunteers in research projects. I may reach the IRBPHS by calling (415) 422-6091, by electronic mail at IRBPHS@usfca.edu, or by writing to:
USF IRBPHS
Department of Counseling Psychology
Education Building
2130 Fulton Street, San
Francisco, CA 94117-1080

APPENDIX B

PRETEST

Month	Sales ($ 000)
January	42
February	49
March	59
April	39
May	56
June	59
July	50
August	49
September	50
October	53
November	

1. Using the data in the table above and a 3-month moving average, which month has a demand forecast equal to 50?

2. A linear trend line for 12 months of data is y = 23.96 + 339x. What is the forecast for the next quarter (Jan, Feb, and March)?
   a) 11160.82
   b) 1380.04
   c) 2023.38
   d) 4431.22
   e) 14310.72

Year	Qtr 1	Qtr 2	Qtr 3	Qtr 4
2008	177	152	49	286
2009	208	151	98	255
2010	?	?	?	?

3. Using the data in the table above, what is the seasonal factor for the second quarter of 2010?

   a) .25
   b) .28
   c) .39

d) none of the above

4. Three forecasting models, all using the same data set, are being compared via their MAD values. The MAD value for Model X is 25.6, Model Y is 20.4, and Model Z is 15.2. Which forecasting model is considered the best?

a) Model X
b) Model Y
c) Model Z
d) Additional information is needed

5. What is the approximate forecast for May using a three-month moving average?

Nov	Dec	Jan	Feb	Mar	Apr
39	36	40	42	47	46

a) 38
b) 42
c) 43
d) 44
e) 47

6. Inventory costs for such things as rent, lighting, security, interest, and taxes are usually classifies as

a) carrying costs
b) ordering costs
c) shortage costs
d) continuous costs

7. All of the following statements concerning shortage costs are true ***except***

a) shortage costs can relate to temporary, as well as permanent, loss of sales
b) shortage costs are many times just educated guesses
c) shortage costs increase as carrying costs increase
d) shortage costs decrease as inventory on hand increases

8. Which of the following is ***not*** an assumption of the basic EOQ model?

a) Demand is known with certainty
b) Order quantity is received gradually over time
c) Demand is constant over time
d) Lead time for orders is constant

Carrying cost:	$11.25/unit/yr
Ordering cost:	$55/order
Demand:	15 units/week
Note: The current order quantity is 94 units. Assume 50 weeks per year.	

9. Using the data in the table above, which of the following statements concerning the current order quantity and EOQ quantity is true (Note: Round EOQ value to nearest whole number)

a) The ordering cost for the current order quantity is $8.78.
b) The total cost for the current order quantity is $985.76.
c) The current order quantity is too small to minimize total inventory costs.
d) The carrying cost for the current order quantity is $528.75

10. The probability that inventory on hand during the lead time is sufficient to meet expected demand is called the

a) service level
b) safety stock
c) reorder point
d) stockout

11. Calculate the reorder point for a company which has an average daily demand of 84 units and a standard deviation of 11 units, orders with a 4-day lead time, and maintains a 95% service level

APPENDIX C

POSTTEST

Month	Sales ($ 000)
January	42
February	49
March	59
April	39
May	56
June	59
July	50
August	49
September	50
October	53
November	

1. Using the data in the table above and a 3-month moving average, which month has a demand forecast equal to 50?

2. A linear trend line for 24 months of data is y = 23.96 + 339x. What is the forecast for the next quarter (Jan, Feb, and March)?
   a) 14,309.88
   b) 2,105.88
   c) 5,156.88
   d) 26,513.88
   e) 362.96

Year	Qtr 1	Qtr 2	Qtr 3	Qtr 4
2008	177	152	49	286
2009	208	151	98	255
2010	?	?	?	?

3. Using the data in the table above, what is the seasonal factor for the second quarter of 2010?

   a) .22
   b) .28
   c) .39
   d) none of the above

4. Three forecasting models, all using the same data set, are being compared via their MAD values. The MAD value for Model X is 25.6, Model Y is 20.4, and Model Z is 15.2. Which forecasting model is considered the best?

a) Model X
b) Model Y
c) Model Z
d) Additional information is needed

5. What is the approximate forecast for May using a three-month moving average?

Nov	Dec	Jan	Feb	Mar	Apr
39	36	40	42	47	46

a) 38
b) 42
c) 43
d) 44
e) 45

6. Inventory costs for such things as rent, lighting, security, interest, and taxes are usually classifies as

a) holding costs
b) ordering costs
c) shortage costs
d) continuous costs

7. All of the following statements concerning shortage costs are true ***except***

a) shortage costs can relate to temporary, as well as permanent, loss of sales
b) shortage costs are many times just educated guesses
c) shortage costs increase as holding costs increase
d) shortage costs decrease as inventory on hand increases

8. Which of the following is ***not*** an assumption of the basic EOQ model?

a) Demand is known with certainty
b) Order quantity is received gradually over time
c) Demand is constant over time
d) Lead time for orders is constant

Holding cost:	\$11.25/unit/yr
Ordering cost:	\$55/order
Demand:	15 units/week
Note: The current order quantity is 94 units. Assume 50 weeks per year.	

9. Using the data in the table above, which of the following statements concerning the current order quantity and EOQ quantity is true (Note: Round EOQ value to nearest whole number)

a) The ordering cost for the current order quantity is \$9.63.
b) The total cost for the current order quantity is \$963.39.
c) The current order quantity is too small to minimize total inventory costs.
d) The holding cost for the current order quantity is \$528.75

10. The probability that inventory on hand during the lead time is sufficient to meet expected demand is called the

a) service level
b) safety stock
c) reorder point
d) stockout

11. Calculate the reorder point for a company which has an average daily demand of 84 units and a standard deviation of 11 units, orders with a 9-day lead time, and maintains a 95% service level

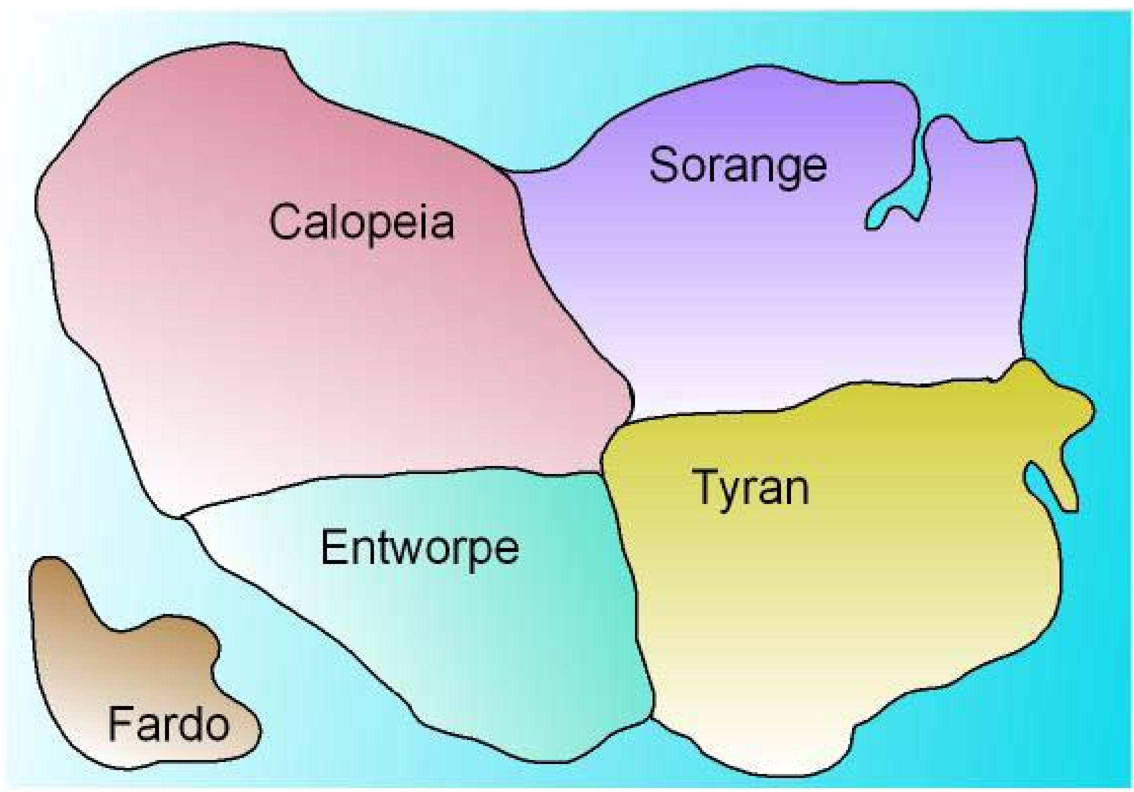
APPENDIX D

SIMULATION 1

The Supply Chain Game

Welcome! The Supply Chain Game is an online simulator where you can expand and manage a supply network on the fictional continent of Pangea. Please navigate through all the links on the left to learn more about the assignment, including instructions for managing your network.

PANGEA



The Market

Jacobs Industries' only product is an industrial chemical that can be mixed with air to form a foam that is:

- Lightweight;
- Stable over a very wide range of temperatures;
- A very efficient thermal insulator;
- A very efficient acoustic insulator.

Jacobs sells its chemical to manufacturers of air conditioner retrofit kits. The manufacturers are all located in the region of Calopeia. They purchase the foam chemical as a substitute for competitors' products. If Jacobs cannot ship an order within 24 hours of receiving the order from the customer, the customer makes its purchase from a competitor without any loss of future demand.

The chemical is shipped in small plastic drums at a price of $1450 a piece. Demand for the chemical is highly seasonal but otherwise very stable. There are no long-run market trends, either upward or downward. The size of orders is very random, with an average size of 7 or 8 drums. Orders arrive randomly throughout each 24-hour day.

It is now day 730, two years after Jacobs began producing and marketing the chemical. A new foam It is now day 730, two years after Jacobs began producing and marketing the chemical. A new foam technology is in development at Jacobs that will render all production capacity and inventory of the current foam obsolete and worthless on day 1460. All customers are aware of the pending new technology and as a result, demand will decrease to zero on day 1460.

Operations and Finance

Jacobs' distribution network consists of a single factory and a single warehouse, both in Calopeia. The warehouse only supplies air conditioner retrofit kit manufacturers, who are all in Calopeia.

Jacobs produces its chemical in batches, loads the chemical into small plastic drums, and then transports the drums from the factory to the warehouse by truck. The warehouse sends drums to customers as orders are received. The cost of fulfilling an order, including the cost of mailing the drum to the customer, is $150 per drum.

The current capacity of the factory is 20 drums per day. More factory capacity can be purchased at a cost of $50,000 per drum per day. For example, expanding the capacity by 10 drums per day for a total of 30 drums per day would be (10)$50,000 = $500,000.

Capacity costs are incurred as soon as the capacity expansion begins. It takes 90 days to complete a capacity expansion. Capacity cannot be retired.

Production in factories is carried out in batches, where each batch is an integer number of drums set by you. The cost to produce one batch equals $1500 plus the number of drums in the batch times $1000. For example, the cost to produce a batch of 10 drums is $1500 + (10)$1000 = $11,500.

The batch of finished drums is shipped from the factory to the warehouse as soon as production of the batch is completed. The drums can be shipped either by truck or one at a time by mail. One truck can carry 200 drums. One truck making a trip from the factory to the warehouse costs $15,000, regardless of how full the truck is. It costs $150 to mail one drum from the factory to the warehouse. Transportation times from the factory to the warehouse are 7 days for the truck or 1 day for mail. There is no practical limit to the number of drums a warehouse can hold.

Both the costs of producing the batch and then shipping it to the warehouse are incurred as soon as production of the batch starts. If there is insufficient cash to pay for the production and shipping of the batch, the factory will remain idle. Production of a batch is triggered when the finished goods inventory (both en route to the warehouse and in the warehouse) fall below the order point, which is set by you.

Jacobs pays insurance and other out-of-pocket holding costs on chemicals once production is complete. These holding costs for one drum for one year equal $100, whether the drum is en route to a warehouse or the drum is physically in the warehouse. There are no such holding costs for work-in-process inventory in the factory. Jacobs earns 10% per year on its cash, compounded daily.

Assignment

Your team has been hired to manage the supply chain for the Jacobs Industries. You can make the following changes to the supply chain:

- Capacity additions to the factory.
- The finished goods inventory threshold that triggers production of a new batch in the factory.
- The factory's production batch size.
- Whether batches are transported to the warehouse by mail or by truck.

Your objective is to maximize the cash generated by the foam technology over the remaining two years of its lifetime. On day 1460 the game will end and all inventory and capacity will be obsolete.

The simulation will run continually at the rate of 104 simulated days per real day, or 1 simulated day about every 14 minutes. You will have control of the game from day 730 to day 1460, or 730 days total. The game will conclude 7 days and about half an hour after it started. During that time you can access your supply chain any time of the day or night.

The winning team is the one with the highest cash position on day 1460.

After the game is over, your After the game is over, your team should turn in a 4-page memo describing the actions you took and in retrospect, whether there were other choices that would have allowed your team to do even better. You will graded on the use of conceptual tools from class that you use to justify your conclusions.

Registering Your Team

Before the simulation begins, you must register your team. Before you register you will need:

- The course registration code provided by your instructor.
- A team name and password that you make up.
- The names of the students on the team.

The team name and password may only consist of numbers and lower case letters with no spaces or punctuation.

After registering, if you want to make any changes to your team name, team password, or the students' names on the team, you can go back to the registration page, enter the code again, enter your team name and password you created earlier, and make your changes. To completely delete your team, delete all the student names and submit.

Click here to open a new window and register your to open a new window and register your team.

Logging In

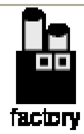
Once the game has begun you can access your firm by logging in using your team name and password.

If you have popup blocker, you will need to allow popups from the web site. Also, if you have modified your security settings, make sure you have not disabled cookies. There are some less common problems that students sometimes have:

> Click here if you get a "connection lost" message at the top of the screen after you log in.
> Click here to open a new window and log in.

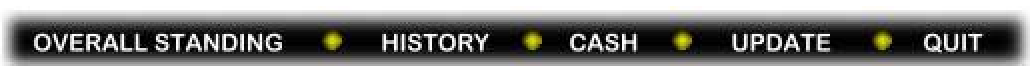
Viewing Data and Changing Parameters

After you log in, you will see three icons in the Calopeia region. Clicking on each icon will open a window presenting buttons to view historic data and make changes:

	Plot past demand, past lost demand, and your firm's past cash position.
	Plot past WIP inventory, add production capacity, and change order point, order quanity, and shipping method.
	Plot past finished goods inventory and shipments, and change order point, order quantity, and shipping method.

When you click on the factory or the warehouse, you will also see a field for **priority level**. In this assignment, the priority level does not affect your supply chain.

The menu bar below the map of Pangea provides additional functions:



- **Overall Standing** allows you to view all the teams' current cash balance in rank order.
- **History** allows you to view all your historic changes to your supply chain.
- **Cash** shows the starting cash, and uses and sources of cash that resulted in your current cash position.
- **Update** refreshes your screen, updating the cash position and day appearing above the map of Pangea
- **Quit** logs you out.

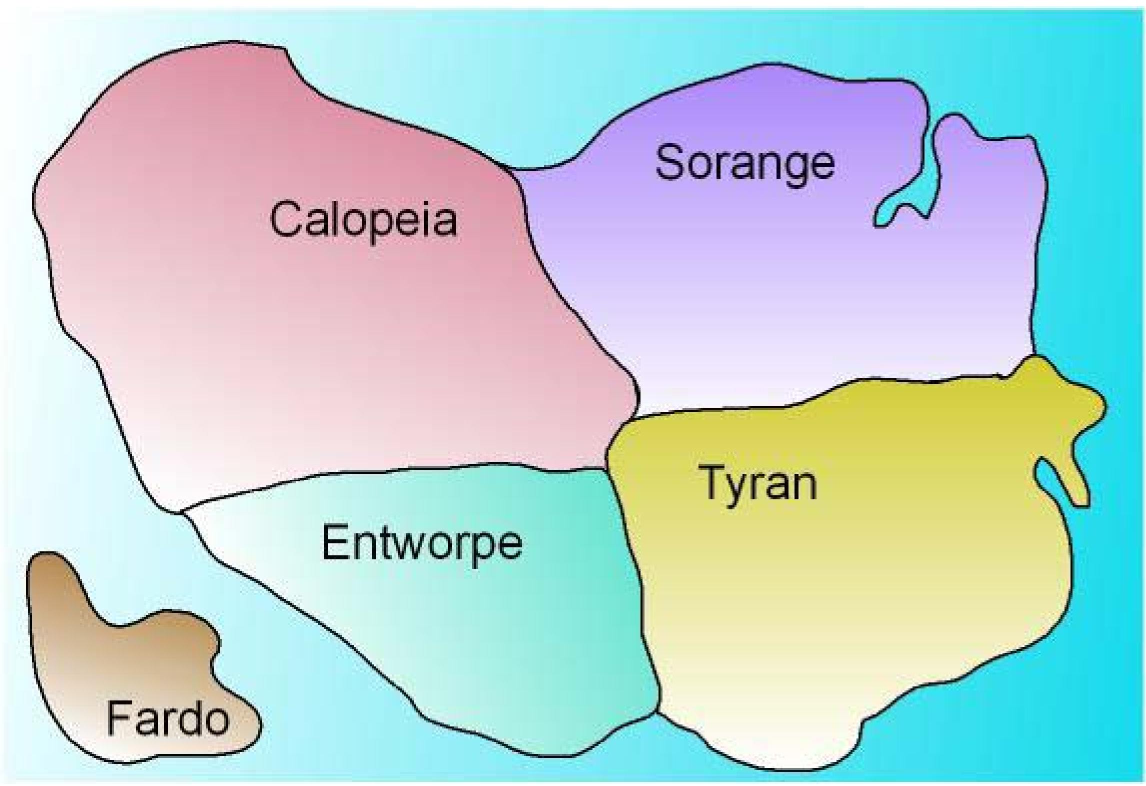
APPENDIX E

SIMULATION 2

The Supply Chain Game

Welcome! The Supply Chain Game is an online simulator where you can expand and manage a network of factories and warehouses to supply new markets in new regions on the fictional continent of Pangea. Please navigate through all the links on the left to learn more about the assignment, including instructions for managing your network.

PANGEA



The Product

Jacobs Industries' only product is an industrial chemical that can be mixed with air to form a foam that is:

- Lightweight;
- Stable over a very wide range of temperatures;
- A very efficient thermal insulator;
- A very efficient acoustic insulator.

Jacobs sells to manufacturers of products that will pay a premium for foam insulators with these properties. All of Jacobs' customers purchase the foam chemical as a substitute for competitors' products. If Jacobs cannot meet the order when it is received, the customer makes its purchase from a competitor without any loss of future demand.

Jacobs began marketing to manufacturers of air conditioner retrofit kits on day 1 and on day 640 began marketing to other markets. Click on the the different region names on the left for details.

Jacobs will begin migrating demand to a new Jacobs will begin migrating demand to a new technology using a different supply chain network on day 1430. Click on the "End of Life" link for details.

Calopeia: Air conditioner retrofit kits

The original application of the foam was for kits to retrofit or repair old industrial air conditioners. The properties of the foam made it possible to improve the efficiency of existing air conditioners within the constraints imposed by existing facilities. The industry that builds and sells these kits is concentrated entirely in Calopeia. The market is highly seasonal but otherwise very stable. There are no long-run market trends, either upward or downward. The size of orders is very random with an average size of 7 or 8. Orders also arrive randomly.

Sorange: Hardwood floor laminates

Hardwood floors are coming back into fashion. A common product addressing this market is a laminated wood panel that is made to snap together to easily cover a floor. However, poor acoustic properties of the laminates have been a problem in apartment buildings and condominiums where sound is easily transmitted to downstairs neighbors. Manufacturing of the laminates is concentrated in Sorange and two large manufacturers of laminates have recently added premium product lines with better acoustic insulation. Those laminates are a market for Jacobs' foam chemical.

Although order size and arrivals are random, the long run averge demand will grow linearly from day 640 until day 1430. The average order size is about 8 drums and demand is not seasonal.

Tyran: Premium home appliances

Customers of premium home appliances, especially driers and dishwashers, are willing to pay a premium for sound insulation. An appliance manufacturer with factories in Tyran and Fardo is offering a premium acoustic insulation option on several of its high-end appliances. Those appliances are a market for Jacobs' foam chemical.

Orders arrive to Jacobs directly from the appliance factories. Both order size and order arrivals are random. Demand began on day 640 and grew to its final long-run average a month later. Long-run average demand is not seasonal and is not trending either upward or downward. The average order size is about 8 drums.

Entworpe: Insulation products for commercial builders

A single manufacturer supplies insulating quilts for insertion into walls in new construction projects where both wall thinness and thermal insulation are important. These projects include laboratories inside office buildings and saunas inside commercial gyms. The quilts are a market for Jacobs' foam chemical.

The quilt manufacturer uses a reorder point policy where 250 units are purchased whenever its inventory drops to a predetermined level. So although orders are always for 250 units, orders arrive randomly. Demand started on day 640 and was stable by day 670. Long-run average demand is not seasonal and is not trending either upward or downward.

Fardo: Private airplanes

A make-to-order assembler of single-engine airplanes uses the foam as an insulator. The order size and order timing are random, although the average order quantity is about the same as that of the appliance factories in Fardo and Tyran described earlier. Demand began on day 640 and stabilized by day 670. Long-run average demand is not seasonal and is not trending either upward or downward.

End of Life Issues

A new foam A new foam technology is in development that will render the current technology obsolete. Factories producing the new foam will come online on day 1460. All customers are aware of the pending new technology, and as result, demand for all customers were decrease linearly beginning at day 1430, reaching 0 on day 1460.

Overview

Jacobs' distribution network consists of a single factory and a single warehouse, both in Calopeia. The warehouse only supplies air conditioner retrofit kit manufacturers, who are all in Calopeia.

Jacobs produces its chemical in batches, loads the chemical into small plastic drums, and then transports the drums to the warehouse by truck. The warehouse sends drums to customers as orders are received.

New Markets

About a year and a half into operations, Jacobs began looking for new markets and discovered a handful of industries where Jacobs foam would be a superior substitute for the insulating foam currently used in those industries. Marketing campaigns for these About a year and a half into operations, Jacobs began looking for new markets and discovered a handful of industries where Jacobs foam would be a superior substitute for the insulating foam currently used in those industries. Marketing campaigns for these target customers began on day 640. Regular communication with its target customers allows Jacobs to monitor the demand for its product in each of the new markets. However, Jacobs had not begun actually selling to any of the new markets yet. Jacobs is only selling to the original market in Calopeia.

Decisions

Jacobs management would like to serve the new markets it has identified if serving those markets is profitable. However, serving those markets could be logistically complex. Some decisions to be made include

- Which new markets should Jacobs sell to?
- When should Jacobs begin serving its new target markets?
- Should Jacobs continue to serve its original market?
- Should the factory in Calopeia be expanded?
- Should factories in other regions be built?
- Should warehouses in other regions be built?
- How should Jacobs schedule production?
- How should inventory in the warehouses by managed?
- How should chemicals be transported from factories to warehouses?
- Which warehouses should serve each target market?

You have been hired to make these decisions. Your goal is to maximize cash position generated by the foam You have been hired to make these decisions. Your goal is to

maximize cash position generated by the foam technology over its lifetime. On day 1460, the technology will be obsoleted by another technology currently in development.

Production parameters

A factory can only produce one batch a time. The more capacity a factory has, the faster it produces a batch of a given size. The cost of a factory building is $500,000 regardless of the factory capacity. The cost of factory equipment and fixtures is proportional to capacity: Capacity of one drum per day costs $50,000. For example, the cost to build a new factory with a capacity of 5 drums per day is $500,000 + (5)$50,000 = $750,000. Adding an additional capacity of 2 drums per day later would cost (2)50,000 = $100,000.

It takes 90 days to either construct a new factory or to add capacity to an existing factory. The cost of the factory is incurred as soon as construction begins. Capacity cannot be retired.

Production in factories is carried out in batches, where each batch is an integer number of drums set by you. The cost to produce one batch equals $1500 plus the number of drums in the batch times $1000. For example, the cost to produce a batch of 10 drums is $1500 + (10)$1000 = $11,500.

Warehousing parameters

A new warehouse costs $100,000. There is no practical limit to the number of drums a warehouse can hold. It takes 60 days to build a warehouse and the cost of the warehouse is incurred as soon as construction begins.

Jacobs pays insurance and other out-of-pocket holding costs on chemicals once production is complete. These holding costs for one drum for one year is $100, whether the drum is en route to a warehouse or the drum is physically in a warehouse. There are no such holding costs for work-in-process inventory in the factory.

Transportation parameters

Finished drums are shipped from the factory to the warehouse as soon as production is completed. The drums can be shipped by either truck or mail. One truck can carry 200 drums. If the batch is less than 200 drums, then less than a truckload will be used. The cost of full or less-than-full truckload is the same. If drums are shipped by mail, the shipping cost is proportional to the number of drums being mailed. Transportation costs are as follows:

Origin and destination	cost per truckload	cost to mail one drum
Same region	$15,000	$150
Different regions on continent	$20,000	$200
Between continent and Fardo	$45,000	$400

Transportation times are as follows:

Origin and destination	truck	mail
Same region	7 days	1 day
Different regions on continent	7 days	1 day
Between continent and Fardo	14 days	2 days

Financial and other parameters

All customers will pay $1450 per drum. The drum must be shipped within 24 hours of receiving the order or the order is lost. Warehouses may partially fill orders and one order may be filled from multiple warehouses.

All order fulfillment is by mail, so the cost to fulfill an order is:

- $150 per drum if the order is in the same region as the warehouse
- $200 per drum if the order and the warehouse are in different regions on the continent
- $400 per drum if the order is on Fardo and the warehouse is on the continent, or the order is on the continent and the warehouse is on Fardo.

Interest accrues on cash at 10% per year, compounded daily.

Assignment

Your team has been hired to manage the supply chain for the Jacobs Industries. You can make the following changes to the supply chain:

- New factories and warehouses in regions outside Calopeia.
- Capacity additions to existing factories.
- For each factory the finished goods inventory level at each warehouse that would trigger production of a new batch for that warehouse.
- For each factory, the size of batch produced for each warehouse.

- Whether batches are transported from each factory to each warehouse by mail or by truck.

Your objective is to maximize the cash generated by the foam technology over the remaining two years of its lifetime. On day 1460 the game will end and all inventory and capacity will be obsolete.

The simulation will run continually at the rate of 104 simulated days per real day, or 1 simulated day about every 14 minutes. You will have control of the game from day 730 to day 1460, or 730 days total. The game will conclude 7 days and about half an hour after it started. During that time you can access your supply chain any time of the day or night.

The winning team is the one with the highest cash position on day 1460.

After the game is over, your After the game is over, your team should turn in a 4-page memo describing the actions you took and in retrospect, whether there were other choices that would have allowed your team to do even better. You will graded on the use of conceptual tools from class that you use to justify your conclusions.

Changing Your Team Name or Password

You will play with the same team as in the first game. To make any changes to your team name, team password, or the students' names on the team, you can go back to the registration page, enter the code again, then enter your team name and password you created earlier, and make your changes.

Once the game has started, you may not modify your Once the game has started, you may not modify your team.

Logging In

Once the game has begun you can access your firm by logging in using your team name and password.

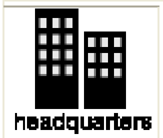
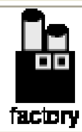
If you have popup blocker, you will need to allow popups from the web site. Also, if you have modified your security settings, make sure you have not disabled cookies. There are some less common problems that students sometimes have:

Click here to open a new window and log in.

Viewing Data and Changing Parameters

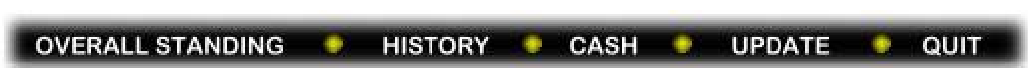
After you log in, you will see three icons in the Calopeia region: headquarters, a factory, and a warehouse, You are allowed a maximum of one factory and one warehouse in each of the other four regions. A black factory or warehouse icon signifies the factory or warehouse is currently operational. A gray icon signifies the factory or warehouse is under construction. To begin construction of a new factory or a new warehouse, click on the region where you would like to begin construction and fill in the resulting form.

Clicking on each icon will open a window presenting buttons to view historic data and make changes:

	Plot past demand, past lost demand, and your firm's past cash position. If there are multiple warehouses, there will also be a description and choice of fulfillment policies.
	Plot past WIP inventory, add production capacity, and change order point, order quantity, shipping method, and priority to each warehouse.
	Plot past finished goods inventory and shipments. Change order point, order quantity, shipping method, and priority from each factory. Select the regions in which that warehouse can fulfill demand.

The terms in the forms are hyperlinked to more detailed definitions.

The menu bar below the map of Pangea provides additional functions:



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