An Evaluation of Blended Instruction in Terms of Knowledge Acquisition and Attitude in an Introductory Mathematics Course

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Dedication

The most important component of any person's life is the partner they have. This dissertation is dedicated to my best friend and wife, Shannon. Without her words of encouragement, emotional support, focus, reassurance, and occasionally forceful prodding, this work would never have been completed. This degree represents all of her efforts as well as mine. I am forever indebted for her love and support. I love you.

Abstract

A medium-sized accredited public university located in southeastern Minnesota has been offering an introductory undergraduate mathematics course with a consistent curriculum in two instructional formats: face-to-face and blended. Previously the course was offered only through a face-to-face instructional format while currently, it is only offered in a blended instructional format. This case study explored the influence that the method of instruction had on student achievement on common assessments, how a blended instruction course design impacted the attitude of students, and the amount of knowledge acquired in a blended instruction environment.

A blended course is one taught by combining teacher-centered face-to-face instructional elements with online learning components and online course management tools. In more general terms, blended instruction is a term used to describe instruction or training events or activities where online learning, in its various forms, is combined with more traditional forms of instruction such as "classroom" learning. The terms *hybrid* and *mixed mode* are references to the same type of instruction and therefore used synonymously.

An instrument developed by Martha Tapia and George Marsh measured changes in attitude toward mathematics related to a blended instructional course design. While one area of interest was the level of procedural knowledge acquired in a blended instructional environment versus that of a face-to-face setting, an additional interest was student comprehension beyond procedural knowledge. This study noted applications of the common knowledge students used to demonstrate their comprehension and sense-making ability. In order to evaluate the additional level of understanding, this study asked questions of students enrolled in a blended instructional environment via a series of interviews as well as observing classroom activities designed to allow for further exploration of content and demonstration of knowledge beyond that allowed for in a face-to-face setting.

Results from this study indicated a statistically significant difference in comparing final course grades and final examination grades of the students enrolled in the blended instruction designed course versus the face-to-face lecture courses while the instructor was held constant. Students were less anxious working on assigned problems and assessments as they familiarized themselves with the design and instructional strategies. In addition, students were more engaged in discussions as the semester progressed, and students experienced the benefits of communicating with group members. The results also indicate that students enrolled in a blended instruction course perceive that the classroom environment promotes interactions, and they are involved in classroom discussions and activities.

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CHAPTER 1: INTRODUCTION

Rationale

The continued growth of online education cannot be overstated; partially and completely web-based instruction in education is here to stay (Allen & Seaman, 2010). With traditional resources becoming increasingly scarce, the appeal of incorporating online instruction as a cost-effective option (Kirby, 1998) is piquing the interest of school administrators. Universities and colleges in the United States have undergone a technological transformation as educational technology has become woven into all aspects of higher education. Despite predictions that growth in online education would begin to level off, colleges and universities reported the highest-ever annual increase in enrollment for online courses – more than 21 percent – for fall 2009 compared to the previous year, the most recent information available (Allen & Seaman, 2010). The authors, as part of The Sloan Consortium, report that approximately1.6 million students took at least one online course in 2002, increasing to almost 5.6 million in 2009. Furthermore, Allen & Seaman state in that, in 2002, online enrollment comprised 9.6% of the total enrollment in degree-granting postsecondary institutions and that this figure continued to grow to 29.3% of total enrollment in 2009. The growth rate of online education shows no sign of decrease and is far outgaining the growth rate of the overall student population in higher education (Paden, 2006), with 98% of large, public institutions having at least one online offering (Allen & Seaman, 2007).

Courses utilizing blended instruction integrate online learning, in its various forms, with more traditional teacher-centered forms of instruction such as "classroom" learning. Blended courses promise, according to Jeffrey Young (2002), "the best of both worlds" (p. 33), offering some convenience of an entirely online course without the complete loss of face-to-face contact (Colis & Moonen, 2001; Graham, 2005; Lindsay, 2004; Osguthorpe & Graham, 2003; Picciano & Dziuban, 2005; Twigg, 2003; Young, 2002). Higher education is attempting to utilize the strengths of online courses and face-to-face traditional courses by developing and offering blended courses. It is in this blended approach that some faculty design a more effective course compared to that of a completely face-to-face or completely online design (Garnham & Kaleta, 2002; Garrison & Kanuka, 2004; Graham, 2005; Graham, Allen & Ure, 2003; Osguthorpe & Graham, 2003). One of the basic concepts underlying blended instruction is that "those who use blended learning environments are trying to maximize the benefits of both face-to-face and online methods – using the Web for what it does best and using class time for what it does best" (Osguthorpe & Graham, 2003, p. 227).

Students who have trouble studying mathematics indicate they struggle having to understand the theories and memorize the procedures (Shafie, Ahmad, Janier, & Sarlan, 2007). The relationship between attitude toward mathematics and achievement in mathematics has been a focal point in higher education research (Bassette, 2004; Ma & Joshor, 1997; Tapia & Marsh, 2001; Tapia & Marsh, 2004; Tapia & Moldavan, 2004). A frequently recognized and researched predictor of success in mathematics is attitude (Aiken, 1970; Bassarear, 1991; Fennema & Sherman, 1976; Ma & Kishor, 1997;

Sandman, 1980; Tapia, 1996; Waycaster, 2001). In many of these studies, it was not conclusive that traditional methods influence student attitudes toward learning mathematics. Research has concluded that "attitudes toward mathematics are extremely important in the achievement and participation of students in mathematics" (Tapia & Marsh, 2001, p. 5), and there may be a relationship between attitude toward mathematics and ability in mathematics (Dwyer, 1993).

This study examines the attitudes of students toward mathematics in a precalculus mathematics course at a midwestern public university. Using an attitude survey, the Attitudes Toward Mathematics Inventory (ATMI; Appendix A), which has been used in previous research studies (Curtis, 2006; Schackow, 2005; Sisson, 2011; Tapia & Marsh, 2000), this study focuses on measuring several dimensions of students' attitudes toward mathematics, including their enjoyment of mathematics, their perceived value of mathematics, their self-confidence in working with mathematics, and their motivation to continue taking courses in mathematics. With the help of course redesign, the present study attempted to determine if a blended instruction environment that was more student-centered allowed for changes in student attitudes toward mathematics and assisted student acquisition of course content.

Statement of the Problem

The potential for improving the efficiency and effectiveness of learning and teaching is often cited as a reason to implement blended instruction (Brown, 2001; Garnham, & Kaleta, 2002; Van Camp, 2000; Young, 2002). Many studies comparing face-to-face and entirely online education have summarized that learning in an online format can be as successful and equally effective as learning in a face-to-face environment (Garnham & Kaleta, 2002; Garrison & Kanuka, 2004; Graham, 2005; Graham, Allen & Ure, 2003; Osguthorpe & Graham, 2003). There has been a recent increase in numbers of proponents of a third alternative – blended instruction – as having the potential to produce comparative, if not better, results than either of the distinct formats. Pearcy (2009) noted that the areas in which blended instruction has advantages might be a result of blended instruction combining the strengths of face-to-face instruction (increase in the number of intimate interactions and possibility for immediate feedback) and online learning (use of technology, asynchronous setting, and interactive features). Many universities are turning to the blended model to solve space shortages, offer schedule flexibility, and improve the overall learning experience (Lindsay, 2004; Picciano & Dziuban, 2005; Young, 2002).

In addition to an exploration of any blended instruction effect, the acquisition of knowledge is also examined. For this study, procedural knowledge is seen as the understanding of educational tasks and the surroundings under which educational goals are realized (Byrnes & Wasik, 1991). Further, students have the potential to efficiently solve problems as they approach automaticity. It is through practice that automation is accomplished by allowing rapid recall and performance of the acquired procedural knowledge with “minimal conscious attention and few cognitive resources” (Johnson, A., 2003). Baroody (2003) continues that procedural knowledge is not completely open to “conscious inspection” and can, thus, be hardly expressed verbally or explained through “higher mental processes” which results in procedural knowledge often being linked to specific problems or problem types. This study will examine the extent that students acquire knowledge in a blended instruction setting.

A medium-sized accredited public university located in a small midwestern city (referred to hereafter as *Public University*) has been offering an introductory undergraduate applied precalculus course (referred to hereafter as *Math* 112) with a consistent curriculum in two instructional formats: face-to-face and blended. Previously the course was offered only through a face-to-face instructional format that was predominantly teacher-centered while currently, it is only offered in a blended instructional format in which there was an incorporation of student-centered activities and learning experiences. This study explored the influence that the method of instruction had on student achievement on common assessments, how a blended instruction course design that was more student-centered impacted the attitude of students, and the amount of knowledge acquired in a blended instruction environment. This study compared academic achievement, as measured by final examination and final course grades, in Math 112 taught in the two instructional formats. In addition, effects on student attitude towards mathematics were evaluated through researcher observations, interviews, and collection of artifacts.

Research Questions

The research questions that were examined in this study included the following:

1. What differences exist in the procedural knowledge of students enrolled in a pre-calculus mathematics course following a blended instruction format compared to students in a face-to-face environment?

2. What kinds of understandings beyond procedural knowledge do students in a blended instruction environment exhibit?

3. How do student attitudes toward mathematics evolve in a blended instruction format?

Definition of Terms

For the most part, unless otherwise attributed, a majority of definitions are taken and/or paraphrased from Schlosser and Simonson's comprehensive summary of definitions in *Distance education: Definition and glossary of terms* published by the Association for Educational Communications and Technology (2006).

Face-to-face instruction. The terms *onsite, face-to-face, traditional,* and *classroom instruction* are all used interchangeably. "Traditional classroom instruction is defined as time and place bound, face-to-face instruction, typically conducted in an educational setting and consisting primarily of a lecture/note-taking model" (Ramage, 2002, Methodology section, paragraph 1). For this study, the researcher is using teacher-centered face-to-face instruction as the underlying definition of this instruction.

Online instruction. Although wide varieties of definitions exist, for the purposes of this study, online instruction is defined as instruction where "the student is physically separated from the faculty and 'connected' through the use of a computer and a network or Internet link" (Ramage, 2002, Methodology section, paragraph 1). The communication takes places through software that typically allows for the threading of conversations wherein a message along with all subsequent comments to a message are available as a running log in the classroom (Collison, Elbaum, Haavind, & Tinker, 2000), online chat, virtual classrooms, self-paced content, etc.

Blended instruction. A term used to describe instruction or training events or activities where online learning, in its various forms, is combined with more traditional forms of instruction such as "classroom" learning. The terms *hybrid, mixed mode,* and *blended instruction* all reference the same type of instruction, i.e. "courses that combine face-to-face classroom instruction with online learning and reduced classroom contact hours (reduced seat time)" (Dziuban, Hartman, & Moskal, 2004, p. 2). *Blended instruction* is not utilized when the instructor uses the Internet in the classroom, but rather it is when face-to-face learning is combined with other distance delivery systems.

Procedural knowledge. The present study will define this to be the ability to execute action sequences to solve problems (Rittle-Johnson, Siegler, & Alibali, 2001).

Letter grade. The evaluation of student's performance by an instructor in a given course is represented by a letter grade issued for the course. Possible letter grades that can be issued are A, B, C, D, and F. The A letter grade represents the highest level of achievement, and F represents the lowest level of achievement, also known as a failing grade. Each semester hour of credit attempted receives honor points used to calculate student grade point average according to the following: Each "A" credit = 4 Grade Point Average (GPA) points, each "B" credit = 3 GPA points, each "C" credit = 2 GPA points, each "D" credit = 1 GPA point, and each "F" credit = 0 GPA points.

Attitude. This term will refer to a "predisposition to respond in a favorable or unfavorable manner with respect to a given attitude object" (Oskamp & Schultz, 2005, p. 9).

Attitude toward mathematics. This study will utilize the definition provided by Haladyna, Shaughnessy & Shaughnessy: "a general emotional disposition toward the school subject of mathematics" (1983, p. 20).

Purpose of the Study

Online learning systems have emerged as the preferred instructional model in college-level distance education. Using a home computer and Internet access, students situated anywhere in the world can attend a class online. Classroom discussion among students and with the instructor, along with the completion and submission of assignments, can be conducted electronically and either within or outside the confines of a physical classroom space. Utilizing the current and emerging technologies creates active learning opportunities (Garfield, 2004; Malone & Bilder, 2001) while simultaneously sparking an interest for the students and providing an alternate educational pedagogy for instructors.

At the same time that online learning has gained a foothold in higher education, a new blended, or hybrid model of instruction has appeared that integrates the face-to-face classroom experience with online education. Although combining face-to-face learning with various components of distance education is not new, what is new is the blending of purely online learning that is student-centered with purely face-to-face learning that tended to be teacher-centered. Some theorists and researchers tout blended instruction as the best of both instructional worlds through a balance of electronic access to knowledge coupled with human interaction for those not willing to commit to instruction delivered entirely online (Allen & Seaman, 2003; Allen, Seaman, & Garrett, 2007; Conhaim, 2003; Osguthorpe & Graham, 2003; Paden, 2006; Young, 2002). Others also claim that blended instruction is more effective for teaching procedural knowledge as blended instruction results in better outcomes compared to strictly online or strictly face-to-face instruction (Sitzmann, Kraiger, Stewart, & Wisher, 2006; Zhao, Y., Lei, J., Yan, B., Lai, C., & Tan, H. S., 2005), and blended instruction may encourage deeper and more active learning (Bonk, Kim, & Zeng, 2006; King, 2002).

Even though blended instruction is gaining support and attention, the level of growth it is experiencing is not as apparent. While research over the past several years appears to indicate that students can be as successful in learning in an online environment as in a face-to-face setting (Barry & Runyan, 1995; Cole, 2000; Gagne & Shepherd, 2001; Hiltz, Zhang & Turoff, 2002; Russell, 1999; Schulman & Sims, 1995; Swann, 2003, 2004), colleges and universities recognize that there are advantages and disadvantages to offering courses in the respective formats. “Comfort and convenience were cited repeatedly as positive elements” of online learning (Spooner, Jordan, Algozzine, & Spooner, 1999, p.3). Despite the convenience of online courses, the lack of face-to-face physical interaction is one of the major limitations of this instructional format (Kirby, 1999; Kruger, 2000). The differences have led some educators to conclude that instructional methods should be chosen based on their relative advantages and disadvantages (Edward & Fritz, 1997).

There exists a curvilinear relationship between the effort put forth by students and the amount of learning (understanding) that transpires. Cottrell & Robinson (2003) created a model (see Figure 1) that shows the dual role of the objectives of most courses is to provide students with the information required along with the tools for applying the knowledge to applicable problem situations. According to Cottrell & Robinson, initial learning happens at a fast rate due to the uniqueness of the strategy being implemented in the classroom (objective #1). The student reaches an eventual plateau level of learning as they maintain a certain amount of consistency in effort put forth. It is then after the student is able to work with and understand the technical aspects of the information being presented that students can fine-tune their abilities, leading to another leveling out after

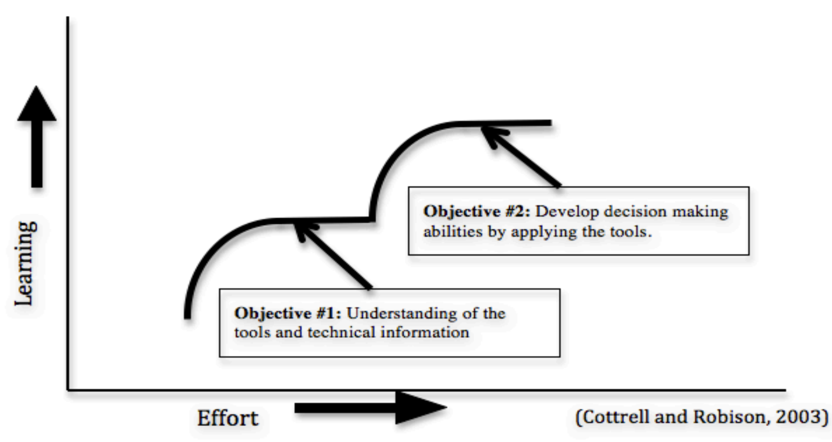

Figure 1: The relationship between students' learning and effort for achieving higher order objectives.

practice with the newly acquired knowledge leading to skill and thoughtful decision-making (objective #2) being developed. In essence, two objectives exist within the classroom: (1) understand the technical material, and (2) apply the technical material.

To illustrate this development of understanding, the acquisition of knowledge related to linear functions will be used as a reference. In a precalculus setting, students are originally introduced to the language, basic information regarding functions, and specifically, linear functions. Students typically begin by describing a function through a series of repeated interpretations, focusing on individual input and output values. This suggests that students do not view functions as generalized processes. However, when they begin to explore and reflect upon representations through practical applications present in the blended instruction design, the result is a deepened understanding of the functions themselves and a progression toward Cottrell and Robison's second objective.

An underlying component to education is helping students attain a high level of understanding and comprehension. As students encounter difficult material, a blended instruction environment that is student-centered may support students to understand ways to apply what they are encountering. What is important is that educators understand the issues surrounding effective implementation of blended instruction courses. The student-centered blended instruction environment has the potential to help students understand and apply skills by providing access to knowledge and offering timely feedback from instructors and peers (Robison, 2004).

Assumptions

This study is based on a series of assumptions:

1. The homogeneous characteristics of students enrolled in blended and face-to-face courses remains consistent.
2. The students were intrinsically motivated to learn and fully participate in the course.
3. The participants gave honest answers and opinions to all inventories and interviews.
4. The participants had the ability to learn the subject matter.
5. The curriculum for Math 112 is virtually identical across the two methods of instruction, since the curriculum is centrally developed by the university to ensure that textbooks, assignments, objectives, and outcomes are similar in all sections of the course taught at Public University. As a component of the identical nature between the methods of instruction, assessments are identical.

Delimitations

Delimitations describe "the population to which the study specifically applies and for which generalizations can be made" (McDade, 1999, p. 21). This study examines the topic through the lens of one select population and has the following delimitations:

1. Because of classroom and student data-access issues, the study was limited to one midwestern public university.

2. The findings and results may or may not generalize to other subject areas, other methods of instruction, or other institutions of higher education.

Significance of the Study

The number of students enrolled in higher education programs continues to grow in the United States and had reached 3.18 million students by the fall semester of 2005 (Allen et al., 2007). This enrollment figure indicates a substantial growth from the figures from previous years: 2.3 million in 2004 (Allen & Seaman, 2006) and 1.9 million in 2003 (Allen & Seaman, 2004). The number of undergraduate mathematics programs available online continues to increase, and many of these programs will begin or continue to incorporate some form of face-to-face experiences for learning. This blended instruction format may improve upon the advantages that face-to-face and online learning offer while eliminating the disadvantages. Ultimately, there is potential to advance the quality and accessibility of introductory mathematics courses.

In the academic environment, the initial cost-saving benefit of online instruction is being replaced with a refined understanding of integrating technology into an overall strategy for learning (Gayeski, 1998; Osguthorpe & Graham, 2003; Pearcy, 2009; Wilson, 2003). Pearcy (2009) continues this thought in her position that "blended learning is sometimes preferable because it provides pedagogical richness and access to knowledge, social interaction, and personal agency."

Although there is still some resistance towards entirely virtual learning environments, students as well as faculty have started to recognize the potential advantages of integrating aspects of online learning (Jaffee, 1998). While the face-to-face lecture method is regarded as an efficient approach, easily controlled by the teacher, and conducive to predictable and manageable student learning (Kim & Kellough, 1987), it has been criticized for stifling creative thinking, not allowing for much student involvement in decision making, and lacking intrinsic sources for student motivation. In courses following a face-to-face format that is primarily teacher-centered, students may not have a chance to benefit from collaborative learning, especially in large-enrollment courses. Face-to-face classroom discussions directed more toward the instructor, where vocal students tend to dominate, could frustrate learners with a more introverted personality (Pearcy, 2009). Additionally, discussions may be superficial, spontaneous and limited (Rovai & Jordan, 2004), and lecture-based courses may fail to promote deep learning (Campbell, 1998).

A combination of numerous concerns led Saba (1999), a leading theorist in the distance learning field to advise potential researchers that the "proper question is not whether distance education is comparable to a hypothetical 'traditional,' or face-to-face, instruction, but if there is enough interaction between the learner and the instructor for the learner to find meaning and develop new knowledge" (p. 2). The focus of current research studies on blended instruction in introductory mathematics has been on supplementing online courses with face-to-face learning activities. What is needed are research studies that examine blended instruction in mathematics at the introductory program level in order to provide educators with evidence of its success and offer suggestions to apply the blended instruction concept. The findings of this study address the voids in research as well as provide evidence of the contributions that blended instruction can make in introductory mathematics courses at the program level.

Overview of the Dissertation

This study is organized around six chapters. Chapter 1 introduces the literature, a rationale for the study, and presents the research questions and definitions used in the study. Chapter 2 presents a review of the literature related to this topic emphasizing prior research on interactions in a blended instruction environment. Chapter 3 outlines the research design and methodology used to investigate the research questions and further discusses the Attitudes Toward Mathematics Inventory (ATMI) designed by Tapia and Marsh (2004). Chapter 4 presents the cases utilized in this research. Chapter 5 presents the results of the data analysis and findings. Chapter 6 includes a summary of this research study, discussion of the findings, recommendations for future studies, and concludes with a summary of the dissertation.

Summary

This study evaluates the attitude towards mathematics of students enrolled in a mathematics course utilizing a blended instruction design, and the acquisition of procedural knowledge is further used to evaluate this hybrid format. In doing so, this study contributes to answering the question "do blended courses really offer the best of both worlds?" Specifically, the study assesses feedback from students enrolled in a mathematics course utilizing the blended instruction environment and their perceptions regarding self-confidence, value, enjoyment, motivation, as well whether there is a sense of higher levels of understanding and appreciation of the mathematics introduced to the students in the classroom setting. Discussions also center on the extent that students are able to develop their understanding of the mathematical content of the course through activities integrated into the blended instruction approach. Being able to explain and demonstrate levels of understanding in ways not present in the lecture-based format are studied.

CHAPTER 2: LITERATURE REVIEW

This chapter begins with a brief overview of face-to-face lecture as well as the development of distance education and the transition to online learning. What follows is an evaluation of the effectiveness of distance and online learning and a transition to incorporate computer-aided and blended instruction. The present study continues with a definition of attitude and sections describing the difference between "mathematics attitude" and "attitude toward mathematics," including the development of attitude instruments and a focus on the Attitudes Toward Mathematics Inventory that was implemented for this study. The final section describes relevant research on attitude toward mathematics and the effects attitude has on knowledge acquisition in mathematics. Throughout the review of literature for this study, an emergent theme of attitude and success in mathematics was a significant factor affecting the success of college students.

Face-To-Face Lecture

A face-to-face lecture classroom can be defined as one in which the learning is primarily teacher-centered and located predominantly within the confines of a classroom. Suggested by Haladyna, Shaughnessy, and Shaughnessy (1983), success is influenced by the teacher and the learning environment. A description of a traditional face-to-face classroom environment would include the predominantly one-way direction of information; the instructor typically acts as the sole presenter of material and information.

Historically, the learning environment in a face-to-face lecture classroom has been viewed as rigid and there can be more of a presentation of the material rather than a discussion among the participants. A major criticism is that there sometimes can be little opportunity for collaborative learning, discussions, or spontaneous creativity in some face-to-face learning environments that are teacher-centered (Rovai & Jordan, 2004; Sisson, 2011).

Classrooms designed around a predominantly teacher-centered, face-to-face method of instruction have unique advantages. Robison (2004) mentions that the emotively supportive face-to-face environment of the classroom allows instantaneous feedback, in addition to a social environment, which has been viewed as essential to a quality educational experience. Verbal and non-verbal forms of communication provide the instructor clues to the level of student understanding and engagement by the students in the classroom.

The face-to-face classroom usually requires everyone travel to a single location, and there is a fixed amount of time for interaction (Robison, 2004). Furthermore, larger class sizes restrict the opportunity for social interaction and the individual attention students might receive (Robison, 2004; Zener & Uehlin, 2001).   Private interaction between teacher and student is often severely limited in a busy classroom.

There are many benefits of the face-to-face classroom design. Zenger & Uehlein suggested nine:

i. Students found the enthusiasm of an effective instructor for the content of the course contagious and motivational.

ii. Students preferred learning in a social environment.

iii. There was a feeling of accountability in the face-to-face classroom as a result of periodic quizzes and attendance requirements.

iv. Spontaneous and indirect learning occurred when students interacted within the face-to-face classroom.

v. By limiting the potential for other activities/distractions, face-to-face sessions enabled students to focus more on their learning.

vi. Discussing the course content allowed for a comfortable exchange of ideas.

vii. There is a certain level of comfort and familiarity with learning in a group setting, thus a face-to-face setting could ease anxiety.

viii. The pace of the course could be controlled by the instructor in a face-to-face setting based on observations of the class thereby having an influence of knowledge acquisition.

ix. The experiences of the face-to-face setting allowed the students to practice and observe skills discussed in the classroom while simultaneously receiving feedback from the instructor.

Despite a long history of general effectiveness, the needs of some learners are not met within face-to-face classroom settings, as a result, distance and online learning has been able to meet some of those needs (O'Quinn & Corry, 2002; Robison, 2004). Such programs may mean the difference between furthering and foregoing the additional education because of the high opportunity cost of doing so (Chen & Jones, 2007). Any discussion about distance and online education must begin with the background and development of the programs, which is the discussion in the next section.

Overview of Distance Education and the Transition to Online Learning

Schlosser and Simonson's (2006) definition of distance education describes it as institution-based, formal education in which the learning group is separated and interactive telecommunication systems are used to connect instructors, learners, and resources. Moore and Kearsley (2005) defined distance education as:

> …planned learning that normally occurs in a different place from teaching and as a result requires special techniques of course design, special instructional techniques, special methods of communication by electronic and other technology, as well as special organization and administrative arrangements. (p. 2)

Contrary to the thought by many that distance education is a somewhat recent phenomenon, distance education can be traced as far back as the early 1700s to the implementation of correspondence studies designed for training in agriculture and mining (MacGregor, 2001). Another early and well-known example is that of Sir Isaac Pitman who, in 1840, offered correspondence courses related to learning shorthand (Matthews, 1999; Watkins, 1991). Instruction was offered through correspondence study programs in the United States, Germany, Australia, Japan, Germany, China, and the United Kingdom by the late 1800s and early 1900s (Keegan, 1996; Matthews, 1999).

Distance learning, in its broadest definition, can be thought of as any learning environment in which there is a physical separation of the instructor and the student (Comey, 2009; Holmberg, 1995; Keegan, 1996; Moore & Kearsley, 2005; Verduin &

Clark, 1991). One of the first higher education institutions to apply correspondence study toward an academic degree was the Chautauqua College of Liberal Arts in 1883. Other institutions followed, and, by the early 1900s, higher education institutions such as the University of Wisconsin, the University of Kansas, and the University of Chicago were introducing their own correspondence study programs (Morabito, 1997; Watkins, 1991).

If the first generation of distance education was thought of as the period of correspondence study development, then the second generation included the evolution of print materials, along with the integration of broadcast media, audio and video cassettes, and telephone conferencing (Sumner, 2000). Whereas the history of distance education could be tracked back to the early 1700s in the form of correspondence education, technology-based distance education might best be linked to the introduction of audiovisual devices into the schools in the early 1900s (Jeffries, 1997). The uses of motion pictures and slides as a component of distance education are examples of these first iterations to include the emerging technologies interconnected with print media.

From this beginning, educators have been searching for new technologies to eliminate barriers of access and time limitations in the higher education setting. During its use for instructional purposes, the radio appeared to be the next technology emerging for use in distance education, but its implementation never gained widespread use (Nasseh, 1997; Watkins, 1991). However, lessons learned from the radio as an instructional tool did clear the way for instructional broadcast television. Broadcast television became utilized in distance education during the late 1950s in the United States, and, in particular, in community colleges throughout the 1970s. The utilization of broadcast television led to classes known as "telecourses" which further evolved as cable and satellite televisions began transmitting the courses, along with videocassettes being mailed to students (Wright, 1991). Near the end of the 20^{th} century, there were over 240 consortiums that produced and licensed telecourses to colleges and universities as part of their respective degree programs (Freed, 1999). The development and improvement of distance education was evident in the second generation as it progressed beyond telecourses and involved audiotapes and print media. Matthews (1999) noted that in the case of the British Open University, there was a combination of multiple forms of media and methods of instruction in order to optimize the learning experience involving distance education.

Throughout these developments in distance education, there continued to be a problem of communication only occurring in one direction – the students received the information through some form of distance media and had minimal interaction with the instructor or other students. In many institutions, there had been a dual existence between telecourses and face-to-face courses since the early 1980s. Swienciki (1996) has stated that distance learning, especially telecourses, "accommodates nontraditional learners and students living in rural settings" (p. 179). There were some instances of teleconferencing that involved student-to-student and student-to-instructor interactions, but major shifts in student-to-faculty communication in distance education would not be advanced until the incorporation of the Internet in the 1990s (Sumner, 2000). With the influence of the computer-age throughout the past decades, distance education and distance learning is now commonly associated with online learning. The vast history of distance education includes great efforts to gain validation and acknowledgment in traditional academic circles. Despite the implementation of various distance education technologies and methods over the years, the most common and popular form of emergent distance education is asynchronous online education.

Computer-assisted instruction was one of the earliest uses of computers in distance education. The computer was an additional means of delivering content to students, much as instructional media was used in the second generation of distance education (Kearsley, 2000). As Moskal and Dziuban (2001) observed, the "advances in computer hardware and software, the prevalence of computers in U.S. homes, and easy access to the Internet" (p. 15) opened the eyes of educators so that they could realize the budding potential of the computer. Although using a computer to view the instructional material was not new, the use of computers as a way to communicate and interact with faculty and fellow students in either an asynchronous or synchronous manner was innovative. With the affordability of personal computers, larger numbers of colleges and universities are developing and offering online courses and degrees.

Online education has emerged as the forerunner in terms of preference for distance education. There were abundant offerings of online education in the 1990s, with higher education being particularly prevalent in that regard. Jones International University, the first fully online institution, was founded in 1983 (Jones International University, 2005) and the University of Phoenix offered the first entirely online MBA program in 1989. Seeing the need for a grouping of online higher education institutions, the Western Governors University formed as a consortium in 1998 (Kinser, 2002).

There have been significant increases in the number of institutions offering distance education in a variety of forms. Carnevale (2000) noticed that distance education programs in higher education increased 72% from 1995 to 1998 while the proportion of schools offering asynchronous courses grew from 22% to 60% during the same period. When examining higher education institutions offering distance education courses, numerous independent studies (Allen & Seaman, 2004; Carnevale, 2001; Waits & Lewis, 2003) have found that approximately 90% of the institutions that were studied offered asynchronous online courses. In regards to the number of students enrolled in the online courses, surveys and estimates in 2004 stated the number was between one and two and a half million (Allen & Seaman, 2004; Carlson, 2004). The number of students enrolled in online courses continues to increase as there are now over 5.6 million students taking at least one online course in 2009 (Allen & Seaman, 2010).

There are two main factors that contribute to the growth of online education – students enjoy the flexibility and access online classes provide (Marquand, 1998; Green, 2003; Sutton, 2003) and the comfort level of faculty and academic leaders with the new methods of delivering instruction has increased (Conhaim, 2003; Sloan, 2003). This occurred in part because faculty and academic leaders are comfortable not only with this new instructional delivery method, but are also accepting it on a more regular basis as a quality alternative to traditional teacher-centered face-to-face instruction (Conhaim, 2003; Sloan, 2003). In a national survey of chief academic officers, Allen & Seaman (2004) wrote that 52.6 percent of the officers perceived online learning as substantial to the strategic success of their institutions.

Over the past two decades, research in distance education has increased and grown remarkably. The scope of the research is varied with some focusing on the curriculum (Feasley, 2003) or the relationship between the instructor and learner (Saba, 2003). Comparisons of instructional methods have also been the focus of other researchers such as Maki and Maki (2002) who recapped several studies involving the comparison of traditional face-to-face and web-based instruction. Their inconclusive and mixed results determined that there were some studies that favored web-based courses, some that favored face-to-face courses, and others in which there was no significant difference in student achievement between the two methods of instruction.

Evaluation of the Effectiveness of Distance and Online Learning

The augmentation of face-to-face instruction with online material provides structure to defining computer-aided instruction. In just over the past decade, there have been a number of studies on the effects of computer-aided instruction (Kinney & Kinney, 2002; Kinney & Robertson, 2003; Kinney, Stottlemyer, Hatfield, & Robertson, 2004). One of these studies, conducted by Kinney, et al. (2004), involved 123 universities and colleges which discovered that when computer-aided instruction was used by students, more learning happened in less time, higher grades were reported on exams, and overall attitude towards mathematics improved.

Different aspects of knowledge acquisition are applied through the utilization of computer-aided instruction and computer enhancements. Many universities and colleges incorporate electronic textbooks and support systems such as MyMathLab© and

WebAssign© that allow students access to an unlimited number of practice problems and a variety of instructional assistance tools. Another variation of computer-aided instruction is Assessment and Learning in Knowledge Spaces (ALEKS©). A benefit of this instruction is that it can be customized for each student, through an initial online assessment, in order to establish the performance level of the student. Afterwards, the ALEKS system determines the course content suitable for each student – a personalized prescription designed to help the student achieve success (Taylor, 2008). Advantages of these types of systems include immediate feedback to the student along with the ability to incorporate computer-aided instruction into a completely online course.

A study by Brocato (2009) reviewed the current research related to computer-assisted instruction, conducted an examination over a thirteen-semester period of time involving students enrolled in developmental courses at a college in Mississippi in two types of classes, face-to-face lecture and computer-aided instruction, and noticed a positive influence of computer-aided instruction. During the first seven semesters, students were enrolled in face-to-face lecture courses and then for the remaining six semesters were taught in a computer-aided laboratory utilizing a computer program with a specific curriculum developed by members of the Mathematics Department at the community college (p. 10). Brocato found that, in the computer-assisted classes, there were significant increases in final grades in addition to an increase in the number of withdrawals from the course (p. v). When attempting to explain the increase in the number of students that withdrew, the researcher noted that withdrawing students tend to have a lower level of performance compared to students who completed the course. The final grade point average (GPA) for the face-to-face lecture delivery class was 2.087 on a scale of 4.0, and the final GPA in the computer-assisted course was 2.397 on a scale of 4.0 (pp. 52 – 53).

Two other studies, Hagerty and Smith (2005) and Li and Edmonds (2005), discovered that students earned higher grades when receiving computer-assisted instruction in mathematics compared to students not receiving computer-assisted instruction. Taylor (2008) examined student achievement in courses that used a web-based, computer-assisted intermediate algebra program with those in a face-to-face lecture-based class utilizing ALEKS (p. 37). The study found that mathematics achievement improved with the computer-aided instruction more than in the face-to-face lecture-based course design (p. 43). In a related study, Duka (2009) examined the incorporation of a technology-based component, MyMathLab, into a developmental mathematics course. This study found that the average grade for students using the technology component was higher, 76.1%, as compared to the non-technology group with a 69.7% average (p. 19).

Various studies of a comparative nature have been conducted indicating that students can be equally successful learning in an online environment versus that of a primarily lecture-based setting (Barry & Runyan, 1995; Cole, 2000; Comey, 2009; Gagne & Shepherd, 2001; Hiltz, Zhang & Turoff, 2002; Russell, 1999; Schulman & Sims, 1995). To further this concept, an exhaustive review of research findings by Karen Swan of the Sloan Consortium concluded that, “there is no significant difference on gross measures of learning between students taking online courses and students taking traditional courses" (Swan, 2004). Even with such findings, colleges and universities recognize that there are advantages and disadvantages of offering courses in the traditional face-to-face format and the online format. Within the framework of distance learning, particularly courses that follow asynchronous formats, more flexibility is available in relation to time and space, and there is less interaction between participants compared to a face-to-face course (Kirby, 1999). These differences have lead some educators to conclude that even though there are not significant differences in learning outcomes, the method of instruction should be selected after a review of the advantages and disadvantages to determine the most appropriate format (Edward & Fritz, 1997).

Thomerson (1995) conducted a review of literature comparing the cognitive outcomes between students enrolled in distance learning and students enrolled in face-to-face classrooms and concluded that they were virtually the same. In that review by Thomerson, researchers noted that among distance learners, there were significantly lower levels of student to teacher interaction, lower levels of satisfaction with the course among students, and displeasure with the structure of the course along with the learning environment itself when compared to students enrolled in a traditional face-to-face course. There is also additional literature suggesting that the dissatisfaction among distance learners is possibly linked to lower retention rates of students taking online courses versus those taking traditional face-to-face courses (Kerka, 1996). Some contend that the lack of face-to-face physical interaction is one of the major limitations of distance education and may contribute to the problems of retention and student satisfaction (Kirby, 1999; Kruger, 2000).

Russell (1999) conducted a seminal review comparing 355 studies related to technology and distance education. Going as far back as 1928, Russell suggested that when course materials and teaching methodology were held constant, there were no significant differences in outcomes for students enrolled in distance courses compared to traditional face-to-face courses. In a manner related to that of Russell, Sitzmann et al. (2006) compared online instruction to that of the face-to-face setting and concluded that the two methods were equally effective when procedural knowledge was the focus and that online instruction was more effective for teaching declarative knowledge.

The academic community has criticized the quality and rigor of distance education much in the same manner as other non-traditional methods of instruction (Paden, 2006). The findings of Russell were supposed to help answer questions regarding the quality of education offered through non-traditional methods of teaching. However, Russell is not without critics who question his methods of research and the manner in which he selected the studies he reviewed. Arguments aimed at discrediting his work assert that his research lacks a theoretical framework (Li, 2002; Merisotis & Phipps, 1999a) and that Russell failed to state the method in which studies were selected other than collecting those that showed no significant difference (Zhao, Lei, Yan, Lai, & Tan, 2005). In terms of the studies, some wonder whether or not Russell was systematic and accounted for all variables (Merisotis & Phipps, 1999b; Worley, 2000).

According to Huffman, Goldberg, and Michlin (2003), there is a trend in which the face-to-face lecture class has transitioned from an instructor-centered format into a constructivist approach wherein the learning is viewed as a "process where students interpret information in light of existing knowledge, and actively construct and reconstruct understandings, rather than receive information from an authoritative source such as a teacher" (p. 152). The role of the teacher is to create situations that will encourage their students to make the necessary mental constructions between information that they already understand and the new material they are learning (Math Forum, 2007). Part of this transition has been leading to the continued development of blended instruction that is more student-centered.

Blended Instruction

The term online learning is widely used and has many different meanings. There are numerous references in literature to Web-based courses, online courses, completely online courses, Web-assisted courses, Web-supplemented courses, hybrid or blended courses, and other iterations of instructional methods that utilize the Web (Leh, 2002). There are some that consider all these terms to be synonymous, however, there is also an emerging distinction between them in contemporary literature (Comey, 2009; Graham, Allen, & Ure, 2003; Leh, 2002; Muse, 2003; Osguthorpe & Graham, 2003; Willett, 2002; Young, 2002). What is becoming more accepted is a definition of online courses as those courses in which the instructors meet with the students entirely in an online manner over the Internet while blended courses are those in which there is some face-to-face instruction combined with some online aspect along with some course management tools that are online (Comey, 2009; Lamb, 2001; Mortera-Gutierrez, 2004; Osguthorpe & Graham, 2003; Smith, 2001).

Despite the popularity of blended instruction as an instructional method, in the academic world, there has not been much research examining the effectiveness of blended instruction compared to that of the face-to-face lecture-based instruction (Chen & Jones, 2007). Many colleges and universities have been experimenting with the implementation of blended instruction and some administrators are adjusting their marketing; no longer is there as strong an emphasis on marketing completely online programs to those students not able to come to the physical campus (Cottrell & Robison, 2003; Young, 2002).

In an attempt to take advantage of the benefits of the more traditional face-to-face method of instruction and the strengths of online courses, many colleges and universities are developing and offering blended courses. The blended instruction needs to be a thoughtful and organized combination of face-to-face and online learning within the course so that the learning experiences of the students are enriched. One recent study reported that close to 55% of all post-secondary institutions offer at least one course in a blended format (Allen, Seaman, & Garrett, 2007). Another study reported the number to be closer to 80% among all institutions and 95% among institutions offering doctoral degrees (Arabasz, Boggs, & Baker, 2003).

Instructors recognize that there are benefits to both face-to-face instruction and online instruction. Regarding the issue of how to incorporate blended instruction, there exist three categories for blended instruction systems: (a) *enabling blends* – issues of access and convenience are addressed, (b) *enhancing blends* – adjusting processes already in place in the traditional face-to-face setting (e.g., offering resources and materials online), and (c) *transforming blends* – instituting major alterations to the instructional method in order to take full advantage of the technology (Graham, 2006; Wang, 2009).

As blended instruction is becoming a more prevalent instructional method, it is imperative that strategic plans be created in order to provide direction and focus towards appropriate pedagogical techniques that involve blended instruction (Bonk et al., 2006). One reason for implementing a blended instruction approach is that blended instruction combines the best of both online and face-to-face lecture instruction. It was noted in the Bonk et al. (2006) research that blended instruction focuses on what is happening during the live interaction with the instructor. In the teacher-centered face-to-face format, a significant amount of class time is focused on the bottom layers of the triangle for Bloom's taxonomy (see Figure 2) whereas in the blended model, more facilitator time can be focused on the top layers like application, synthesis, evaluation, and analysis.

(adapted from Bloom, B.S. (Ed.), Engelhart, M.D., Furst, E.J., Hill, W.H., & Krathwohl, D.R. ,1956)

Figure 2: Adapted Bloom's taxonomy

Students appreciate the social interaction not only with fellow students but also with the instructor in a face-to-face setting lending itself to a two-way form of communication (Robison, 2004; Sisson, 2011). The positives of online instruction routinely are cited as the immediacy of feedback for the students, the ability to individualize the instruction based on the needs of the student, and the time flexibility (Comey, 2009; Robison, 2004; Sisson, 2011; Sitzmann et al., 2006).

A concern regarding blended instruction, made by Osguthorpe and Graham (2003), warned of inept planning when, “the face-to-face contact features a poorly-delivered lecture with no student participation, and the online portion of the course includes tedious, over-prompted forms of practice” (p. 228). The challenges of successful blended instruction include issues related to the proper blend between face-to-face lecture and online instruction (Christensen, 2003), how interactions that are sometimes in-person or synchronous, while other instances are asynchronous, have an effect on learning, when face-to-face interaction should occur, the level of assistance to provide learners in a blended environment, and how to supplement technological support and training to learners in the face-to-face lecture and online formats (Graham, 2006). Osguthorpe and Graham (2003) posit that there are other elements that one should contemplate when designing a blended course: 1) online and face-to-face learning activities, 2) online and face-to-face students, and 3) online and face-to-face instructors. By selecting the elements that are to be blended along with the manner in which they are combined, instructors implementing this instructional method can design their course to meet the needs of various settings, content, and students (Comey, 2009) through activities that are both instructor-centered as well as student-centered.

Evidence supporting the benefits of blended instruction is apparent through various research studies. Sitzmann et al. (2006) performed a meta-analysis of 96 experimental studies of online and face-to-face lecture classroom instruction from 1996 to 2005. The results of the Sitzmann et al. (2006) analysis resulted in their stating that when teaching procedural or declarative knowledge, a blended instruction environment is more effective, primarily because of implementation of the best of face-to-face lecture and online learning. An earlier meta-analysis (Zhao et al., 2005) resulted in no significant difference between face-to-face lecture and online learning in terms of overall effectiveness; but, they did note that courses implementing blended instruction resulted in what they called "better learning outcomes" when compared to the face-to-face lecture or online courses.

While early research on environments and settings by Vahala & Winston (1994) did not produce generalizable statements regarding the impact of any one type of environment on the learning process, they did show that the classroom environment influences learning. As Vahala and Winston (2003) reviewed, "if the goal of instruction is to encourage or facilitate student learning, then it seems clear that instructors should carefully examine the kind of social climate that is created in their classrooms and whether that climate is likely to promote or detract from learning" (p. 120). Graham (2006) further noted that the increased implementation of blended instruction and its application in higher education and workforce settings could lead to improvements in pedagogy and increases in cost-effectiveness and flexibility. Furthermore, according to Bonk et al. (2006), the use of blended instruction may "foster learning communities, extend training events, offer follow-up resources in a community of practice, access guest experts, provide timely mentoring or coaching, present online lab or simulation activities, and deliver prework or supplemental course materials" (p. 560).

While a change in classroom design has an effect on knowledge acquisition of students in a mathematics classroom, other components have influence. Another aspect that is considered for this study is the attitude towards mathematics of a student enrolled in a mathematics course.

Definition of Attitude

This section will discuss how attitude about mathematics influences student learning. The historical development of the definition of attitude in educational settings will be discussed and the definition to be used in this study will be stated.

Beginning in the 1940s, researchers have studied the attitudes of students and the possible influence post-secondary education has on changes in behavior (Astin, 1977). Psychologists have continued to discuss how attitude should be defined, beginning with Allport (1935), who developed a comprehensive definition of attitude: "An attitude is a mental or neural state of readiness, organized through experience, exerting a directive or dynamic influence upon the individual's response to all objects and situations with which it is related" (p. 810).

Progressing from what Allport described, most definitions of attitude have mimicked him, and, according to the research of Oskamp and Schultz (2005), "have become rather similar in their main emphases, though differing in some details" (p. 8). New points of emphasis became readily apparent in the 1970s (Sisson, 2011). Aiken (1970) and Bem (1970) ventured out of the norm and developed their own definitions of attitude. Aiken's definition was one in which attitude is "a learned predisposition or tendency on the part of an individual to respond positively or negatively to some object, situation, concept, or another person" (p. 551). The succinct definition of Bem states, "Attitudes are likes and dislikes" (p. 14). Fishbein and Ajzen (1975) added to Aiken's definition to include consistency and the notion of learning.

The psychological community continues to develop several additional definitions of attitude. Nearly two decades after Aiken and Bem, Eagly and Chaiken (1993) emphasized evaluation with their definition: "Attitude is a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor" (p. 1). A few years later, Morris (1996) defined attitude as an organization of feelings, tendencies, and beliefs toward something, known as the attitude object. Furthermore, he argued, attitudes are acquired through learning, are then developed through experiences, and can predict behavior. Lefton (1997) regarded attitudes as patterns of feelings that last for extended periods of time (potentially lifelong) and that those attitudes and beliefs about other people, ideas, or objects are based on experiences and shape a person's future behavior – an extension of Morris' definition. Adding to the discussion is Hannula

(2002) who states attitude is “someone’s basic liking or disliking of a familiar target” (p. 25).

The input from the psychology and general educational research community has led to a variety of related, yet murky, definitions of attitude. The commonality that many of these definitions for attitude has is the notion that attitude makes a difference when considering the ability of a student to comprehend the content in a classroom setting. This study incorporates the amalgamation of years of definitions offered by Oskamp and Schultz (2005): “An attitude is a predisposition to respond in a favorable or unfavorable manner with respect to a given attitude object” (p. 9).

Differences Between Mathematics Attitude and Attitude Towards Mathematics

A natural continuation of the previous definitions of attitude is to consider that a person has either positive or negative feelings regarding some attitude object (Sisson, 2011). Attitude and mathematics can be divided into two views. The first establishes a connection between the math attitudes of the students and their achievement in mathematics (Anttonen & Deighan, 1971; Vachon, 1984; Wolf & Blixt, 1981). The alternate view compares the attitude of students towards mathematics with respect to their achievement or acquisition of knowledge in mathematics (Shashaani, 1995; Sisson, 2011; Tapia & Marsh, 2004).

Mathematics attitude is a tendency to respond to mathematics in either a favorable or unfavorable way (Hart, 1989). This is a direct application of how Oskamp and Schultz defined general attitude. Kadijevich (2008) wrote that in viewing attitude as a response to mathematics, mathematics attitude would include: behaviors (e.g. “I will apply for a job involving mathematics”), beliefs (e.g. “Mathematics helps me understand science lessons”), and reactions that are emotional (e.g. “I like solving mathematical problems”, “I feel upset when solving mathematical problems”). In other words, in making a connection to what Kay (1993) stated, a measurement of mathematics attitude should investigate affective, behavioral, and cognitive domains, which could possibly be represented by liking mathematics, displaying self-confidence in comprehending mathematics, and appreciating the usefulness of mathematics.

Students with a “better attitude towards mathematics had significantly higher achievement scores than those students with poor attitudes towards mathematics” (p. 31) was a finding in Manswell-Butty’s (2001) study. Their performance in mathematics was also influenced by attitude. The influence attitude has on mathematics achievement, the conclusion of Manswell-Butty’s study does state that attitude is a relevant factor and that educators need to be aware that a student’s performance is impacted by their attitude toward mathematics. These results suggest that educators should not ignore or forget that efforts need to be made to help improve the negative attitude of students toward mathematics.

Caution needs to be taken when considering mathematics attitude and attitude towards mathematics, as the wording of each viewpoint is similar and there is potential for confusion. The attitude of students and their achievement in mathematics has been examined as a potential causal relationship of attitude and achievement and any relationship between attitude toward mathematics and overall achievement in mathematics (Haladyna et al., 1983; Ma & Kishor, 1997; Wolf & Blixt, 1981). The current study examines the attitude of students toward mathematics and knowledge acquisition in a mathematics course by implementing an instrument to measure attitude as part of evaluating effectiveness of a classroom setting.

Development of Attitude Instruments

In order to assess the attitude of students toward mathematics, researchers needed to formalize and standardize instruments to measure attitude. One of the initial attitudinal instruments widely accepted was the Dutton Scale, which measured what the author called "feelings" towards mathematics (Dutton, 1954). In the decade that followed, Gladstone, Deal, and Drevdahl (1960) developed other one-dimensional scales as well as by Aiken and Dreger (1961). Progress continued in the 1970s, as Aiken (1974) established an attitudinal instrument that would assess the value and enjoyment students have with regard to mathematics. Other mathematics education researchers (Michaels & Forsyth, 1977; Sandman, 1980) continued to develop multi-dimensional attitudinal scales.

Despite some usefulness and practicality, these attitudinal instruments paled in comparison to the Fennema-Sherman Mathematics Attitude Scales developed in 1976 (Fennema & Sherman, 1976). The instrument developed by these two researchers is actually a group of nine individual scales: (1) Attitude Toward Success in Mathematics Scale, (2) Mathematics as a Male Domain Scale, (3) and (4) Mother/Father Scale, (5) Teacher Scale, (6) Confidence in Learning Mathematics Scale, (7) Mathematics Anxiety

Scale, (8) Effectance Motivation Scale in Mathematics, and (9) Mathematics Usefulness Scale. Notwithstanding the fact that the Fennema-Sherman Mathematics Attitude Scales take approximately 45 minutes to complete the 108 items, it remains one of the more popular instruments for measuring attitude used in research in the past 30 years.

The sheer length, both in time and in volume, of the Fennema-Sherman Mathematics Attitude Scales was a factor in Tapia and Marsh (2004) identifying a need for a shorter instrument that addresses what they deemed important factors for research in attitudes toward mathematics: anxiety, confidence, enjoyment, motivation, and value. This is a direct connection to the second view of attitude, which is a comparison of attitude towards mathematics with respect to achievement in mathematics. As a result of the desire for a more concise measurement instrument, Tapia and Marsh developed the Attitudes Toward Mathematics Inventory (ATMI), which will be discussed in more detail in the following section.

Attitudes Toward Mathematics Inventory

The Attitudes Toward Mathematics Inventory was chosen for use in this study because it has been used to analyze changes in attitudes of college mathematics students enrolled in a college algebra course (Curtis, 2006) and a developmental mathematics course (Sisson, 2011). Another study situated in a university setting examined whether the attitude of students enrolled in a mathematics methods course changed during their participation in the course (Schackow, 2005), a direct application of enhancing blends brought forth in other research (Graham, 2006; Wang, 2009). Additionally, in the United

Kingdom, Fuson (2007) used the ATMI to analyze potential relationships between mathematics anxiety and age, ethnicity, and gender for adult learners enrolled in colleges. The prevalence of ATMI use in the mathematics education research field legitimates its use in this study.

Tapia and Marsh (2004) developed the ATMI so they could measure and "address factors reported to be important in research" (p. 16). Their original inventory was a 49-item instrument with a Likert-scale format. The current iteration has been reduced to a 40-item questionnaire that still follows a Likert-scale format. Tapia and Marsh (2000) recommend the need to recognize the importance of attitude and development of a positive attitude toward a subject as "probably one of the most prevalent educational goals" (p. 5). The authors view attitude as an internal characteristic that is affected by individual perceptions. Educators can affect internal factors of perceptions by controlling external factors like instruction and classroom characteristics.

The ATMI measures anxiety, confidence, enjoyment, motivation, and value. The anxiety assessment is a composite score measuring the overall anxiety towards mathematics that a student has. Confidence determines to what extent students view their overall performance in mathematics; enjoyment measures the level to which students appreciate attending mathematics classes; motivation rates the desire, interest, and general persistence a student has for enrolling in additional mathematics classes; and value gauges how much a student deems mathematics as being useful, relevant, and possessing worth in relation to their personal and professional lives (Tapia & Marsh, 2004).

In research it is worthwhile to know if the instrument you are using will always elicit consistent and reliable response even if questions were replaced with other similar questions. When you have a variable generated from such a set of questions that return a stable response, then your variable is said to be reliable (Creswell, 2009). Cronbach's alpha is an index of reliability associated with the variation accounted for by the true score of the underlying construct being measured. The developers of the ATMI calculated the Cronbach alpha to estimate internal consistency and reliability of the scores on the subscales. The scores for enjoyment of mathematics produced a Cronbach alpha of .89, the motivation factor produced a Cronbach alpha of .88, the self-confidence items had a Cronbach alpha of .95, and the value of mathematics factor produced a Cronbach alpha of .89. These data indicate high level of reliability of the scores on the subscales (Tapia & Marsh, 2004).

Pearson's correlation coefficient is a statistical value that measures the linear relationship between two variables and ranges in value from +1 to -1, indicating a perfect positive and negative linear relationship respectively between two variables (Creswell, 2009). Tapia and Marsh (2004) utilized a Pearson correlation coefficient to determine test-retest reliability in a four-month follow-up of the 40-item inventory. The developers administered the ATMI to 64 students who had previously taken the survey, resulting in a coefficient for test-retest for the total scale was .89. The coefficients for the subscales were as follows: Enjoyment .84, Motivation .78, Self-confidence .88, and Value .70. The results of these data indicate that scores on ATMI are stable over time.

Knowing information about their students is of importance for all instructors. Having information concerning student attitudes toward mathematics at the beginning of the semester is an essential aspect to have available, as there are connections to success or failure rates for some students. The developers of the ATMI, Tapia and Marsh (2004), have written:

> [S]uccess or failure in mathematics is greatly determined by personal beliefs … Regardless of the teaching method used students are likely to exert effort according to the effect they anticipate, which is regulated by personal beliefs about their abilities, the importance they attach to mathematics, enjoyment of the subject matter, and the motivation to succeed. (p. 8)

Relevant Research on Attitude Toward Mathematics

A thorough examination of attitude toward mathematics has occurred (Aiken, 1970; Aiken, 1976; Ma & Kishor, 1997; Shaughnessy, Haladyna, & Shaughnessy, 1981; Sisson, 2011; Tapia & Marsh, 2001). Besides those that have been discussed in previous sections of this study, Neale (1969) defined attitude toward mathematics as an accumulated gauge of "a liking or disliking of mathematics, a tendency to engage in or avoid mathematics activities, a belief that one is good or bad at mathematics, and a belief that mathematics is useful or useless" (p. 632). As part of their research, Haladyna, et al. (1983) define attitude toward mathematics as "a general emotional disposition toward the school subject of mathematics" (p. 20). The researchers also caution that this definition is not to be confused with an "attitude toward the field of mathematics, toward one's ability to perform in the field of mathematics, or toward some specific area with mathematics (e.g., geometry, word problems)" (p. 20). Ma and Kishor (1997) further

Neale's definition of attitude toward mathematics to include the affective responses of students to the easy/difficult dimension as well as the importance/unimportance dimension of mathematics. Hannula (2002) suggests that attitude can be viewed as an expressive temperament toward mathematics. Within Hannula's definition are four components:

1. The emotions the student experiences during mathematics-related activities;
2. The emotions that the student automatically associates with the concept 'mathematics';
3. The evaluations of situations that the student expects to follow as a consequence of doing mathematics; and
4. The value of mathematics-related goals in the student's global goal structure. (p. 26)

An overview of research on attitude toward mathematics and knowledge acquisition in mathematics shows a positive relationship. Attitude toward mathematics, student participation, and knowledge acquisition are inferred to have an important relationship (Shashaani, 1995). Having a non-negative, if not positive, attitude will lead to the comprehension of concepts by students, which in turn will promote confidence in general aptitude regarding mathematical procedures and processes (Furner & Berman, 2003). Widely accepted by many researchers and educators is that a strong relationship exists between knowledge acquisition and attitude toward mathematics. Curtis (2006) and Sisson (2011) found a direct relationship between attitude toward mathematics and success in a mathematics course. The attitude of a student toward mathematics has a direct influence on numerous aspects of that college student's career: the potential for success in their mathematics course, the mathematics courses that the student selects, and the choice of a mathematics-related career or mathematics-related degree.

The research of Suydam and Weaver (1975) concluded math teachers believe that if students have an interest in mathematics, they will effectively acquire knowledge. Furthermore, the researchers suggest that teachers should consider "creating, developing, maintaining, and reinforcing positive attitudes" (p. 45). Other general research on attitude in a mathematics course suggests that attitude can be a predictor of final course grade (Thorndike-Christ, 1991), and students with positive attitudes about mathematics demonstrate greater effort, persistence on tasks, and show efficiency in acquiring knowledge when compared to students with negative attitudes about mathematics (Ma & Kishor, 1997). In the past decade, while using the Aiken Attitude Survey, Bassette (2004) also proposed a connection between a positive attitude score and final exam score. What the research is suggesting is that the promotion, development, and preservation of a positive attitude toward mathematics is a significant contributor toward knowledge acquisition by students (Aiken, 1972; Braswell, Lutkus, Grigg, Santapau, Tay-Lim & Johnson, 2001; DeCorte & Op'tEynde, 2003; Gallagher & De Lisi, 1994; Ma & Kishor, 1997; Neale, 1969; Shashaani, 1995; Singh, Granville, & Dika, 2002; Sisson, 2011; Thorndike-Christ, 1991). Aiken (1972) summarized this best when he stated the connection between knowledge acquisition and attitudes "is frequently higher for mathematics than for school subjects with more verbal content" (p. 23).

Not all of the research focused on students having positive attitudes; there are students with a negative attitude toward mathematics. According to Tapia and Marsh (2004), students with "negative attitudes toward mathematics have performance problems simply because of anxiety" (p. 16). Students appear to have a more positive attitude towards mathematics at the elementary level, and that, unfortunately, tends to become negative for many students as they progress through the grades. Curtis (2006) stated younger students view mathematics as "meaningful, interesting, and a worthwhile subject" (p. 12). These elementary students deem math to be a subject that is important and is one that can be learned (Sisson, 2011). What may eventually develop is a tendency for students to withdraw from mathematics and mathematics-related fields – an example of what Thomas Friedman refers to as the "steady erosion of America's scientific and engineering base" (p. 253).

A meta-analysis conducted by Ma and Kishor (1997) involved an examination of the relationship between knowledge acquisition and attitude toward mathematics of 113 studies involving students at both the elementary and secondary school level. The four research questions guiding their analysis were:

1. Can a relationship between attitude toward mathematics and achievement in mathematics be determined using the metric correlation coefficient?
2. Is there a relationship among gender, grade, ethnicity, sample selection, sample size, and time period?
3. Is there an interaction among gender, grade, and ethnicity?

4. Can the magnitude of the causal relationship between attitude toward mathematics and achievement in mathematics be determined? (p. 29).

Multiple researchers concluded that there were indications of a positive and reliable relationship between attitude toward mathematics and achievement in mathematics (Bassette, 2004; Bershinsky, 1993; Curtis, 2006; Schackow, 2005; Sisson, 2011). While each of these guiding questions are worth investigating, the scope of the current study will integrate the first and fourth questions in relation to the evolution of student attitude in a blended instructional format.

Summary

The advancement of online courses and the general integration of the Internet into course design continue, primarily as a reaction to the demands of students. The number of students arriving on higher education campuses with comprehensive knowledge of computers and an expectation of using the Internet as a component of their entire learning experience grows (Comey, 2009; Green, 2003; Sutton, 2003). Concurrently, there is an upsurge in the demand of students to also have courses and learning formats that are flexible in order to accommodate the time constraints of their busy schedules. For working adult students, comprising almost 40 percent of the undergraduate population, this is especially true (U.S. Department of Education, 2000). It follows, given the increase in number and transformation of new demands from students, that partial or completely online learning is the fastest growing sector in education (Comey, 2009; Conhaim, 2003; Waits & Lewis, 2003). Highlighting this aspect is that over 3.9 million students enrolled in at least one online course during the fall semester in 2007, accounting for the approximately 20 percent of all students in higher education taking at least one online course (Allen & Seaman, 2008).

With enrollment in online course growing and the number of online courses increasing, researchers are attempting to make sense of this innovative form of instruction and the impact the methodology has on student knowledge acquisition and attitude. Given that results of many studies show no significant difference in learning outcomes between students taking online and face-to-face lecture courses (Barry & Runyan, 1995; Cole, 2000; Gagne & Shepherd, 2001; Hiltz, Zhang & Turoff, 2002; Russell, 1999; Schulman & Sims, 1999; Swan, 2004) several researchers are calling for a deeper understanding of the distance learning environment and its impact on students' learning and satisfaction (Arbaugh, 2000; Clark, 1994; Phipps & Merisotis, 1999a; Russell, 1999; Surry & Ensminger, 2001). There is a multitude of information gathered from studies exploring issues regarding student satisfaction with online classes (Johnson, 1999), the relationship between attitudes toward computers and the desire to take online classes (Robertston & Stanforth, 1999), the nonacademic needs of online students (Bayless, 2001), the impact of demographic differences on performance and retention in online and face-to-face courses (Crabtree, 2000), and motivation and perceived educational needs between online learners and face-to-face lecture learners (Yellen, 1998). Responding to input from students and the results of studies of this variety, the higher education community is becoming aware that completely online classes are not necessarily the best fit for all students or for all content (Carr, 2000; Comey, 2009; Crabtree, 2000; Dexter, 1995; Sorg, 2000; Sutton, 2003; Twigg, 2003).

There has been a need on the part of students for flexibility in learning, both in the learning format as well as the course offering access. Online learning certainly accommodates the flexibility needs, yet it is not a "one-size-fits-all" solution. Developing and implementing instructional formats that utilize online learning systems while maintaining components of traditional face-to-face instruction continues to be the response of universities and colleges (Comey, 2009; Twigg, 2003). The blended instruction model has emerged in the literature as researchers and practitioners are taking notice (Comey, 2009; Graham, Allen, & Ure, 2003; Leh, 2002; Muse, 2003, Osguthorpe & Graham, 2003; Willett, 2002; Young, 2002). Courses following a blended instruction format tout the best of both worlds, incorporating the convenience of a completely online course while still featuring face-to-face interaction (Colis & Moonen, 2001; Comey, 2009; Graham, 2006; Osguthorpe & Graham, 2003; Twigg, 2003; Young, 2002).

Recent trends show that blended courses are gaining more and more popularity in higher education. However, there continues to be a lack of research examining how students in the current Web-based society are receiving the merging of elements from distance learning and traditional face-to-face instruction. The literature review identified that attitude towards mathematics is a critical component contributing to student satisfaction with face-to-face and distance learning environments. As blended learning classes continue to be developed, in part, to expand interaction and intensify attitude and satisfaction, the need for further research is necessary.

CHAPTER 3: METHODOLOGY

Introduction

This chapter establishes a rationale as to why the case study was utilized as the appropriate methodology for this research. To begin, the organization of the research is provided along with an overview of the initial procedures incorporated. The next sections of this chapter include a brief discussion of the research setting, participants, an overview of the data collection, and an account of the sources of information. Following that is an explanation of the data analysis and the validation of the data. It is in the concluding portions of this chapter that the role of the researcher, along with the limitations of the study, is discussed.

Methodology

This study uses the case study design and methods followed that of Yin (2003) and Merriam (1988). The descriptive case study method and design is well suited to this study because of its ability to answer the research questions appropriately in addition to information being collected without changing the environment (i.e., nothing is manipulated). "The case study is preferred in examining contemporary events but when the relevant behaviors cannot be manipulated" (Yin, 2003, p. 7). Two additional resources can be investigated in case studies; (1) interviews with those involved in the events, and (2) direct observation of the events. The strength of the case study approach is in its ability to examine a "full variety of evidence – documents, artifacts, interview, and observations" (Yin, 2003, p. 8).

This researcher's questions asked "what" and "how." Yin's (2003) approach to choosing the appropriate strategy considers three conditions: the type of research question, how much control the investigator has over the events, and whether or not the focus in on contemporary or historical events and to what extent (see also Merriam, 1988). The investigator had no control over the course design or instruction occurring outside of the timeframe of the activities implemented as a component of this study. The criteria for selecting the participants is that they were enrolled in a blended instruction introductory mathematics course within the current school term, so the events are contemporary, and that specific variables or events have not been identified to the investigator and cannot be easily separated from the context makes case study design appropriate for this study.

The case study can be difficult to classify due to multiple methods used by researchers in a variety of disciplines (Stake, 1995). Schramm (as cited in Yin, 2003, p. 12) summarized the purpose of case studies when he stated "the central tendency among all types of case study, is that it tries to illuminate a decision or set of decisions: why they were taken, how they were implemented, and with what results." Case studies are additionally used as a way to "contribute to the knowledge of an individual, group, organizational, social, political, and related phenomenon" (Platt, as cited in Yin, 2003, p. 13). Moreover, the case study design is preferred when "circumstances and research problems are appropriate rather than an ideological commitment" (Platt, as cited in Yin, 2003, p. 13).

The purpose of this study was to investigate the experience of students enrolled in a pre-calculus course using a blended instruction format and compare their experience with that of students taking a similar pre-calculus course that utilized a face-to-face instructional format. The problem to be investigated is whether student achievement is impacted by the method of instruction as well as why and how course design impacts the attitude of students and their acquisition of knowledge in a blended instruction environment. A medium-sized accredited public university located in southeastern Minnesota has been offering an introductory undergraduate mathematics course with standardized curriculum in two instructional formats: face-to-face and blended. This study will compare academic achievement, as measured by both grades on a common final examination as well as final course grade, changes in attitudes toward mathematics related to blended instruction, and acquisition of knowledge beyond procedural processes.

One of the introductory mathematics courses that Public University offers to its students is Math 112 – an applied pre-calculus course having non-mathematics majors as its primary audience. Many of the students enrolled in this course will be taking a non-technical applied calculus course as a continuation of this applied pre-calculus course. Public University has offered this course to its students via two methods of instruction: face-to-face and blended. What follows in the next sections is a restatement of the research problem, the design of the research, and the research questions reiterated along with the procedures used to answer each research question.

Based on the work of Yin (2003) and Merriam (1988), the case study research method was chosen as the most appropriate way to answer the research questions. Employing case study methodology ideally affords for the in depth comparison required. The design and methods to be used are described in this chapter. The researcher will be the sole investigator acting as both observer and interviewer.

The following research questions guided the research study:

1. What differences exist in the procedural knowledge of students enrolled in a pre-calculus mathematics course following a blended instruction format compared to students in a face-to-face environment?

2. What kinds of understandings beyond procedural knowledge do students in a blended instruction environment exhibit?

3. How do student attitudes toward mathematics evolve in a blended instruction format?

Overview of Procedures

The following section describes the procedures that the researcher used to obtain approval for the study. Approval procedures included University of Minnesota Institutional Review Board (IRB) and the IRB approval of Public University.

Approval

The researcher simultaneously sought approval from the University of Minnesota's Institutional Review Board and the IRB of Public University. The proposal for this study was submitted to both IRBs in July 2012 and both universities granted approval in August 2012.

Informal discussions about the study began in the fall of 2012. In October of that year the researcher met with an instructor at Public University who acknowledge the need for an examination of the mathematics instruction in his introductory mathematics class to understand the attitudes that students had toward mathematics. The instructor was also redesigning the method of his instruction from a face-to-face instructor-centered approach to a from of blended instruction that was more student-centered. The instructor wanted to address the declining attitudes towards the subject by students in his classes.

Recruitment

Following approvals from the IRBs of the University of Minnesota and Public University, the researcher again met with the instructor in mid November 2012 at which point he gave permission to implement the study in his course. There was also a discussion related to the recruitment of students for inventories, observations, and interviews. At this meeting the instructor was provided a copy of the proposal submitted and approved by the dissertation committee for this study, including consent forms to be distributed to and discussed with the students at Public University. The researcher again met with the instructor in January 2013, as it was deemed important to reiterate the processes involved in the study and the important roles students would play, if they chose to continue to participate in the study. The researcher also reviewed the consent form provided and discussed the documents that would be collected as part of the study.

During the first introduction to the students in the blended instruction design course, in spring 2013, the researcher distributed and verbally read the content of the consent form and reminded the students that their participation was completely voluntary. The students were also assured that any identifiable or personal information that might be acquired during the course of study would be kept confidential.

The following week, the second week of the course, the data collection began in addition to the solicitation of volunteers for further observation and interviews. After an additional return to the classroom to recruit participants, a total of four students agreed to be part of the extended observation and interview component of the case study.

Research Setting

To conduct a sound qualitative study, a realistic site must be acquired. Creswell (2009) defines a realistic site as one where entry is possible, the researcher is likely to be able to build a trusting relationship with the participants in the study, and the data quality and credibility of the study are reasonably assured. The participants for this study were selected from students enrolled at Public University. Access to classrooms, programs, and students was easily accomplished. There were also many opportunities to develop trusting relationships with the participants.

Public University has an undergraduate enrollment of approximately 8400 students. The population of students on the Public University campus is 87.7% White, 1.9% Asian, 2.0% Black, 2.2% Hispanic, and 6.2% other. 39.0% of the students are male while 60.9% are female. Of this population, 90.4% are full-time students.

Students participating in this study were enrolled in a college pre-calculus course in the spring semesters during 2012 and 2013. To enroll in this course, students must have completed Intermediate Algebra or have an appropriate Math ACT Sub score between 18-22.

This pre-calculus course is an introductory mathematics course designed as an introduction to calculus for those students that are not mathematics majors. A general listing of major focus areas of the course shows that course concentrations is the algebraic and symbolic manipulation of linear functions, quadratic functions, exponential and logarithmic functions, trigonometric functions, polynomial and rational functions, inverses and compositions of functions, transformations of functions and their graphs, and applications. In addition, the course emphasizes problem-solving skills including unit analysis, changing representations (graphical, tabular, formulaic, and verbal) of data, comparison of solutions with intuition, and analysis of various solution methods.

Participants

For the purposes of this research it should be noted that there are three groups of participants contributing to this study. Greater detail related to each of the groups is provided in Chapter 4, however a general summary is stated in this section. The participants were chosen through convenience sampling because students selected the instructor and class times when they enrolled. It should be noted that there were not two separate groups running concurrently, rather there was one historical (face-to-face) group and one current (blended) group of students. The reason for this was that the Mathematics and Statistics Department of Public University made the decision to only offer sections of Math 112 in a blended instructional format, whereas Math 112 had previously been offered entirely in a face-to-face format.

The first group of students is the collective that was enrolled in Math 112 during spring 2012 at Public University. For this group, the researcher had no interaction and was able to collect grades in order to incorporate in the data analysis, which will also be discussed in a later section. The second group was the Math 112 section during spring 2013 at Public University. The researcher was able to observe this group in addition to collecting attitude inventories, final examination grades, and final course grades. The last group of participants was a subsection of the second group and it was the four students that the researcher was able to observe in the classroom working on the group lab assignments as well as conduct interviews after each observation.

Methods

Data Collection

Gathering data from a variety of sources is an essential component of the case study methodology (Merriam, 1988; Stake, 1995). Researchers should maximize the benefits of case studies by incorporating as many sources as possible when answering the research questions (Yin, 2003). To facilitate understanding of the influence of the variables considered in this study, the researcher gathered information from a variety of sources and obtained answers to the research questions that comprise this study. Glesne (1999) and Creswell (1998) list interviews, observation and document collection, and open-ended surveys as sources of evidence. Table 1 shows the timing of the data collection.

Table 1

Timing of Data Collection

Fall 2012	
Interviews with instructor	Collect site description and classroom artifacts including course syllabus, final exam grades, and final course grades
Spring 2013	
Interviews with instructor	Collect classroom artifacts including course syllabus, final exam grades, and final course grades
Classroom visits	Administer and collect Attitudes Toward Mathematics Inventory at the beginning and end of the semester, collect group lab activities
Classroom observations	Field notes of group work
Post-observation interviews	Audio recording of interviews with four students and transcription of interviews

Both quantitative and qualitative data were collected for this study including grades (quantitative), survey data (quantitative and qualitative), interview data (qualitative), and documents such as course syllabi (qualitative) as illustrated in Figure 3 on the following page. These sources provided data necessary to determine the effectiveness of implementing a blended instruction approach and which aspects had an impact on student attitudes.

PROCEDURAL KNOWLEDGE	BEYOND PROCEDURAL KNOWLEDGE	STUDENT ATTITUDE
(a) Comparison to face-to-face instructional design through final examination and final course grades	(a) Group activities (b) Observations and field notes (c) Assessment of student work	(a) ATMI

Post-observation interviews with students

Figure 3: Tools used in the research.

Unit and Final Examinations. At the conclusion of units related to the content, all students were administered a summative unit assessment as another measure of acquisition of knowledge beyond what is considered procedural. A comparison of overall student trends as well as an evaluation of the students participating in group interviews and observations added to the discussions with the groups and assessed overall effectiveness of the blended instruction environment. The final examination (Appendix E), previously administered to students enrolled in the same course structured in a face-to-face format, was administered to students enrolled in the blended instruction designed course. This allowed for comparison of procedural knowledge acquired in courses structured as either a face-to-face or blended instruction course while acting as a control for quantitative analysis.

Attitudes Toward Mathematics Inventory. This study assesses student attitude toward a blended instruction instructional format. The Attitudes Toward Mathematics Inventory (Appendix A) provided information on how students viewed themselves as students of mathematics before enrolling in, as well as near the completion of, the introductory mathematics course. The instrument to measure mathematics attitudes was administered to all students participating in the study at the beginning and the end of the semester. This instrument, developed by Martha Tapia and George Marsh (2004), had the purpose of attending to attitudes in mathematics relating to self-confidence, value, enjoyment, and motivation toward the content. The authors originally administered their instrument to 545 students enrolled in mathematics courses. The original Attitudes Toward Mathematics Inventory (ATMI) was a 49-item, Likert-scale format; it has since been reduced to 40 items. In order to gauge the internal consistency of the scores of the updated inventory, the Cronbach alpha coefficient was calculated. The resulting alpha was 0.96 of the 40 items, thereby indicating a high degree of internal consistency. Furthermore, the item-to-total correlation varied from 0.50 to 0.82.

Observations and Group Assignments. The researcher documented student participation through observations multiple times during the semester. The researcher noted the interaction between students while they were working on collaborative assignments (Appendix D) related to the course content. It was through these observations that the researcher gained insight into how the blended instruction environment promoted knowledge acquisition and its effect upon attitude toward mathematics. The researcher noted techniques used and application of knowledge while preparing to interview the students.

Student Interviews. The researcher interviewed student participants multiple times during the semester. The researcher followed an interview protocol (Appendix J) while conducting the interviews; the interviews took approximately thirty minutes and were audio recorded for future reference and transcription. The discussions began with an opportunity for the students to comment on thoughts regarding the collaborative tasks completed in the classroom. Further questions were related to conclusions and observations the researcher made.

The purpose of the student interviews was to collect data on student thoughts and reactions to the tasks assigned throughout the duration of this study. In addition, students were asked questions designed to check how they perceived their attitudes toward mathematics as well as what specifically transpired in the course and its impact on their perception. It was through the interviews that students identified techniques used in the classroom and their corresponding attitude (enjoyment, motivation, self-confidence, value) toward each technique. They also were also provided the opportunity to discuss ways in which topics were presented, whether they perceived an increase in confidence to perform the mathematics, and whether they were able to comprehend the material. The interviews also served to build rapport with the students in order to obtain honest responses.

What follows is a restatement of the research questions along with a brief description of how the researcher incorporated the data that was collected in order to respond to each research question.

Research Question 1: *What differences exist in the procedural knowledge of students enrolled in a pre-calculus mathematics course following a blended instruction format compared to students in a face-to-face environment?*

In order to answer this research question, the scores of the final examination given to students in the face-to-face format as well as students enrolled in a blended instruction format were analyzed. The examinations were graded using the same rubric and by multiple scorers in order to compare grade distributions between the two instructional formats. Furthermore, by having the same instructor teach the course in a face-to-face format as well as the blended instruction format, the researcher attempted to control for instructor effect when comparing final course grades to answer the first research question.

The researcher also compared final course grades between the two offerings of Math 112. The method for determining student grades was not the same for the two sections (see Appendix K). In order to normalize the grades between the sections, the researcher was granted access to the grades of the spring 2013 section of Math 112. The purpose of this process was to be able to recalculate the spring 2013 grades according to the spring 2012 grade determination. Any grade category not offered in spring 2012 was not included in a revised spring 2013 grade (the participation and labs categories). An adjustment was made to the spring 2013 grade format so that it modeled that of spring

2012. Thus, a more comparable analysis could be performed after the revised spring 2013 grades were calculated to match spring 2012. More detail regarding this normalization process is explained in Chapter 4.

Research Question 2: *What kinds of understandings beyond procedural knowledge do students in a blended instruction environment exhibit?*

For the second research question, data was collected from a variety of sources:

i. There were multiple, face-to-face student-centered collaborative activities (labs) in which all students enrolled in the blended format participated. The researcher was able to collect and analyze the submissions of each group in response to the prompts and guiding questions of each student-centered activity.
ii. Observations and field notes of the interactions within a specific group were conducted while students were working on the activity in class.
iii. The researcher met with the members of the group being observed in order to conduct interviews related to the tasks performed and acquire additional insight as to the observations.
iv. Unit assessments of student comprehension were given to all students in order to gauge the effectiveness of the activities and the understanding beyond and retention of procedural knowledge.

Research Question 3: *How do student attitudes toward mathematics evolve in a blended instruction format?*

There were two sources of information used to answer the third research question. An adapted version of the Attitudes Toward Mathematics Inventory developed by Tapia and Marsh (2004) was completed by students in the blended format near the beginning and end of the semester. Secondly, during the interviews with the students of interest in the observations, students were asked questions regarding their attitudes towards mathematics beyond that of the ATMI.

Data Analysis

When combined as a collective, these multiple sources of data allowed this researcher to obtain a rich description of the group setting of the classroom being observed and an understanding of the experiences of the students, in addition to their attitudes and perceptions during the instructional moments. This is consistent with the proposition of Yin, in that the variety of sources of data allow for a comprehensive collection of data that may not be afforded through one source of examination.

Interview data were analyzed to identify common themes of the experiences of students enrolled in the course implementing a blended instruction format. Coding and analysis of interview data followed the constant comparative method (Glaser, 1965) by implementing four steps: (a) comparing occurrences applicable to each factor, (b) incorporating categories and their properties, (c) defining the theory, and (d) writing the theory.

Three primary categories were generated to analyze student interview data for this study: (a) perception of students related to the advantages of the blended instruction experience, (b) perception of students related to the disadvantages of the blended instruction experience, and (c) the effect on student attitude toward mathematics while enrolled in a blended instruction course.

The analysis of data for this research study began with the process of data reduction in order to find emerging themes. Data reduction refers to the process of choosing, streamlining, and converting the data from the variety of forms in which it was collected: researcher field notes and observations, transcriptions of student interviews, attitude inventories, and student lab and examination submissions. The researcher looked for common themes among student responses to interview questions, their comments made, and observations recorded by the researcher. Any information given to the researcher not related to the research questions was not used in the study. In addition, data related to attitude was included in written summaries, coding of student behavior related to blended instruction, analysis looking for themes, cluster of ideas around common ideas, and researcher notes. Following the data reduction process, the researcher continued the analysis in order to search for descriptive conclusions in the data.

Observation data were analyzed to determine if there were any qualitative differences among the participants. It was also employed to find emergent trends that would add to the overall analysis of the student participants. After each observation, the researcher compared and summarized observation notes on each participant in the group.

A spreadsheet was created to record the incidents for each category in order to compare them. The columns created in the spreadsheet allotted for identifiers for the students and incidents recorded from the interview transcriptions. The instances from each interview were appended to the spreadsheet and compared with those recorded from other interviews. Themes were generated based on comparing the incidents. An additional “Themes” column was added to the spreadsheet. The themes were routinely revisited, analyzed, and combined throughout the comparison and coding process.

Upon coding the student interview data, the researcher asked a statistician with over twenty years experience in post-secondary education and statistical consulting, to independently code one of the interview session based on the primary categories and themes created by the researcher. The Cohen’s Kappa statistic was used to assess inter-rater reliability when observing or otherwise coding qualitative/categorical variables (Creswell, 1998). Kappa is considered to be an improvement over using percent agreement to evaluate this type of reliability, with a Kappa greater than .70 being considered satisfactory (Creswell, 1998). For the comparison of the two codings, a Kappa of .81 was calculated. Some disagreements were resolved through discussions in order to reach a final coding agreement. A result of the collaboration between the researcher and statistician was a final coding revision that was used to categorize the student interviews one final time.

Validation

In an attempt to strengthen the credibility of the study, "the triangulation of multiple and different data sources provide corroborating evidence to support researcher's analysis" (Creswell, 2009, p. 208). The triangulation of data occurred through the process of comparing data from multiple sources and a variety of viewpoints (Stake, 2005). Furthermore, the researcher utilized member checking when the participants were allowed to review and verify the accuracy of the collected data. Accuracy is guaranteed when member checking is incorporated and there is no misrepresentation of the data collected (Stake, 2005).

Role of the Researcher

The researcher was the sole investigator in this study. The researcher has eleven years experience teaching in a secondary setting as well as ten additional years experience working in postsecondary education, the last two of which have been involved in designing and teaching courses that utilize a blended instruction format. This researcher has also worked collaboratively with other faculty to design, develop, and teach their courses in a similar blended format. The researcher is comfortable working with faculty and students and did not have difficulty establishing trust or rapport with the participants. Glesne (1999) mentions two roles that a researcher plays in a qualitative study: researcher as researcher and researcher as learner. The researcher as researcher role includes data gathering through interviews, reading, observation, and data analysis. Merriam (1988) points out that "the importance of the researcher in qualitative case study cannot be overemphasized. The researcher was the primary instrument for data collection and analysis. Data are mediated through this human instrument, the researcher, rather than through some inanimate inventory, questionnaire, or machines" (p. 19).

The researcher as learner role includes being self-aware from the outset of the study. Acknowledgment and consideration of the researcher's bias and pre-disposition throughout the study assisted the researcher to become a "curious student who comes to learn from and with research participants" (Glesne, 1999, p. 41). The researcher must become a good listener to learn from the participants, instead of approaching the interviews as an expert. Being a researcher as learner placed the investigator in a position to be constantly open to new thoughts and ways of looking at the data. The researcher was able to take on the researcher as learner role in order to create and maintain open communication with the participants. Additionally, Glesne (1999) points out that in considering validity issues, it is important not only to recognize the researcher's expertise in regards to the study, but also their "subjective relationship to the research topic" (p. 17). The researcher is a proponent of blended instruction and thus was constantly aware of this subjectivity in order to monitor and use it properly. In qualitative research, bias is not controlled in an attempt to keep it out of the study, but as Glesne (1999) states:

> When you monitor your subjectivity, you increase your awareness of the ways it might distort, but you also increase your awareness of its virtuous capacity. You learn more about your own values, attitudes, beliefs, interests, and needs. You learn that your subjectivity is the basis for the story that you are able to tell. It is the strength on which you build. It makes you who you are as a person and as a researcher, equipping you with the perspectives and insights that shape all that you do as researcher, from the selection of the topic clear through to the emphasis you make in

> your writing. Seen as virtuous, subjectivity is something to capitalize on rather than to exorcise (p. 109).

One of the ways a researcher can monitor subjectivity is using a researcher's journal (Creswell, 2009), an activity this researcher engaged in throughout the study.

The expertise and experience that the researcher has in the blended instruction environment facilitated his ability to gather rich data sources and analyze the data to find common patterns and emerging themes across the cases. The researcher's monitoring and use of his subjectivity will allow him to tell the story in meaningful and verifiable ways (Glesne, 1999).

Limitations of the Study

There were several limitations to this study that need to be acknowledged. Each of these issues is explained below:

1. The study was limited to multiple sections of one mathematics course, Math 112, offered at Public University during the spring semesters of 2012 and 2013.
2. The researcher involved in this study has some background in the development and implementation of blended courses and, as a result, approached the development of this study with a positive perspective on the use of student-centered blended courses in a public university setting.
3. There is no control for instructor experience or training in using a blended instruction format in this study. While the instructor has previous experience

teaching in a teacher-centered face-to-face environment, the instructor also has emerging experience teaching in the blended format.

4. Students involved in the study varied with regard to prior knowledge, skills, and attitudes with blended courses.

Summary

By using a mixed-methods design, the researcher assessed potential benefits of using a blended instruction approach to course design in an introductory mathematics course.

The participants in the study were students enrolled in an introductory mathematics course taught in a face-to-face and a blended instruction format. Once the semester commenced, the students in the blended instruction format completed an Attitudes Toward Mathematics Inventory to establish their perceptions in their abilities in the mathematics classroom utilizing a blended instruction format. The ATMI established attitudes related to enjoyment, motivation, self-confidence, and value for mathematics. Solicitation for student volunteers produced a subset of students that were used in group observations and interviews, allowing them to expand on their feelings and experiences in the blended instruction classroom. Other sources of data included submission of student assessments and researcher field notes.

This study sought to discover how student attitudes and performances were affected by a blended instruction format, in particular, how the opportunity to participate in student-centered activities impacted attitude and performance. The qualitative measures used in this study offered the opportunity for students to give detailed explanations and statements related to their evaluation of the course. The quantitative data provided statistics that supported the qualitative data related to change in attitude. This will provide valuable information for instructors who wish to use blended instruction strategies along with those who wish to use attitude assessment as a portion of their course design.

CHAPTER 4: PRESENTATION OF THE CASES

This chapter present two cases to be profiled – one for each of the classes in which data was collected. Each profile is presented in the same manner beginning with descriptions of the general composition of the assignments and assessments within the course, the physical space of the class, and the structure of the class – including frequency of meeting and grade determination.

Case 1 – Spring 2012: The Face-To-Face Instructional Format

The collection of information regarding the spring 2012 course came from interviews with the instructor in addition to analysis of documents. The researcher was unable to observe the class directly, which provides a rationale as to why this study was unable to compare attitudes of students in the face-to-face instructional format.

Previous offerings of this course at Public University utilized a face-to-face instructional course format. All students were required to use a print version of the textbook as an instructional tool and reference, as well as a source of exercises for homework. The homework assignments were not submitted on a regular basis nor did students receive feedback provided on the assignments unless the student consulted with the instructor before or after regular class time. In order to gauge student understanding, there were two midterm exams and a series of in-class quizzes used as assessments. The structure of the class was predominantly teacher-led with occasional comments and questions from students, generally related to the assignment or immediate lecture. As is

Figure 4: Face-to-face instruction classroom physical space.

shown in Figure 4, the physical design of the classrooms did not allow for interaction between many students; the desks were arranged in rows facing the front of the classroom.

During subsequent interviews with the instructor of this course, the researcher was informed that this class met three times a week – on Mondays, Wednesdays, and Fridays. The time allotted for each class was fifty minutes. The instructor self-described the typical class meeting as being lecture-based with the classroom discussion being led by the instructor. It was also noted by the instructor that the lectures would be comprised of answering an occasional question related to homework, followed by the stating of any pertinent formula, theorem, and/or process, concluding with a demonstration of related examples. The instructor would pose a question for the students to work on, either by themselves of alongside a classmate. During this time, the instructor would walk around the room to monitor student progress and guide students that needed some assistance.

Self-reporting by the instructor noted that in-class problem solving as was described would occur two to three times a week and that it would typically utilize five minutes of class time.

Over the course of the semester, the semester grades for the students were based upon the following categories and respective percentage of grade: homework and quizzes (40%), two unit assessments (15% each), and one comprehensive final examination (30%). The homework portion was comprised of a submission of a few select problems that students had a few days to complete, write up solutions and comments, and then they would wait two or three classes (approximately one week) in order to receive feedback from the instructor. The assessments included problems that were extensions of the homework, and very often they were related to the problems assigned as homework.

Case 2 – Spring 2013: The Blended Instructional Format

In contrast to the spring 2012 course, mathematics courses utilizing a blended instruction format exhibited qualities that distinguish the design from the face-to-face mathematics classrooms at Public University. Rather than a physical print version of the textbook, students utilize an electronic version of the textbook. The advantage to electronic books was that students do not have to carry a large print version with them, students had access to material over the Internet, video and other support are available through the publishing company, and there was a link to ask the instructor for assistance through the electronic textbook.

This class met two days a week, Tuesdays and Thursdays, for eighty minutes each day. During the class meeting times, there was typically a combination of some teacher-led instruction along with some student-centered instruction. There were also times when there was reduced class time – a direct component of the blended instructional format. There were aspects of this course that varied in how information and course content was experienced by the students. Since this was a blended instructional format course, there were times in which there was instructor-centered face-to-face instruction being implemented. On other occasions, as will be described in a later section of this chapter, the instruction was student-centered in a face-to-face setting through either "mini problems" or collaborative, face-to-face student-centered labs. There were also times when students would be exposed to procedural knowledge either through in-class direct instruction or through online supplementary supports.

The course being studied for this research utilized the online management system WebAssign© for access to the electronic textbook and homework assignments. Appendix L displays sample screen shots of a typical question assigned as homework along with showcasing the alternate supplements to instruction made available through the resource. The publishers describe WebAssign as allowing instructors the ability to create online assignments and electronically transmit them to their class; students submit answers online and WebAssign grades the assignment and instantly provides feedback on their performance (WebAssign, 2013). The READ IT link takes the student to the location in the electronic textbook related to the exercise. There is also access to online media support a searchable database and the ability for the student to annotate their own notes. The MASTER IT link allows students to view the entire solution, attempt another similar exercise, or have the solution shown in steps. The CHAT ABOUT IT section allows students to link to the corporate/national online support if the student requires immediate online assistance. Students can also contact their instructor and ask questions specific to their example – the instructor can see the exact question the student is working on and the response(s) that the student has given. Furthermore, students can request an extension on the due date.

In addition to required curriculum format and access, another difference between the face-to-face design and blended instruction design is the classroom layout (see Figure 5). Students are arranged in groups, situated around a peninsula-shaped table in which students face each other and have access to a display monitor to which individual laptops can be connected. This monitor can display information from the instructor or other student work groups. The arrangement of seats allows for a natural flow of conversation

Figure 5: Blended instruction classroom physical space.

and collaboration on assignments. This investigation focused on the general attitude of students towards mathematics in a blended instruction course along with the acquisition of knowledge beyond that of procedural knowledge. While there are other aspects of equal importance (i.e. pedagogical aspects of the online textbook's design, online video lectures, online discussion groups, issues that relate to reading print versus digital text, and usability of the online textbook and the course web site) this research did not attend to those components.

In the Math 112 course implementing a blended instructional approach, the semester grades for the students were based upon the following categories and respective percentage of grade: homework (20%), participation (10%), face-to-face student-centered collaborative labs (20%), quizzes (20%), two unit assessments (10% each), and one comprehensive final examination (10%). A comparison of the grading scale between the two cases is provided in Table 2.

Table 2

Categories and Percentage of Final Grade for Math 112 Sections

Case 1		Case 2	
CATEGORY	PERCENTAGE	CATEGORY	PERCENTAGE
Homework/Quizzes	40	Homework	20
Exam 1	15	Participation	10
Exam 2	15	Labs	20
Final Exam	30	Quizzes	20
		Exams	20
		Final Exam	10

With the implementation of an online management system, the instructor in the blended instructional format was able to regularly assign homework with the expectation that would be attempted and used as a learning tool. By utilizing the online system, students would receive immediate feedback on any homework problem submitted and they were allotted up to five attempts at each problem. There was not a requirement for instructor interaction on the homework submissions, although the instructor could, at any time, monitor the progress of any student on any assignment.

This researcher is classifying student-centered instruction as the opportunities provided in class for interaction between students as they applied previously discussed content. Many times this would involve periods of 10-15 minutes in which the students were presented a scenario related to the procedural knowledge they had acquired. The instructor referred to these as "mini problems" as a way that he distinguished them from the collaborative face-to-face student-centered labs. During this time, the instructor would observe the students and offer guided advice, without answering direct questions such as "Is this correct?" or "Are we doing this right?" There would then be a whole class discussion and sharing of processes – displayed on the monitors for each group. The instructor noted that this was definitely an aspect that he could not incorporate in the previous model of instruction. In general, half of the class time comprised these informal problem-solving scenarios with summative discussions, although not every class would be dedicated to that schedule.

While a student could work on these "mini problems" alone (most did not), there were also collaborative face-to-face student-centered labs in which all students had to work in groups of three or more. These face-to-face student-centered labs are discussed in greater detail in the next chapter and can be found in Appendix D. Some class time was dedicated to the introduction of these collaborative face-to-face student-centered labs and the researcher was able to observe the group of four students participate in their discussions related to these activities. During these discussions, the instructor again would observe each group and interact only to clarify interpretation of instructions. There was no observed guidance related to how to complete the activity. The purpose of these scenarios was to provide the opportunity for students to apply the procedural knowledge they had been acquiring.

The institutional setting of Public University for this study utilized a combination of two categories for blended instructional systems: *enhancing blend* and *transforming blend* (Graham, 2006; Wang, 2009). The researcher is noting this distinction as the mathematics department at Public University is not only adjusting processes already integrated in the previous face-to-face setting (enhancing), but they are also implementing major adjustments and modifications to the method of instruction in order to take advantage of the available technology (transforming). The extent of success of these implementations is the focus of discussion in the next chapter.

Participants were individuals enrolled in an introductory mathematics course taught in a blended instruction format. Four students enrolled in the course were observed on multiple occasions during the semester while they were working on lab assignments in class. A summative description of the students is provided in Table 3.

Table 3

Description of Students Observed and Interviewed

Student	Gender	Year	Classification	Major	Self-Described Math Interest
A	Female	Senior	Non-Traditional	Business Administration	Disinterested but can tolerate it
B	Male	Sophomore	Traditional	Business	Low-level
E	Female	Sophomore	Traditional	Business Administration	General interest and desire to do well
M	Male	Junior	Traditional	Undeclared	Ambivalent

Student A was a female in her final year of coursework at Public University. She was a Business Administration major who returned to the post-secondary setting after working a few years immediately after high school, thus she is classified as a non-traditional student. When asked to describe her interest level in mathematics, she stated that math was "never one of my favorite subjects, but I can do it and tolerate it." Two of the students were female and two were male.

In comparison, Student B was a male, second-year student that was a Business major that enrolled at Public University immediately after high school. His description of his interest level in mathematics was straightforward, "the only reason that I am taking this math class is because my major requires it and my advisor said I had to take it."

Another second-year student was Student E, a female that also came to Public University directly from high school. As a Business Administration major was also advised to enroll in the Math 112 course as a prerequisite for her major. However, her level of interest was vastly different compared to Student B; she stated that, “I appreciate it [math], I don’t like it, but I understand that it is going to be important for me to use in my other courses.” Later she went on to state that she generally puts in a lot of time in all of her classes as she had a strong desire to do well in her courses, even though she may not always achieve her goals.

The fourth of the students that were observed and interviewed is Student M. He is a junior at Public University, in his fourth year at the university. He has yet to declare a major but he was most leaning towards something in the Business or Business Administration areas. The interest level of Student B in mathematics is best described as ambivalent. This description came about from interviews with Student B in which he stated that “I could care less about math” and that “if I have to take it I will.” He did not envision that he would take more than what was required for him in terms of math courses at Public University.

CHAPTER 5: RESULTS

The problem investigated was whether student achievement is impacted by the method of instruction, which aspects of course design and/or instruction are more effective and successful, as well as why and how course design impacts the attitude of students and their acquisition of knowledge in a blended instruction environment versus that of a face-to-face classroom. The students serving as the focus of this study were being taught in a blended instructional format by an instructor that had previously taught the course in a face-to-face format. The instructor noticed that when he taught the face-to-face version of the course he focused more on helping students learn and follow procedures rather than help them make sense of the concepts and apply these ideas to real-life situations. The instructor wanted the students to have additional time to explore and experience the mathematics being discussed. The impetus for a change was the instructor noticing that students did not appear to have an enjoyable experience while participating in the class. In addition, the instructor was making the transition to a blended instruction format to allow students different opportunities to express the mathematics they were learning while assessing the students who have different levels of understanding through various tools not available in the face-to-face learning format.

Specifically, this study assesses feedback from students enrolled in a blended instruction environment and their perceptions regarding enjoyment, motivation, self-confidence, value, as well as if there is a sense of higher levels of participation and a more positive feeling about the classroom atmosphere and structure. This chapter presents the analysis of the data. Results from the analysis of data obtained in this study are reported in this chapter in tabular and narrative form. The presentation of the data analysis is organized according to the three research questions.

Analysis Related to Research Question 1

What differences exist in the procedural knowledge of students enrolled in a pre-calculus mathematics course following a blended instruction format compared to students in a face-to-face environment?

The final examination used in the face-to-face and blended instruction courses assessed primarily procedural knowledge. This is a consistent measure to assess acquisition of procedural knowledge in the two instructional formats and is indicative of the types of performances assessed at the procedural level. The mean percentage on the final examination was higher for blended instruction at 75.39 (on a 100-point scale) when compared to that of face-to-face instruction at 63.06. Table 4 summarizes the results of a one-way between subjects analysis of variance (ANOVA) test. The test indicated a

Table 4

ANOVA Table for Final Examination Percentage by Method of Instruction

Method of Instruction	Mean	Standard Deviation	*F*-value	*p*-value
Face-to-face	63.06	4.23	4.56	.0376*
Blended	75.39	3.92		

* significant at $p < .05$

statistically significant difference in knowledge acquisition as determined by final exam grade between instructional modalities, $F(1, 50) = 4.56, p = .0376$.

By having the same instructor teaching the course in a face-to-face format as well as the blended instruction format, the researcher attempted to control for instructor effect when comparing final course grades. Table 5 summarizes the results after the researcher attempted to account for influences that may be attributed to the inclusion of group projects and lab assignments as they were part of the blended instruction course design and were not part of the face-to-face learning format grading including the collection and comparison of grades during the same semester of the school year – specifically, the spring semester. The student-centered group projects and lab assignments unique to the blended instruction format had a positive effect on the overall grade of the students. The group projects and lab assignments allowed students the opportunity to further elaborate their thoughts while providing an opportunity to demonstrate knowledge not available to students in the face-to-face setting. Final course grades for students enrolled in the blended instruction format were recalculated after removing group assignments from the final grade. In similar fashion to the analysis conducted with final examination grade, the

Table 5

ANOVA Table for Final Course Grade Percentage by Method of Instruction

Method of Instruction	Mean	Standard Deviation	*F*-value	*p*-value
Face-to-face	71.82	3.21	4.25	.0438*
Blended	81.28	3.27		

* significant at $p < .05$

mean percentage on the final course grade was higher for blended instruction at 81.28 (on a 100-point scale) when compared to that of face-to-face instruction at 71.82. A one-way between subjects ANOVA test indicated a statistically significant difference in knowledge acquisition as determined by final course grade between instructional modalities, $F(1, 59) = 4.25$, $p = .0438$.

Analysis Related to Research Question 2

What kinds of understandings beyond procedural knowledge do students in a blended instruction environment exhibit?

This section describes days in the blended instruction classroom when discourse surrounding a mathematical task occurred. The discourse was conducted in an open format where students freely gave their input, with little encouragement or prompting from the instructor, with the goal of completing the assigned application or task.

For this study, procedural knowledge is considered an awareness of the formal language or symbolic representations as well as an understanding of the rules, algorithms, and procedures. Perhaps the most commonly accepted definition of procedural knowledge in mathematics is attributed to Hiebert and Lefevre (1986):

> One kind of procedural knowledge is a familiarity with the individual symbols of the system and with the syntactic conventions for acceptable configurations of symbols. The second kind of procedural knowledge consists of rules or procedures for solving mathematical problems. Many of the procedures that students possess probably are chains of prescriptions for manipulating symbols. (p. 3)

One example of classroom discourse observed by the researcher that is indicative of how students acquire knowledge beyond that of procedural and demonstrates their understanding occurred during a student-centered collaborative assignment related to modeling linear functions (Appendix D). Previous instructor-led class meetings consisted of discussions in which linear functions were featured. In order for students to extend their understanding and make connections between actual data and incorporate linear functions in understanding and explaining mathematical applications, the students were instructed to situate themselves in their working groups. They were given the background information to explain the lab assignment and then instructed to begin their analysis. The goal for the instructional time in class was for students to create an $x - y$ scatter graph to be used to determine the linear relationship between two quantities after agreeing upon the data to be used. The members of the group needed to obtain their own data from any available source (for which all groups in the course chose to use the Internet) for the exercise and contribute in completing a lab report. Groups were required to graph the two quantities, one as a function of the other, and then analyze the graph to determine a linear model that describes the relationship between the independent and dependent variables. Additional analysis of the graphs and data occurred outside the instructional and observational time permitted to the researcher.

Before analyzing the results of observations of student work on the collaborative project related to liner functions, this study examined the procedural knowledge that was assessed in class by citing specific questions from the final examination related to linear functions. Following are references to examples of student work from the collaborative assignments addressing linear functions and a consideration of why these group assignments assist students in acquiring knowledge beyond that of procedural. Connections to the researcher's field notes while observing class discourse as well as reference to student interviews are incorporated.

To begin the analysis of the types of procedural knowledge questions asked of students, this study provided an example of two final examination questions related to linear functions (see Figure 6). These questions were selected because they appeared on the common final examination administered to students enrolled in the face-to-face course as well as the blended instruction course and were representative of the types of questions asked of students throughout the semester during homework, classroom discussions, quizzes, and mid-semester examinations. This example highlights what the researcher classifies as procedural knowledge in that the level of application of knowledge is not considered at a level beyond procedural knowledge. In particular, the students at the procedural level are being asked to state a numeric value for slope that can be interpreted as the coefficient of x, rather than an interpretation of slope as a rate of

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1) Let $f(x) = \frac{1}{3}x + 1$

   What is the slope, m, of the line $y = f(x)$? Is $f(x)$ increasing or decreasing?

2) Find an equation of a **linear function**, $g(x)$, that passes through $(1,3)$ and $(3,7)$.

Figure 6: Procedural knowledge final examination questions related to linear functions.

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change. In order for a student to successfully respond to the first question, they merely need to demonstrate the ability to recall an introductory template for linear functions and the definitions of associated variables, specifically slope (m), then determine if a function is increasing or decreasing based on the value of m. The student is not asked to demonstrate an understanding of the concept of slope; they merely have to know that slope is the number in front of x. In order for a student to successfully respond to the second question, the student would need to recall a formula for determining slope and substitute the calculated value into a general linear function.

These two examples clearly demonstrate Hiebert & Lefevre's (1986) "rules or procedures for solving math problems." What needs to be stressed is that there is not much, if any, application of knowledge or extension to other fields in either of these questions. If a student can recall memorized processes, they would be considered to understand the concept in a sufficient manner for these problems. There is not a requirement of the students to express their understanding of slope as a rate of change, nor are there situations in which students need to demonstrate a robust understanding of identification of independent and dependent variables.

Linear Functions Modeling Lab Analysis

The modeling lab on linear functions described in Figure 7 asks students to apply the procedural knowledge they acquired to make sense of a new situation with which the student may not have familiarity. This activity, focusing on beyond procedural knowledge, is in contrast to the recall of facts asked of students on the final examination. Hiebert & Lefevre (1986) also define knowledge beyond that of procedural as:

> …knowledge that is rich in relationships. It can be thought of as a connected web of knowledge, a network in which the linking relationships are as prominent as the discrete pieces of information. Relationships pervade the individual facts and propositions so that all pieces of information are linked to some network. (p. 3)

Math 112 – Modeling Lab (Linear Functions)

Background: This lab instructs students on how to create a simple *x* – *y* scatter graph which can be used to find the linear relationship between two quantities. Each student will be assigned to a group for this exercise. The members of the group will obtain their data for the exercise as a collaborative unit and each member of the group will contribute in completing a lab report. Students will be required to graph the two quantities, one as a function of the other, then the graph will be analyzed to determine a linear fit of the data.

Figure 7: Beyond procedural knowledge lab question related to linear functions.

The researcher interviewed the four students of interest for this study. During these interviews the students indicated that when they were asked to recall procedures and mimic formulae as part of the requirement for the activity, they exhibited a level of forgetfulness. There was a desire on the part of students to experience mathematics rather than just do mathematics. Highlighting the desire for purposeful problems are the following replies from two students interviewed as part of this study. They were asked, "How is the mathematics that you do in this class different from the mathematics that you have previously done?" to which their responses were:

> Student A: In other classes, I memorize the information to get it done and then it's done and that information is out of my head. Because, you just do what you have to do to get through it and get a grade.

Student E: I have taken courses [like this one] that have had a high degree of interaction with the students, and I have learned more in those classes because you are applying the information and not just taking quizzes and tests. You are interacting with other people and applying it [the knowledge acquired].   What was evident in observations and interviews is that students appreciated working together along with being able to apply the concepts and procedures that they were learning on an individual basis. It was in these group situations that students were required to perform more than a routine calculation or repeat a response, as was illustrated by Student E's previous comment.

Further analysis of this phenomenon continued as the researcher looked at the open-ended application related to linear models presented to the observed students. What will be discussed are the features of these applications in comparison to the procedural assessments.

Classification of prompts and collaborations such as the one found in Figure 6 as beyond procedural knowledge is due to many factors. By not having the data immediately made available to the students, the project became of value as the group decided what was of interest to them as part of their analysis in completing their project. That enthusiasm continued as they searched for data on the Internet. Not having to respond to teacher-driven prompts added to the open-endedness of these applications. The instructor desired to have students demonstrate mathematics at upper levels of thinking according to Bloom's taxonomy (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956): *analyzing* by breaking the information presented to them into its component parts to explore relationships, *evaluating* by developing and applying standards and algorithms, and *creating* an original product as a result of collaborative thinking.

The researcher witnessed students engaged in discussions centered on linear functions for an entire 80-minute class. The appreciation for mathematics and the ability to experience the value of the content had improved for those students involved in a course utilizing a blended instruction format. Student B, when asked, "What do you think about the cooperative learning activities and their impact on your attitude toward mathematics?" responded:

> The problems we work on in class are often real world problems that could come up in a business setting down the road. The applications make me realize that I will use math in the future, and I should know how to use it. The group projects give me a better understanding for the use of math in the business environment.

The group that was the focus of this study opted to use the price of cotton between 1950-1970 as the data set for their project. A subsequent interview with the group members revealed that two of the members were in an economics course together in which the topic of textiles and commodities had been discussed. There was a carryover of this discussion to mathematics class, allowing for reinforcement of the applications and an appreciation of the content. During the same interviews, the students also recalled being able to locate the information on the Internet making finding data an easier task.

One of the first prompts the students had for this project was to create and analyze the graph related to the data set chosen by the group. Previous class discussion had been related to slope, trend lines, and interpretations of the relationships between dependent and independent variables. If students were to exhibit knowledge beyond that of procedural knowledge, a certain level of understanding must be conveyed in their responses to class prompts. The researcher observed a twenty-minute discussion centered on the selection of a topic to use for the lab and a mathematically rich debate regarding whether the data selected met the requirement for linearity. Afterwards, the students for this project selected the data set shown on the next page, in Figure 8. The subsequent interviews with the group members reaffirmed that "finding real-world data to use was the most difficult part." This is one aspect that the researcher considered beyond procedural knowledge because the students had to determine if the data was in fact linear rather than being provided the information and told it was linear. The students had to apply what they had recently learned to reach their acceptable conclusion.

Table of values (20 different points) from the points we acquired from:

(http://answers.google.com/answers/threadview/id/33770.html)

Years (since 1950)	Price (in U.S. dollars) per pound
0	40.07
1	37.88
2	34.59
3	32.25
4	33.61
5	32.33
6	31.75
7	29.65
8	33.23
9	31.66
10	30.19
11	32.92
12	31.9
13	32.23
14	31.07
15	29.37
16	21.75
17	26.7
18	23.11
19	22
20	21.98

Figure 8: Student-selected data for linear function lab.

The way in which the students displayed their data represented their understanding of independent and dependent variables. The researcher observed the students determining the independent and dependent variables for the data set. This is a departure from procedural knowledge since, rather than being told what the independent and dependent variables are (similar to stating which quantity to use for the *x*-variable and which is the *y*-variable on a graph) the students had to discuss this issue. Knowing they were to be analyzing the price of cotton over time, the students demonstrated they knew time was the independent variable, and price was the dependent variable. This carried over to discussions outside of class in which the students completed their analysis.

As Figure 9 shows, the students were able to correctly select the independent and dependent variables in order to create an appropriate scatter plot of the data. During the creation of this graph, there was some discussion between group members related to the observation that some of the values for price increased during certain periods. The original thought was that it was not linear because they believed all of the prices should be decreasing. However, another member of the group mentioned that this is actual data, and prices will not always go down. The realization that “over time it looks like it [price]

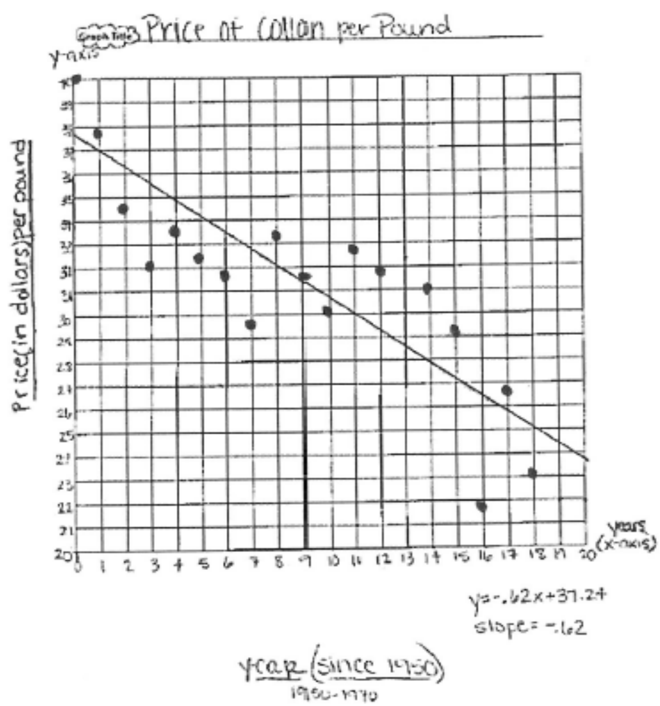

Figure 9: Student graph related to linear function lab.

is going down" demonstrates greater understanding of linear functions as the students applied their knowledge to the real-life scenario they had selected. Furthermore, the students were answering open-ended questions rather than parroting responses to wrote procedures.

As part of the assessment in this lab, students were asked to analyze the graph to determine if a linear model fit the data. To establish a level of understanding for this open-ended request, the students being observed interpreted a trend line for the data. This did not occur until after the final establishment that the data was linear. The linearity concept is not trivial; rather than being provided linear data and instructed to follow rote procedures, the students spent time discussing properties of linear functions in order to determine if the real-world data they were using was in fact linear. The position of the trend line in Figure 9 shows that the students interpreted the results correctly. This furthered the extension beyond procedural knowledge as the students had to determine which data points they were going to use in establishing a trend line, as opposed to the final examination item in which they were specifically instructed as to which points to use in their calculation. In the procedural final exam question, students merely had to use the points and follow a memorized procedure.

To further exhibit that they had proficiency beyond procedural knowledge, students continued to provide evidence of understanding that was not rote. As part of the lab assignment being discussed, the observed group chose to display their information in order to convey their understanding of analyzing a graph and reporting on relevant results.

ANALYZE THE GRAPH

- Our graph represented an overall negative slope, (**-0.62**), illustrating that as the years since 1950 increased the price of cotton (in U.S. dollars) per pound has decreased
- We identified an approximate linear relationship between our data using the points (9, 31.66) and (17, 26.70) ... **y=-0.62x+37.24**
- Our variables are indicated as follows:
  - Independent Variable (x-axis) : Years (since 1950)
  - Dependent Variable (y-axis) : Price (in U.S. dollars) per pound
- We found the y-intercept to be = 40.07

WORK

All work below is based on the points (9,31.66)(17,26.70)

To find the linear equation we used the points....(9, 31.66)(17, 26.70)
Equation: y=mx+b

To Find Slope: (26.70-31.66)/(17-9)
=4.96/8
=-0.62

Using Slope To Find Equation: y =-0.62x+b
31.66=-0.62(9)+b
31.66=-5.58+b
b=37.24

y=-.62x+37.24

Figure 10: Student analysis of graph and data related to linear function lab.

What is shown in Figure 10 is that not only could the students recall procedural knowledge, such as calculating slope, but also they could summarize their understanding of how to interpret slope and apply it properly to the data. The students were to analyze the graph and, based on their observations, identify a possible linear relationship between the two variables, drawing the trend line that adequately describes this relationship. For this particular data, the group was able to relate the negative value calculated for slope as "illustrating that as the years since 1950 increased the price of cotton (in U.S. dollars per pound) has decreased." This is an illustration of understanding beyond procedural knowledge –a focal point of improvement that courses following a blended instruction design are striving to advance. The students illustrated their comprehension of slope through their description of the overall relationship between independent and dependent variables. Their understanding was not as a rate of change, which would be a high level of understanding, but they could at least relate the negative aspect of slope as more than just a value. This shows the connections they were able to make with previously learned mathematics. The students knew that the value of slope was negative, but they also wanted to convey that they knew what the negative value meant: that prices were decreasing as time increased. Students did not have to state a coefficient of x; they had to demonstrate a deeper understanding of what slope represents. This showed the students comprehending slope at a level higher than procedural but not quite at the level of understanding slope as a rate of change; they saw it is more of a correlation between the independent and dependent variables.

The final source of information submitted for this collaboration was the additional calculations they performed in order to determine if the linear model created fit the data (see Figure 11). The students compared the values for three known data points they acquired from the Internet to the corresponding values the linear model predicted. The

Predictions of known data points ...

Year	1951	1952	1953
Prediction	36	35.38	32.11
Actual	37.88	34.59	32.25

Error	1.88	.79	.14

1) y=-.62(2)+37.24
   =36 actual: 37.88

2) y=-.62(3)+37.24
   =35.38 actual: 34.59

3) y=-.62(4)+37.24
   =32.11 actual: 32.25

Predictions of unknown data points ...

Year	1971	1972	1973
Prediction	24.22	23.6	22.98

1)y=-0.62(21)+37.24
=24.22

2)y=(22)+37.24
=23.6

3)y=(23)+37.24
=22.98

Figure 11: Additional calculations and predictions of data related to linear function lab.

students also used the linear model to calculate values for three data points that were not known (also acquired from the Internet) in order to determine if the trend line continued. The summary provided by this group stated,

> We think that the unknown data points would continue to be linear with the data. Yes, we think that a linear model would be a good choice and we are very confident with our prediction because the unknown points would continue to be linear with the linear progression line (sic).

The researcher had the opportunity to observe this specific instance when group cooperation worked well academically. The group of students was working on a particular application of linear functions. During the initial analysis of data, instead of group a member agreeing with the more vocal students, a discussion took place and the researcher noted that consensus was reached. This demonstrates the high degree of effectiveness that groups can have on the understanding of knowledge, especially knowledge beyond procedural, for the students participating in the collaboration.

Exponential Growth and Decay Lab Analysis

In a similar manner, the researcher observed students collaborating on another lab assignment related to exponential growth and decay (Appendix D). For comparative purposes, Figure 12 on the following page shows a procedural knowledge question asked of the students on an assessment. As was the case with questions related to linear functions, much of the information is provided to the students with the expectation that students repeat a learned procedure by following a memorized formula or procedure.

Find a formula for the exponential function, *g(x)*, graphed below.

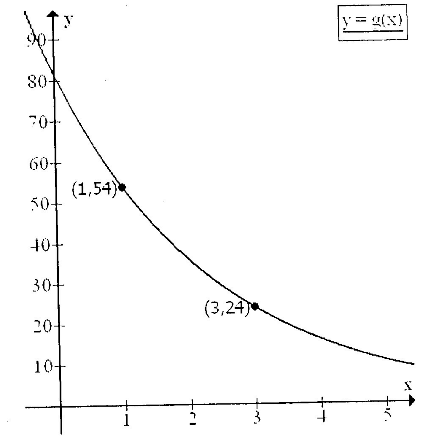

Figure 12: Procedural knowledge assessment question related to exponential functions.

There is no interpretation of information, rather an expectation to perform a calculation based on information already provided. Final examination questions that merely addressed procedural knowledge (i.e. did not allow students the opportunity to demonstrate their conceptual understanding), included:

- Find an exponential function that passes through the points (0 , 48) and (4 , 3).
- Suppose a radioactive substance has a half-life of 12 years. How long would it take for a 100 mg sample to decay to 70 mg?

This is contrasted to the exponential growth and decay lab in which students created their own data, made the respective graph, then interpreted and analyzed the information. The observed students commented, "It's helpful, learning how to use this stuff; it was an applied review of what we had been working on." Figure 13 shows the

Calculation analysis:

Both functions produced results similar to the original data. For the "near points" function, the predictions for trials (1), (3), and (5) had errors of (0), (-3.3), and (1.7), for a total error (in absolute value) of (5). For the "end points" function, the same predictions resulted in errors of (-5), (-1.42), and (0.03), for a total error (in absolute value) of (6.58).

While both function predicted data close to the original, we determined that the "near points" function is more accurate than the "end points" function due to it lower amount of error.

Summary:

The exponential formula is "P" multiplied by "a" raised to the power of "x" or $f(x) = Pa^x$. "P" represents the number of M&M's we began with, while "a" represents the decay factor from trial to trial, and "x" represents the number of trials.

In this experiment our predictions for the "near points" were closer to the original data than those from the end points. This is the opposite of what happened with our exponential growth experiment. There was slightly more error as much error in the "end point" function compared to the "near point" function.

We feel fairly confident with our predictions using the "near point" equation because using those 3 particular points the absolute value of the error totaled at less than 5. Using the better model (near point) we tested that in our 7^{th} trial we would only have (0.86) M&M's left. Because the 7^{th} trial resulted in a quantity less than (1), we would run out M&Ms after the 7^{th} trial.

However, no matter how many trials we run with either function, the number of M&Ms will never be exactly (0). We tested this by using an "x" value of (100) to predict the result of (100) trials, but both functions returned an output that was larger than (0).

Figure 13: Analysis and summary of graph and data related to exponential growth and decay lab.

---

analysis and summary that the students submitted after being asked to graph the data, create two trend curves using different data points, and explain which model was better. A final question asked the students to explain when the prediction states there will be a value of zero. Students were using data that they had to create, inherently adding a sense of connection to the process. The responses that were provided by the observed group show knowledge beyond a simple calculation. This group offered a rationale for their reasoning and, in the process, demonstrated the ability to make sense of exponential decay that was not evident in the procedural knowledge assessment.

The concerns of the instructor utilizing a face-to-face instructional method was that instruction tended to be teacher-centered with the focus being on what and how the teacher chooses to teach. In the blended instructional format content and available assistance were targeted and individualized compared to the face-to-face model. The students are at the center of the instructional process throughout the delivery of the content. Course material for this particular course was designed such that students apply concepts to their personal and immediate learning situations. Lab questions and situational scenarios were to be answered based upon the individual experiences of each student. In other words, each student had a unique interaction with the concepts presented throughout the course activities.

Analysis Related to Research Question 3

How do student attitudes toward mathematics evolve in a blended instruction format?

To answer this research question, the researcher focused on two concerns: student attitude towards mathematics and student attitude towards blended instruction. The purpose of this study was to parse the two, sometimes related, objects of attitude (mathematics and blended instruction) through triangulation of data acquired via inventories, interviews, and field notes from observations.

Attitude Toward Mathematics and the ATMI

The purpose of Tapia and Marsh (2004) developing the ATMI was to measure and "address factors reported to be important in research" (p. 16). The ATMI measured confidence, enjoyment, motivation, and value.

For research question three, initial attitude scores were collected from students enrolled in a pre-calculus course in the second week of the spring 2013 semester; the ATMI was then administered a second time during the 13^{th} week of classes to determine an end-of-semester attitude score. Descriptive statistics were calculated for each survey statement including mean, standard deviation, and mean difference. There will also be further discussion about the matched pairs ANOVA analysis run on the data collected resulting in corresponding *t*-values and *p*-values. Composite attitudinal scores were then calculated for each of the four factors of the ATMI: enjoyment of mathematics, motivation for mathematics, self-confidence in mathematics, and value of mathematics.

Descriptive statistics were calculated for each survey subcategory. Within the ATMI, 10 statements address enjoyment, 5 address motivation, 15 address self-confidence, and 10 address value. The average per-item scores range from one to five, with one indicating the most negative attitudinal response ("strongly disagree") and five indicating the most positive attitudinal response ("strongly agree"). Using the statistical software program JMP® Pro 10.0, a Cronbach's alpha was calculated to determine reliability; it was evaluated to be .80, indicating a strong internal consistency. Cronbach's alpha reliability coefficient normally ranges between 0 and 1. However, there is actually no lower limit to the coefficient. The closer Cronbach's alpha coefficient is to 1.0, the greater the internal consistency of the items in the scale. George and Mallery (2003) provided the following guidelines: "> .9 – Excellent, > .8 – Good, > .7 – Acceptable, > .6 – Questionable, > .5 – Poor, and < .5 – Unacceptable" (p. 231). An alpha of .8 is a reasonable goal for internal consistency.

Having retained four subscales, Cronbach's alpha was calculated to estimate internal consistency and reliability of the scores on the factors. The enjoyment factor contains 10 items with an initial mean of 2.88 (*SD* = 0.98) and end-of-semester mean of 2.98 (*SD* = 1.00). The scores on these items produced a Cronbach alpha of .80. The motivation factor contains five items with an initial mean of 2.65 (*SD* = 0.93) and end-of-semester mean of 2.72 (*SD* = 0.98). These items, when scored and summed, produced a Cronbach alpha of .70. The self-confidence factor contains 15 items with an initial mean of 3.09 (*SD* = 0.92) and end-of-semester mean of 3.15 (*SD* = 0.86). The scores for these items had a Cronbach alpha of .66. The value of mathematics factor contains 10 items with an initial mean of 3.70 (*SD* = 0.90) and end-of-semester mean of 3.58 (*SD* = 0.83). These items produced a Cronbach alpha of .62. These data indicated a high level of reliability of the scores on the subscales. The Pearson correlation coefficient was used for initial to end-of-semester reliability in the follow-up of the 40-item inventory, administered to the 30 students taking the survey. The coefficient for the composite scale was .67, and coefficients for the individual factors were as follows: Enjoyment .67; Motivation .53; Self-Confidence .66; and Value .62. These data indicated a strong positive relationship and that the scores on the inventory and the individual factors are stable over time.

Table 6

t-test Results for Initial and End-of-Semester Change Scores of the ATMI

	Initial Mean	End-of-Semester Mean	Change Score	*t*-value	*p*-value
Enjoyment	2.88	2.98	0.10	2.14	0.0328*
Motivation	2.65	2.72	0.07	0.98	0.3307
Self-Confidence	3.09	3.15	0.06	1.60	0.1103
Value	3.70	3.58	-0.12	-2.76	0.0062*
Composite	3.14	3.16	0.02	1.10	0.2716

Note. Per factor score range from 1 to 5, with 1 representing the most negative attitude and 5 representing the most positive.
* significant at $p < 0.05$

The ATMI has an unequal number of statements for each attitudinal factor leading to an average score to be calculated for each factor in order to make comparisons. Average scores for each component are found in Table 6. The initial composite survey scores of participants were highest for the attitude category of value, with a mean score of 3.70. The lowest initial composite survey scores were for the attitude category motivation, with a mean score of 2.65.

For this study, the ATMI was administered on two separate occasions - during the second week of classes to determine an initial attitude score and during the 13^{th} week of classes to determine an end-of-semester attitude score. The change scores are not independent of each other and are determined by subtracting the initial attitude scores from the corresponding end-of-semester scores for each factor of the ATMI. The sample size of students who participated in the end-of-semester survey was 30. Descriptive statistics were computed for change scores and are listed in Appendix B.

The initial composite attitude scores were subtracted from the end-of-semester composite attitude scores to examine how the composite attitude scores changed over the course of the semester. Table 6 displays a summary of the change scores in which the only factor resulting in negative change scores is the factor of value, with a -0.12 change. All other factors had positive changes over the semester, including the composite attitude score. The initial composite attitude score for the entire student sample was 3.14, and the end-of-semester composite attitude score was 3.16, indicating a slight increase in mean attitude score of 0.02. This indicates that the average overall composite attitudes of students in the sample had a positive change over the spring semester.

A *t*-test was conducted using composite survey scores and end-of-semester scores to determine if there was a significant change in attitude during the semester. A significance level of .05 was used to determine whether the results were significant. The *t*-test results are also shown in Table 6.

A matched pairs analysis of the initial and end-of-semester ATMI responses was used on all of the statements and is reported according to each subcategory. Appendix B lists the matched pairs statistical analysis using the initial and end-of-semester ATMI for each individual survey item per factor, and Appendix C shows the percentage per each statement, both initial and end-of-semester, from the ATMI survey.

In the next few sections, there will be a restatement of the definitions for each of the factors of the ATMI provided by the authors of the instrument in addition to describing and explaining the results of the analysis of quantitative and qualitative data collected in regards to each of the factors from the ATMI. For each factor, general statistical observations will be followed with support from interviews with the focus group of students.

Enjoyment of Mathematics. The ANOVA results reveal a statistically significant difference (increase) in change score for the enjoyment factor (p = .0328). Enjoyment measures the level to which students appreciate attending mathematics classes (Tapia & Marsh, 2004). This indicates that the students in this study have a significant difference in their composite initial attitude scores and their composite end-of-semester scores for enjoyment of mathematics.

The quantitative results collected in this study are also supported by one of the emerging themes identified in researcher observations and interviews. The researcher observed one group of four students on multiple occasions during the instances of students working in groups with the purpose of applying what had been discussed in class in the context of lab activities.

Through dialogue within groups and during interviews, the students in this study commented that they had an increase in general enjoyment of mathematics in the blended instruction format. All of the students interviewed mentioned in subsequent discussions, that they have taken purely online courses at Public University as well as face-to-face courses. What follows are different, yet related responses given by the four students.

> Student E: Problem solving makes me pursue math and figure out the answer. When I understand what we are learning in math I enjoy being able to answer the questions. (sic)
>
> Student B: As we talk to each other, we come up with a possible process. That makes me enjoy math.
>
> Student M: I like working on the group stuff. It is exciting when we all put our ideas together and try to find a solution and it feels good when we all do well. (sic)
>
> Student A: Working together has helped me and some peers work through problems together, then use those skills later on assessments.

It is worth noting that each of the students had a similar response, though they were not interviewed simultaneously, reinforcing a common theme of appreciation for the design of the course and the opportunity to learn interactively.

To help make a determination as to what contributes to the change in attitude toward mathematics in relation to enjoyment, this researcher analyzed the 10 individual statements associated with this subcategory. In the enjoyment factor, there was a statistically significant difference (p = .0007) when comparing responses between initial and end-of-semester ATMI to statement 30, *I am happier in a math class than in any other class*. This overall sense of enjoyment was also supported by the responses given during the student interviews in which students indicated they were comfortable with the instructional format.

Statement 30 also had the lowest initial mean score (1.97) and an end-of-semester mean score (2.40) for all statements in the enjoyment factor. The highest scoring item in this subcategory, statement 3, *I get a great deal of satisfaction out of solving a mathematics problem*, had an initial mean of 3.50 and an end-of-semester mean of 3.53.

This indicates a large number of students feel satisfaction from solving mathematics problems even though there is not much growth during the semester. These more specific analyses also support the statistically significant improvement in enjoyment of mathematics in the blended instructional format.

The enjoyment factor that students exhibit was also investigated in relation to the online management system used to assist acquisition of procedural knowledge. This aspect was not part of the ATMI, but the researcher did ask the four students he observed and interviewed questions related to their opinions regarding WebAssign and how it affected their procedural knowledge acquisition and general understanding of the course content.

Motivation for Mathematics. There were no statistically significant differences for the motivation factor when comparing responses to the five statements in this subcategory. Motivation rates the desire, interest, and general persistence a student has for enrolling in additional mathematics classes (Tapia & Marsh, 2004). Statement 33, *I plan to take as much mathematics as I can during my education*, did have a p-value of .0698 when the analysis was run. The lowest scoring item in this factor was statement 33, which had an initial mean score of 2.07 and an end-of-semester mean score of 2.30. Although it is not significant, the statement analysis does indicate an increase in the motivation factor of attitude. The responses given during interviews and notes gathered from observations also indicated a reluctance of many of the pre-calculus students to take more than the required amount of mathematics while they are enrolled in school.

Self-Confidence in Mathematics. When students gain confidence in their mathematical ability, they may be willing to attempt mathematics perceived as being out of their range of understanding. Self-confidence determines to what extent students view their overall performance in mathematics (Tapia & Marsh, 2004). The design of a blended instruction class has helped achieve greater understanding, as students advance their knowledge acquisition through interacting with others and watching each other dissect problems. The students in the blended instruction environment came to realize that aspects of the course are manageable and approachable, by thinking through and explaining multiple parts of projects. Comments from two students summarized the improvements in self-confidence:

> Student B: I am much more confident working in groups. Math is much more enjoyable and anxiety goes down. Big ups. Being able to see many example makes me much more confident in my abilities. I feel like I am learning, which is valuable. (sic)

> Student E: Working with others encourages me to want to participate in math more. The more we work on problem solving, the more I feel I am understanding it.

The feelings expressed by Student B are powerful – this student felt as if they were learning and realized the importance of what was happening. Given that the students enrolled in this course were not mathematics majors, being able to appreciate mathematics was vital to student success and knowledge acquisition. Similarly, Student E mentioned a sense of understanding especially after persistent problem solving situations. There could have been the potential for student frustration with open-ended problems requiring analytical thinking; yet, at least for the group observed, students were not frustrated with the subject and felt as if they did comprehend how to make sense of the activities.

In the self-confidence factor, there was one statistically significant difference when comparing responses to the initial 15 statements in this subcategory to the end-of-semester responses. That statistically significant (p = .0190) statement was statement 9, *Mathematics is one of my most dreaded subjects,* which saw an increase in mean score from an initial 2.50 to an end-of-semester mean score of 2.87. Following the recommendation of the author through email correspondence, scoring for this item was reversed and anchors of 1: *strongly agree*, 2: *agree*, 3: *neutral*, 4: *disagree*, and 5: *strongly disagree* were used. The interpretation of these results therefore indicate the change in responses for this survey response is an improvement in self-confidence in that the response of students moved from *agree* towards *neutral*. The analysis of the items in this category indicated that students were nervous and confused in mathematics courses. When asked, the four students observed and interviewed mentioned that they did not dread the class. Rather, they expected to do "fairly well" and had self-assurance.

Value of Mathematics. The ANOVA results displayed in Table 4 reveal a statistically significant difference in change score for the value factor (p = .0062). Value gauges how much a student deems mathematics as being useful, relevant, and possessing worth in relation to their personal and professional lives (Tapia & Marsh, 2004). The results of this study indicate that the students in this study had a significant difference in their composite initial attitude scores and their composite end-of-semester scores toward the value of mathematics and that this difference was significantly negative.

The results of the value subcategory ANOVA analysis are also not supported by the responses provided by the students observed for this study. Students were exposed to more applications of mathematics in the class utilizing a blended instruction format versus the primarily rote or procedural knowledge approach provided in face-to-face classroom design. As a result, there was a sense of value for mathematics instilled in the students as they realized the relevance of the content and applied their knowledge beyond the current classroom.

> Through his lecture, our teacher will give us examples, like real-world examples. We got examples that had to do with business and finance, and I am a business major, so I like hearing those examples in areas that I will be using elsewhere. This class is applying math to real things. This class is the answer to the question of, 'When are we ever going to use this?' and it is giving us examples of real-world math applications. (sic)

The students were able to realize the impact that mathematics could have on their personal and professional/academic lives. They were experiencing an understanding of mathematics in conjunction with applying the content to their experiences outside of the classroom.

An indication that many students in this sample recognize some value of mathematics is that the lowest mean score for all items in this category, either initial or end-of-semester, is above the neutral value of 3.00; there is a positive response to all statements in this category. There was a statistically significant (p = .0014) difference in responses between the initial and end-of-semester ATMI for statement 39, *A strong math* *background could help me in my professional life*. The analysis showed a negative statistically significant difference, although the end-of-semester mean score of 3.33 was still well above neutral.

The interviews with students indicated a positive feeling related to the value of mathematics factor, again contradicting the overall results of the class inventory. The overall analysis of field notes and interview responses to the items in this category suggest that the students in this sample wanted to develop their mathematical skills and believed that mathematics helps acquire knowledge and improve their minds.

Students were further motivated when they engaged in tasks that they perceived as preparing them for the experiences outside the classroom. They understood that effort now has a benefit later. Transfer of learning occurs when learning tasks are structurally similar to tasks that students will encounter.

While attitude toward the subject of mathematics is of importance to this study, there is another area of emphasis to which student attitude can be directed – attitude toward blended instruction.

Attitude Toward Blended Instruction

When asked in an open-ended question related to which aspect of the course helped them the most, the blended students mentioned the class format. In assessing the blended instruction model, the students interviewed for this study emphasized a few factors as an advantage: fewer class meetings in the physical classroom space, to the flexibility that the online component offers, and meetings in small groups. The availability to work anywhere allows students to practice and review whenever it is convenient for them. The combination of small group discussions in class and online content was mentioned a contributing to their success in the course. In addition, having access to the course material online while still being able to discuss it face-to-face with their instructor or peers also helped them acquire information.

> It is great for me to work when I have time.
>
> The online part is more helpful than just the lecture alone. But I would not like it completely online because at least now I have somewhere to go and get introduced to [the material] and then experience it after. I prefer a little more online.
>
> I [have taken] online courses but I just have found that I don't learn as much from them. I memorize the information to get it done and then it is done and that information is out of my head, because you just do what you have to do to get through it and get a grade. I have taken courses that have a high degree of interaction with the students and I have learned more in those classes because you are applying the information and not just taking quizzes and tests. You are interacting with people and applying it.

This approach provides the opportunity for students to focus on mathematics when the student can function most productively.

Emerging from observations and interviews with students was the perception of students related to the advantages of the overall blended instruction experience. The students appreciated the combination of a face-to-face (traditional, teacher-centered) classroom with that of a purely online course. A summative statement from one of the student interviews illustrates this point:

> Homework online is good and then having lectures in person helps. I enjoy the practice part to be online more than it all online. I have had all online courses in the past and it wasn't for me. Hybrid classes are better

> for me because I can see and listen to the teacher and get the content and then use the online part to apply what I have learned. (sic)

The online management system was, at times, well received by the students interviewed. Those who expressed a preference toward online learning complemented the online component for its ease of use.

> I am really starting to get the hang of learning off the computer. Being able to have multiple attempts helps me with my confidence and gives me the opportunity to do my very best.
>
> I like how, the questions, if there is one question but it has five parts, it will walk you through it just by breaking the question apart, when you are first learning something. It will break the question into steps instead of just asking for the overall answer to maybe a very long problem. It will tell you if just that one part of the answer you gave is correct or not. And, if it is, I will just go on and keep going. I like that I can kind of walk through a process and get confirmation as I go.
>
> I like it when there is a video of another teacher going through a very similar example. He doesn't give us the answers, which is smart or else everyone would just go to those videos to get the answers. But, he walks us through the process to something we don't know and we apply it.

Although the course management system offered immediate feedback, a feature appreciated by all students interviewed,

> It is nice to get the homework problems right and get instant feedback to let me know that I am comprehending the concepts. Seeing the concepts in more than one way provides better learning for me.

most students were not as satisfied with the lack of personal attention when they experienced difficulty understanding the course content and there was a delay in response from instructors.

> I prefer having the lecture in person, so I enjoy the hybrid course.
>
> I get kind of nervous not being able to directly ask questions. It is nice to ask questions face-to-face.

For reasons such as this, students appreciated the face-to-face contact as they realized they had opportunities to ask direct questions.

Another component of the blended instruction course design regarded as positive was the collaborative learning environment. Students worked on face-to-face student-centered labs and assignments in groups. These grouping offered students the chance to experience problems with their peers and get help from their colleagues.

> I feel like what we are learning is fun and I understand it.
>
> The flexibility of the online lessons combined with the small discussion groups made the course successful.
>
> I think that what makes this class successful is that it is blended. Having online lessons and in-class participation is good for my schedule.

The interactions between group members develop understandings of knowledge and allowed students to gauge their comprehension based on perception of other students.

The blended instruction environment developed a sense of independence among the students interviewed. The students expressed a willingness to be persistent in their work since they had confidence in their ability. Insight provided by one student was, "By helping me comprehend the math more, I enjoyed it more and had good confidence." With the immediacy of feedback available, the students were able to work on assignments for longer periods of time before seeking assistance from the instructor. They began to trust their abilities and interpretations.

By developing self-discipline, the blended instruction model encouraged students to routinely engage in the variety of assignments. The students interviewed mentioned that they occasionally had a false sense of achievement in the face-to-face classroom because they were mimicking what they had been taught, without being critical thinkers. The notion that merely showing up to class and taking notes was "good enough" was not present in the blended instruction course. Students had group members to whom they were responsible, along with being responsible to themselves.

The comments made by students were not all positive. The major criticism of the blended instruction environment was related to the technical problems associated with the course management system. During the interviews, students stated that a major hindrance to acquiring knowledge resulted from receiving error messages while posting solutions via the course management system as well as computer server (reliability) issues.

> The online system aggravates me; it is frustrating to get the exact answers.
>
> There are many grading errors, which must be solved in this online site. It marks problems wrong which teachers themselves would mark correct.

This is a reflection on the precision required of the online management system utilized in this blended instruction course. Errors related to incorrect variables, which may be overlooked by a human instructor reviewing submissions, are often classified as incorrect by a program, as are other instances of place-value accuracy and form (decimal or fraction) of responses entered by students. Another common complaint was that the online component put too much responsibility on the student as they became partially accountable for their learning in addition to an independent learning requirement.

> I sometimes felt overwhelmed by all of the different places to go for class needs. It is easy to forget things.
>
> Because some of the stuff [class] was online, it made it easy to forget about it and avoid it. I didn't like how everything was on me to learn.

There were also conflicts with various operating systems that the students were using on their computers. There is a delicate balance between the advantages and disadvantages of a blended instruction environment, which at times is dependent upon technology, in order to ultimately help students understand mathematics. Some of the criticism was directed at WebAssign itself because of system downtimes. The various levels of computer experience that could make the online portion difficult also influence student attitude.

Summary

This chapter summarized the findings of the research study and results of the statistical tests used to answer the research questions. Descriptive statistics were calculated to determine the initial composite attitudes of students, as were attitudinal change scores.

The average initial composite attitude scores were above the mean of 3.0 and may indicate that many students had a positive attitude towards mathematics before enrolling in the course. When examining the association between change scores and the factors of the ATMI, a statistically significant association was found in change scores in the ATMI factors of enjoyment and value. All other change scores for the factors of motivation and self-confidence were found to be non-significant.

ANOVA tests were conducted to answer the research question regarding knowledge acquisition in terms of final examination grade and final grade for the course. The results of the one-way between subjects ANOVA test revealed the mean grades for common final examinations for students in courses utilizing the two methods of instruction were significantly different. The difference in mean grades between face-to-face and blended instruction courses were shown to be significant in an additional one-way between subjects ANOVA test.

The interviews and subsequent comments from students included in the study emphasized the importance of having both face-to-face interactions and technology. Perhaps blended instruction matched the stated preferences, although the interviews and responses did not specify such an alternative. Student attitude rests on other factors as well – the enthusiasm and acceptance for the electronic resources available as part of the blended instruction model was highly regarded.

Data analysis revealed that students were quite satisfied with the overall learning experience. Although the satisfaction level of students was not necessarily associated with achievement, satisfied students seemed to have a more positive attitude. In addition, results indicated that students were satisfied with the design of the blended instruction course and the interactions within the course structure.

CHAPTER 6: SUMMARY, DISCUSSION, RECOMMENDATIONS, AND CONCLUSIONS

The previous chapter summarized the findings and results of the analyses used to answer the research questions. This chapter will provide a summary of the study as well as a summary of the findings and conclusions. Recommendations and critical reflections will also be included.

Summary of the Study

By using a mixed-methods design, the researcher assessed potential benefits of using a blended instruction approach to course design in an introductory mathematics course. The participants in the study were students enrolled in an introductory mathematics course taught in a blended instruction format and a face-to-face design. Once the semester commenced, the students in the blended instruction course completed an Attitudes Toward Mathematics Inventory to establish their perceptions in their abilities in the mathematics classroom utilizing a blended instruction format. The ATMI established attitudes related to enjoyment, motivation, self-confidence, and value for mathematics. Portions of these students were used in group observations and interviews in order to allow them to expand on their feelings and experiences in the blended instruction classroom. Other sources of data included submission of student assessments and researcher field notes.

This study sought to discover if student attitudes and performances were affected by a blended instruction format. The qualitative measures used in this study offered the opportunity for students to give detailed explanations and statements related to their evaluation of the course. The quantitative data provided statistics that supported the qualitative finding that there was a change in attitude.

A general analysis of the initial composite scores indicated that, as a collective, the students responding to the ATMI had a somewhat positive attitude towards mathematics prior to their enrollment in Math 112. The factors of enjoyment of mathematics and value of mathematics had a statistically significant association when initial responses on the ATMI were compared to the responses at the end of the semester for both factors. The other ATMI factors, motivation for mathematics and self-confidence in mathematics, had non-significant change scores.

In addition to comparison response scores on the ATMI, statistically appropriate ANOVA tests were used to answer the research question related to knowledge acquisition when the final examination and final course grade were used in the comparison. The final examination used in the face-to-face instruction course was identical to the examination administered in the course utilizing blended instruction. The one-way between subjects ANOVA analysis used for this study showed significantly different mean scores for the common final examination. Furthermore, an additional one-way between subjects ANOVA test analysis revealed a significant difference when comparing mean final course grades between face-to-face and blended instruction courses.

The general feeling of students toward the blended instructional environment, based on interview and observation analysis, was that of satisfaction. This satisfaction, although not directly associated with student achievement, does have some residual effects of improving attitude and increase their propensity to complete instructional goals. The typical feeling of the students interviewed indicated they were in favor of the design of the blended learning course.

In delving into the attitudes of students in a blended instruction course, the interviews conducted with the students highlighted the desire to integrate face-to-face interactions and technology as part of the overall instructional design. It may be that the blended instruction format meets the stated preferences of the students, however, the responses gathered during student interviews did not specifically mention this alternative. Other factors influencing the attitude of students included student disposition, both favorable and displeased, towards the technology integrated in the class.

Discussion of Findings

Students in this research study indicated through interviews they felt more confident in their mathematical abilities. This was attributed to the interactions occurring within the groups brought forth through the blended instruction design of the course. The students stated that working with others and acquiring suggestions from their classmates enhanced their understanding of the concepts being discussed. A critical part of constructing knowledge is the social interactions because it is during those interactions that the formation of ideas takes place. Prominent advocates of the social component being vital to knowledge building were Koehler & Grouws (1992) when they stated that students need not passively absorb information, but rather they should be active in acquiring knowledge.

The researcher witnessed social interactions frequently occurring within the collaborative lab assignments. Subsequent interviews with students provided the opportunity for students to state that when they were in a blended instruction group setting, the design of the lab assignments allowed them to learn from what their group members could demonstrate while teaching their colleagues strategies they themselves had acquired. The major benefit of the blended instruction design perceived by the students was the ability to share thoughts related to problem solving strategies. While functioning within the group dynamic, students also developed individual thinking and reasoning skills, as they needed to communicate their explanations to all group members. The result was that students expressed an understanding of the content as well as an increased persistence in completing extended tasks related to mathematics. The observations from this research are consistent with other investigations stating that group work has a positive effect on student learning (Curtis, 2006; Deeds, Wood, Callen, & Allen, 1999; Grouws & Cebulla, 2000; Hill, Mabrouk, & Roberts, 2003; Panitz, 1999; Rumsey, 1999).

This study was chosen because the researcher and cooperating instructor wanted to see if incorporating a blended instruction design would influence student attitude toward mathematics positively. Over the course of one semester, a blended instruction approach was implemented through course design along with implementing various tasks and projects. Through observations and conversations, the researcher has determined:

1. Introductory mathematics courses should continue to incorporate focused discussion on mathematical content as such conversations encourage conversations among all students and improve the ability of students to carry on academic conversations related to mathematics.
2. When the students are presented with face-to-face student-centered labs and problem solving scenarios, the blended learning approach provides the opportunity to work in groups, discuss the situation, and stay on task. Connections are made to previous knowledge without the instructor having a major influence. Furthermore, there is a residual effect on increased confidence to work on individual assignments or assessments.

An increase in self-assurance was expressed by students and attributed to working with other classmates in order to discuss the math content and processes, along with a feeling of becoming comfortable with the mathematics they encountered. Some students noted homework and assessments were not as difficult to complete. Despite self-confidence not being statistically significant, the qualitative analysis showed that the students noted their confidence had improved through problem solving and the general design of the course. It may be possible that students need time beyond that of one semester to sufficiently familiarize them with the blended instruction environment such that self-confidence increases become statistically significant.

Similarly, students might also need additional time experiencing mathematics in a blended instruction environment in order to develop a sense of value for mathematics. Despite not expanding on the connections of the mathematics experienced in the classroom to personal and continued academic development, the students being observed did express awareness. Repeated comments from students related to various factors of attitude, except for motivation. In only a few instances did a student comment on the connections between their personal experiences and the classroom mathematics they were learning. This may be a result of the focus of the students being on the process instead of thinking about future pursuits related to mathematics. Although the blended instruction strategies were appreciated, no students mentioned that the strategies motivated them enough to learn additional mathematics. In the interview groups, most of the students wanted to complete their math course; for some it was their final mathematics requirement. The students enjoyed the variety of learning methods making the class palatable, but they did not aspire to take more mathematics courses.

Throughout the semester, student reactions toward how the course was being taught and the collaborative and problem solving scenarios varied. Some students were initially apprehensive toward the blended instruction methods utilized in the classroom. During the progression of the semester, there were different reactions as students commented they were less anxious about the mathematics and the course. The various forms of assessments (homework, projects, quizzes, exams) were described as being easier after the students had worked in groups. The collaborative experience and general blended instruction environment offered the students occasions to comprehend the mathematics through multiple representations and methods in order to complete the problem situation they were assigned. The blended instruction classroom allowed students to contribute to a mathematical discussion. This was also witnessed in the collaborative face-to-face student-centered labs in which students expressed they were more comfortable solving problems, and, as a result, were less anxious (more confident) toward working with mathematics in general.

The blended instruction design also allowed classroom discussion to be less contrived and in a more natural setting, proving effective among the students observed. The researcher was able to witness students verbalize the thought processes used in order to communicate their ideas and assist group members in constructing knowledge. While developing problem-solving skills and clarifying misunderstandings, students were communicating in a way that increased their comfort with mathematics. As discussions occurred, the students stated they understood concepts and could remove uncertainty about other apprehensions regarding mathematics. The findings of this study relate the improvement of student disposition towards mathematics to the development of confidence with mathematical topics, a result of talking about mathematics and gaining an understanding (Curtis, 2006; Fennema & Sherman, 1976).

The analysis of the factors of the ATMI were mixed in regards to significance. This study found that for enjoyment of mathematics there was a statistically significant positive change in student attitudes and a statistically significant negative change in value of mathematics. Although self-confidence did not have a statistically significant change for student attitudes, throughout the interviews, students mentioned the increase in poise with mathematics because of the design of the course and discourse with others. Most students indicated the interactions within the group aided in their ability to solve mathematical problems. Through these group conversations, students were able to communicate about mathematics with other people rather than passively writing on a piece of paper. Despite the appearance of assuredness in their abilities, students did not express a desire to take additional mathematics courses.

Recommendations for Future Studies

There is not a large quantity of research on blended instruction as it is a recent innovation in higher education with limited implementation; more research is needed. Future research should compare some combination of face-to-face, online, and blended instructional methods to provide additional insight into the strengths and weakness of each method of instruction. A future study could compare introductory and upper-level mathematics courses in blended formats. Additional variables could include the age, ethnicity, gender, and/or socio-economic status of the students to determine if there is greater success achieved in blended instruction of these different segments of the student population. The researcher recommends that future studies about student attitudes at the collegiate level should address the following questions:

1. Is there a difference in student attitudes towards mathematics based on age, gender, or type of learner?
2. To what extent does the instructor have an impact on student attitude towards mathematics?

3. Is student attitude toward mathematics impacted by a blended instruction design in advanced mathematics courses?
4. What influences are there on acquisition of procedural knowledge when comparing a blended instructional format to that of a face-to-face instructional format?

Conclusions

The purpose of this research was to address potential benefits of utilizing a blended instruction approach towards teaching mathematics at the collegiate level.

This study addressed the need to change student attitudes towards mathematics through implementation of a blended instruction approach to course design. National reports urge educators to become aware of the lack of motivation students have for mathematics. Instructors at the collegiate level need to be cognizant of student attitudes and the impact student attitude has on performance in post-secondary mathematics courses. If college and university students maintain negative attitudes toward mathematics, our society will witness a decrease in mathematics and related majors resulting in a citizenry with insignificant skills.

Using a variety of surveys, interviews, observations, and evaluation tools, this research successfully highlights that there are benefits to using a blended instruction approach in the mathematics classroom. The analysis of the data indicates common themes on improving the attitude of students toward mathematics. The triangulation of data enhanced the findings for this research.

This study recognized that a blended instruction approach to course design improved student confidence in doing mathematics at an introductory level. Students were less anxious working on assigned problems and assessments as they familiarized themselves with the design and instructional strategies. In addition, students were more engaged in discussions as the semester progressed; students experienced the benefits of communicating with group members. The results also indicate that students enrolled in a blended instruction course are more likely to perceive that the classroom environment promotes interactions and they are more likely to be involved in classroom discussions and activities.

The recommendation of this study is that instructors at the collegiate level become aware of the impact student attitude has in the classroom. The researcher recommends that college instructors should become more aware of how blended instruction strategies can be introduced to the courses. This study summarizes the benefits and provides suggestions for course design consideration. The results of this research provide some support for the theory that attitudes toward mathematics may influence performance in mathematics courses. The evidence was not overwhelming, but it appears strong enough to warrant further research to examine the relationship between attitudes and performance in a blended instruction course to determine whether the course design may improve the performance of students, especially for those students with negative attitudes toward mathematics.

The content and subject matter of a course may play a more significant role in student attitude and success in a blended instruction format. Those promoting a blended instruction design in mathematics education should recognize that it may be more challenging for some students, especially at the introductory level, and require better academic support for student and faculty in order to achieve the desired outcomes. While this study supports blended instruction as offering “the best of both worlds” in some respects, caution must be taken to realize the mix matters when attempting to develop effective learning environments.

The results of this study support the theory that attitudes toward mathematics may impact acquisition of knowledge in mathematics courses. The evidence appears strong enough to warrant continued research to further examine the relationship between attitudes and acquisition of knowledge to determine whether intervention for students with negative attitudes toward mathematics could improve performance.

What the researcher has learned is that there is no single recipe for designing a successful blended course. The optimal blend of face-to-face and online learning components may be different based on discipline. While continued research and case studies will continue to be essential resources for those designing classroom methods, instructors will have to re-evaluate their courses in terms of effectiveness. Ultimately, developing a course design that most effectively meets the needs of as many students as possible should remain the goal of any classroom design.

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Appendix A

Attitudes Toward Mathematics Inventory

Student # __________

ATTITUDES TOWARD MATHEMATICS INVENTORY

Directions: This inventory consists of statements about your attitude toward mathematics. There are no correct or incorrect responses. Read each item carefully. Please think about how you fell about each item. Place an X in the box that most closely corresponds to how the statements best describes your feelings. Use the following response scale to respond to each item.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. Mathematics is a very worthwhile and necessary subject.					
2. I want to develop my mathematical skills.					
3. I get a great deal of satisfaction out of solving a mathematics problem.					
4. Mathematics helps develop the mind and teaches a person to think.					
5. Mathematics is important in everyday life.					
6. Mathematics is one of the most important subjects for people to study.					
7. College math courses would be very helpful no matter what I decide to study.					
8. I can think of many ways that I use math outside of school.					
9. Mathematics is one of my most dreaded subjects.					
10. My mind goes blank and I am unable to think clearly when working with mathematics.					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
11. Studying mathematics makes me feel nervous.					
12. Mathematics makes me feel uncomfortable.					
13. I am always under a terrible strain in a math class.					
14. When I hear the word mathematics, I have a feeling of dislike.					
15. It makes me nervous to even think about having to do a mathematics problem.					
16. Mathematics does not scare me at all.					
17. I have a lot of self-confidence when it comes to mathematics.					
18. I am able to solve mathematics problems without too much difficulty.					
19. I expect to do fairly well in any math class I take.					
20. I am always confused in my mathematics class.					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
21. I feel a sense of insecurity when attempting mathematics.					
22. I learn mathematics easily.					
23. I am confident that I could learn advanced mathematics.					
24. I have usually enjoyed studying mathematics in school.					
25. Mathematics is dull and boring.					
26. I like to solve new problems in mathematics.					
27. I would prefer to do an assignment in math than to write an essay.					
28. I would like to avoid using mathematics in college.					
29. I really like mathematics.					
30. I am happier in a math class than in any other class.					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
31. Mathematics is a very interesting subject.					
32. I am willing to take more than the required amount of mathematics.					
33. I plan to take as much mathematics as I can during my education.					
34. The challenge of math appeals to me.					
35. I think studying advanced mathematics is useful.					
36. I believe studying math helps me with problem solving in other areas.					
37. I am comfortable expressing my own ideas on how to look for solutions to a difficult problem in math.					
38. I am comfortable answering questions in math.					
39. A strong math background could help me in my professional life.					
40. I believe I am good at solving math problems.					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Appendix B

Matched Pairs Statistics per Statement from the Initial ATMI and End-of-Semester ATMI Survey

Item	M	SD	Mean Difference	t-value	p-value
Enjoyment of Mathematics					
Initial Q3	3.50	0.97	0.03	0.24	.8130
End-of-Semester Q3	3.53	0.90			
Initial Q24	2.53	0.94	0.24	1.49	.1473
End-of-Semester Q24	2.77	1.19			
Initial Q25[a]	2.83	0.87	0.24	1.76	.0897
End-of-Semester Q25[a]	3.07	1.08			
Initial Q26	2.93	0.87	0.14	1.00	.3256
End-of-Semester Q26	3.07	0.83			
Initial Q27	2.70	1.26	0.17	1.15	.2582
End-of-Semester Q27	2.87	1.31			
Initial Q29	2.60	0.81	0.07	0.44	.6624
End-of-Semester Q29	2.67	0.84			
Initial Q30	1.97	0.72	0.43	3.79	.0007*
End-of-Semester Q30	2.40	0.77			
Initial Q31	3.00	0.87	0.07	0.36	.7216
End-of-Semester Q31	3.07	1.01			
Initial Q37	3.37	0.72	-0.17	-1.31	.2018
End-of-Semester Q37	3.20	0.66			
Initial Q38	3.33	0.71	-0.20	-1.24	.2266
End-of-Semester Q38	3.13	0.86			
Motivation for Mathematics					
Initial Q23	3.20	0.89	-0.17	-0.93	.3619
End-of-Semester Q23	3.03	1.03			
Initial Q28[a]	2.87	1.01	-0.07	-0.36	.7216
End-of-Semester Q28[a]	2.80	0.92			
Initial Q32	2.40	0.81	0.20	1.24	.2266
End-of-Semester Q32	2.60	0.93			

Item	*M*	*SD*	Mean Difference	*t*-value	*p*-value
Motivation for Mathematics (continued)					
Initial Q33	2.07	0.69	0.23	1.88	.0698
End-of-Semester Q33	2.30	0.88			
Initial Q34	2.70	0.84	0.17	0.93	.3619
End-of-Semester Q34	2.87	1.01			
Self-Confidence in Mathematics					
Initial Q9[a]	2.50	1.04	0.37	2.48	.0190*
End-of-Semester Q9[a]	2.87	1.20			
Initial Q10[a]	3.20	0.96	0.00	0.00	1.0000
End-of-Semester Q10[a]	3.20	1.10			
Initial Q11[a]	3.03	0.67	-0.20	-1.36	.1841
End-of-Semester Q11[a]	2.83	0.87			
Initial Q12[a]	3.17	0.95	-0.07	-0.36	.7216
End-of-Semester Q12[a]	3.10	0.96			
Initial Q13[a]	3.13	1.14	0.04	0.21	.8315
End-of-Semester Q13[a]	3.17	1.12			
Initial Q14[a]	3.10	1.06	-0.03	-0.21	.8389
End-of-Semester Q14[a]	3.07	1.05			
Initial Q15[a]	3.63	0.81	-0.03	-0.25	.8012
End-of-Semester Q15[a]	3.60	0.86			
Initial Q16	2.90	0.92	-0.27	-1.97	.0579
End-of-Semester Q16	2.63	0.85			
Initial Q17	2.57	0.82	0.30	1.96	.0592
End-of-Semester Q17	2.87	0.78			
Initial Q18	2.93	0.64	0.00	0.00	1.0000
End-of-Semester Q18	2.93	0.69			
Initial Q19	3.43	0.77	-0.20	-1.99	.0563
End-of-Semester Q19	3.23	0.77			

Item	*M*	*SD*	Mean Difference	*t*-value	*p*-value
Self-Confidence in Mathematics (continued)					
Initial Q20[a]	3.27	0.83	-0.07	-0.42	.6772
End-of-Semester Q20[a]	3.20	0.96			
Initial Q21[a]	3.27	0.98	-0.04	-0.30	.7687
End-of-Semester Q21[a]	3.23	0.82			
Initial Q22	3.07	0.69	0.06	0.44	.6624
End-of-Semester Q22	3.13	0.90			
Initial Q40	3.20	0.81	-0.07	-0.42	.6772
End-of-Semester Q40	3.13	0.94			
Value of Mathematics					
Initial Q1	4.10	0.76	-0.13	-1.16	.2550
End-of-Semester Q1	3.97	0.72			
Initial Q2	4.00	0.69	-0.17	-1.54	.1340
End-of-Semester Q2	3.83	0.53			
Initial Q4	3.93	0.69	-0.10	-0.72	.4762
End-of-Semester Q4	3.83	0.59			
Initial Q5	3.87	0.86	-0.14	-1.00	.3256
End-of-Semester Q5	3.73	0.69			
Initial Q6	3.47	0.94	0.10	0.68	.5006
End-of-Semester Q6	3.57	0.86			
Initial Q7	3.70	1.18	-0.27	-1.55	.1328
End-of-Semester Q7	3.43	0.97			
Initial Q8	3.37	1.00	0.20	1.80	.0831
End-of-Semester Q8	3.57	0.82			
Initial Q35	3.17	0.79	-0.07	-0.47	.6453
End-of-Semester Q35	3.10	0.84			
Initial Q36	3.60	0.77	-0.13	-1.00	.3256
End-of-Semester Q36	3.47	0.94			

Item	*M*	*SD*	Mean Difference	*t*-value	*p*-value
Value of Mathematics (continued)					
Initial Q39	3.83	0.87	-0.50	-3.53	.0014*
End-of-Semester Q39	3.33	0.92			

Note. © Martha Tapia. ATMI used with permission of author. Scoring for most items uses anchors of 1: *strongly disagree*, 2: *disagree*, 3: *neutral*, 4: *agree*, and 5: *strongly agree*.

[a] Scoring for these items is reversed and uses anchors of 1: *strongly agree*, 2: *agree*, 3: *neutral*, 4: *disagree*, and 5: *strongly disagree*. Therefore, on all items, scores range from 1 to 5, with 1 indicating the most negative attitude and 5 indicating the most positive attitude.

* significant at $p < .05$

Appendix C

Percentage Per Response for the Initial and End-of-Semester ATMI Survey

Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Enjoyment of Mathematics					
Initial Q3	3.3	10.0	33.3	40.0	13.3
End-of-Semester Q3	0.0	10.0	43.3	30.0	16.7
Initial Q24	6.7	56.7	13.3	23.3	0.0
End-of-Semester Q24	13.3	40.0	6.7	36.7	3.3
Initial Q25[a]	3.3	36.7	33.3	26.7	0.0
End-of-Semester Q25[a]	3.3	36.7	16.7	36.7	6.7
Initial Q26	3.3	26.7	46.7	20.0	3.3
End-of-Semester Q26	3.3	20.0	43.4	33.3	0.0
Initial Q27	20.0	30.0	16.7	26.7	6.7
End-of-Semester Q27	16.7	30.0	13.3	30.0	10.0
Initial Q29	6.7	36.7	50.0	3.3	3.3
End-of-Semester Q29	10.0	26.7	50.0	13.3	0.0
Initial Q30	23.3	60.0	13.3	3.3	0.0
End-of-Semester Q30	10.0	46.7	36.7	6.7	0.0
Initial Q31	3.3	26.7	36.7	33.3	0.0
End-of-Semester Q31	6.7	20.0	40.0	26.7	6.7
Initial Q37	0.0	13.3	36.7	50.0	0.0
End-of-Semester Q37	0.0	13.3	53.3	33.3	0.0
Initial Q38	0.0	13.3	40.0	46.7	0.0
End-of-Semester Q38	3.3	20.0	36.7	40.0	0.0
Motivation for Mathematics					
Initial Q23	3.3	16.7	40.0	36.7	3.3
End-of-Semester Q23	10.0	16.7	36.7	33.3	3.3
Initial Q28[a]	6.7	33.3	30.0	26.7	3.3
End-of-Semester Q28[a]	10.0	23.3	43.4	23.3	0.0
Initial Q32	10.0	50.0	30.0	10.0	0.0
End-of-Semester Q32	10.0	40.0	30.0	20.0	0.0

Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Motivation for Mathematics (continued)					
Initial Q33	16.7	63.3	16.7	3.3	0.0
End-of-Semester Q33	16.7	46.7	26.7	10.0	0.0
Initial Q34	6.7	33.3	43.3	16.7	0.0
End-of-Semester Q34	10.0	26.7	30.0	33.3	0.0
Self-Confidence in Mathematics					
Initial Q9[a]	23.3	16.7	50.0	6.7	3.3
End-of-Semester Q9[a]	16.7	20.0	30.0	26.7	6.7
Initial Q10[a]	3.3	23.3	26.7	43.3	3.3
End-of-Semester Q10[a]	6.7	23.3	20.0	43.3	6.7
Initial Q11[a]	0.0	20.0	56.7	23.32	0.0
End-of-Semester Q11[a]	3.3	36.7	33.3	26.7	0.0
Initial Q12[a]	0.0	30.0	30.0	33.3	6.7
End-of-Semester Q12[a]	6.7	16.7	40.0	33.3	3.3
Initial Q13[a]	13.3	13.3	23.3	46.7	3.3
End-of-Semester Q13[a]	6.7	20.0	36.7	23.3	13.3
Initial Q14[a]	3.3	30.0	30.0	26.7	10.0
End-of-Semester Q14[a]	10.0	13.3	43.3	26.7	6.7
Initial Q15[a]	0.0	10.0	26.7	53.3	10.0
End-of-Semester Q15[a]	0.0	13.3	23.3	53.3	10.0
Initial Q16	3.3	33.3	36.7	23.3	3.3
End-of-Semester Q16	10.0	30.0	46.7	13.3	0.0
Initial Q17	6.7	43.3	36.7	13.3	0.0
End-of-Semester Q17	3.3	26.7	50.0	20.0	0.0
Initial Q18	0.0	23.3	60.0	16.7	0.0
End-of-Semester Q18	0.0	26.7	53.3	20.0	0.0
Initial Q19	0.0	16.7	23.3	60.0	0.0
End-of-Semester Q19	0.0	20.0	36.7	43.4	0.0

Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Self-Confidence in Mathematics (continued)					
Initial Q20[a]	3.3	16.7	40.0	36.7	3.3
End-of-Semester Q20[a]	3.3	20.0	36.7	33.3	6.7
Initial Q21[a]	0.0	33.3	10.0	53.3	3.3
End-of-Semester Q21[a]	0.0	20.0	40.0	36.7	3.3
Initial Q22	0.0	20.0	53.3	26.7	0.0
End-of-Semester Q22	3.3	20.0	40.0	33.3	3.3
Initial Q40	3.3	10.0	53.3	30.0	3.3
End-of-Semester Q40	3.3	20.0	43.3	26.7	6.7
Value of Mathematics					
Initial Q1	0.0	3.3	13.3	53.3	30.0
End-of-Semester Q1	0.0	3.3	16.7	60.0	20.0
Initial Q2	0.0	3.3	13.3	63.3	20.0
End-of-Semester Q2	0.0	0.0	23.3	70.0	6.7
Initial Q4	0.0	3.3	16.7	63.3	16.7
End-of-Semester Q4	0.0	3.3	16.7	73.3	6.7
Initial Q5	0.0	6.7	23.3	46.7	23.3
End-of-Semester Q5	0.0	6.7	20.0	66.7	6.7
Initial Q6	0.0	13.3	43.3	26.7	16.7
End-of-Semester Q6	0.0	10.0	36.7	40.0	13.3
Initial Q7	6.7	6.7	26.7	30.0	30.0
End-of-Semester Q7	0.0	20.0	30.0	36.7	13.3
Initial Q8	3.3	16.7	30.0	40.0	10.0
End-of-Semester Q8	0.0	16.7	13.3	66.7	3.3
Initial Q35	3.3	13.3	46.7	36.7	0.0
End-of-Semester Q35	3.3	20.0	40.0	36.7	0.0

Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Value of Mathematics (continued)					
Initial Q36	3.3	3.3	26.7	63.3	3.3
End-of-Semester Q36	3.3	10.0	33.3	43.4	10.0
Initial Q39	3.3	6.7	6.7	70.0	13.3
End-of-Semester Q39	0.0	26.7	16.7	53.3	3.3

Note. © Martha Tapia. ATMI used with permission of author. Scoring for most items uses anchors of 1: *strongly disagree*, 2: *disagree*, 3: *neutral*, 4: *agree*, and 5: *strongly agree*.

[a] Scoring for these items is reversed and uses anchors of 1: *strongly agree*, 2: *agree*, 3: *neutral*, 4: *disagree*, and 5: *strongly disagree*. Therefore, on all items, scores range from 1 to 5, with 1 indicating the most negative attitude and 5 indicating the most positive attitude.

Appendix D

Collaborative Assignments Used in Blended Instruction Groups

Math 112 – Modeling Lab (Linear Functions)

Background: This lab instructs students on how to create a simple $x - y$ scatter graph which can be used to find the linear relationship between two quantities. Each student will be assigned to a group for this exercise. The members of the group will obtain their data for the exercise as a collaborative unit and each member of the group will contribute in completing a lab report. Students will be required to graph the two quantities, one as a function of the other, then the graph will be analyzed to determine a linear fit of the data.

Student Directions

- Assemble into your assigned group at a computer connected to the Internet and access the **D2L** Web-site at (https://winona.ims.mnscu.edu/)
- Search for data, you must use a minimum of 15 data points. Once your group has found data, raise your hand and get approval from the instructor.
- Read the **Assignment Handout** provided by your instructor.
- Obtain a piece of electronic **graph paper** from the D2L or other website.
- Complete the assignment.

Assessment

Each of the bullets in the Assignment Handout can be used for assessment based on the following rubric.

Graph: [5 total points]

- Prepare an *x-y* scatter graph plot of the data.

Preparation of the graph will be scored as follows:

5 pts = All of the requirements listed below have been fulfilled.

- **a)** The independent and dependent variable is chosen correctly and plotted on the appropriate axis.
- **b)** The axes scale are appropriate for the data plotted. The scale uses the correct number of place holders provided by the original data table.
- **c)** Each axes are labeled or titled. The graph is given a title.
- **d)** All appropriate units are provided in parentheses near the axis label.
- **e)** The data points are presented correctly.

4 pts = Four of the five requirements have been fulfilled.
3 pts = Three of the five requirements have been fulfilled.
2 pts = Two of the five requirements have been fulfilled.
1 pts = One of the five requirements has been fulfilled.
0 pts = None of the requirements have been fulfilled.

Analyze the Graph: [10 total points]

- Analyze the graph. Based on your observations can you identify the linear relationship between the two variables plotted in the graph? If so, draw the trend line which adequately describes this relationship. **Derive the linear equation for the line that you drew**. Include all calculations necessary to derive this equation. Note: There is more than one correct answer here, use your "common sense" to find a line which closely describes the relationship.

Analysis of the graph will be scored as:

10 pts = All of the requirements listed below have been included.

- **a)** A trend line is drawn on the graph.
- **b)** The trend line is reasonably straight (use a straight edge).
- **c)** The position of the trend line indicates that the student has interpreted the results correctly.
- **d)** The slope of the line is calculated correctly.
- **e)** The calculation for the slope of the line is included.
- **f)** The *y* – intercept is reported correctly.
- **g)** The student has correctly reported the equation for the line, in slope-intercept form.
- **h)** Any calculations involved in finding the equation are included.
- **i)** All work shown is neatly organized.

Student Calculations: [5 total points]

- Use the linear equation (model) to calculate predictions at **known** data points and make comparisons. Show all your work.
- Use the equation to make predictions at **unknown** data points. Show all your work.

Application of the linear equation will be scored as:
5 pts = All of the requirements listed below have been fulfilled.

a) The linear equation used in the calculation is provided.
b) Three known data points are compared with those predicted by the equation.
c) A reasoned analysis is made of the above comparison.
d) A prediction calculation is included.
e) All calculations are correct.

4 pts = Four of the five requirements have been fulfilled.
3 pts = Three of the five requirements have been fulfilled.
2 pts = Two of the five requirements have been fulfilled.
1 pts = One of the five requirements has been fulfilled.
0 pts = None of the requirements have been fulfilled.

Student Summary: [10 total points]

- Summarize your findings. Do the data points acquired from your linear equation compare to the known data points? Based on your findings do you think a linear model is a "good" choice? How confident do you feel about your prediction? Explain.

Analysis of the summary statement is scored as:
10 pts = All of the requirements listed below have been included.

a) The summary is clearly developed and complete.
b) The statement is written in complete sentences.
c) The student has included a comparison between known values and predicted values.
d) The student has included the predictions of unknown values and offered an explanation of confidence in this prediction.
e) The student has provided convincing arguments based on their comparative data analysis.

8 pts = Four of the five requirements have been included
6 pts = Three of the five requirements have been included.
4 pts = Two of the five requirements have been included.
2 pts = One of the five requirements has been included.
0 pts = None of the requirements have been included.

Math 112 – Modeling Lab (Exponential Functions)

Background: This lab instructs students on how to create a simple $x - y$ scatter graph which can be used to explore exponential models of growth and decay. Each student will be assigned to a group for this exercise. The members of the group will generate data as a collaborative unit and each member of the group will contribute in completing a lab report. The raw data will be by following the instructions attached (M&Ms). Students will be required to graph the data by hand and fit and exponential function to the data.

Student Directions

- Assemble into your assigned group and get your supplies from the instructor. They include 1 plastic cup, 2 paper towels, and 50 + M&Ms.
- Read the **Assignment Handout** provided by your instructor.
- Obtain **two** pieces **graph paper** from the instructor.
- Complete the assignment.

Assessment
Each of the bullets in the Assignment Handout can be used for assessment based on the following rubric.

Data/Graph: [5 total points]

- Generate the data by following the attached directions.
- Prepare two *x-y* scatter graph plots of the data.

Preparation of each graph will be scored as follows:
5 pts, 1 for each of the following:

f) The data is provided and based on observation.
g) The independent and dependent variable is chosen correctly and plotted on the appropriate axis.
h) The axes scale are appropriate for the data plotted.
i) Each axes are labeled or titled. The graph is given a title.
j) The data points are presented correctly.

Analyze the Graphs: [10 total points]

- Analyze each graph by doing the following for each. Based on your observations can you identify an exponential relationship between trials and the number of M&Ms? If so, draw the trend curve which "fits" the data to the best of your ability. Derive the exponential equation for the curve by selecting two points on the curve you drew (sufficiently far apart). Include all calculations necessary to derive this equation. Note: There is more than one correct answer here, use your "common sense" to find a curve which fits the data. You might draw a curve which passes through two point, preferable at either end of the data. (i.e. the first or second trial and the last or second to last trial)

Analysis of each graph will be scored as:
10 pts , 1 point for parts a – g and 3 points for h.

a) A trend curve is drawn on the graph.
b) The position of the trend curve indicates that the student has interpreted the results correctly. (The curve should be "near" the data points)
c) The growth/decay factor, ***b***, of the curve is calculated correctly.
d) The calculation for the growth/decay of the line is included.

e) The initial value, ***a***, is reported correctly.

f) The calculation for the initial value is included.

g) The student has correctly reported the equation for the exponential function, in the form .
h) All work shown is neatly organized and the project as a whole is presented well. (worth up to 3 points)

Student Calculations: [5 total points] (For each equation)

- Use the exponential equation to calculate predictions at 3 **known** data points and make comparisons. Show all your work.
- Use the equation to make predictions at an unknown data point. Show all your work.

Application of the exponential equation will be scored as:
5 pts , 1 point for each of the following.

f) The exponential model (equation) is used in the calculations, work is provided.
g) Three known data points are compared with those predicted by the equation.
h) A reasoned analysis is made of the above comparison.
i) A prediction calculation is included.
j) All calculations are correct.

Student Summary: [10 total points] (For each equation)

- Summarize your findings. How do the data points acquired from your exponential equation compare to the known data points? Based on your findings do you think an exponential model is a "good" choice? How confident do you feel about your prediction? Explain.

Analysis of the summary statement is scored as:
10 points, 2 for each part below.

a) The summary is clearly developed and complete.
b) The statement is written in complete sentences.
c) The student has included a comparison between known values and predicted values.
d) The student has included the predictions of unknown values and offered an explanation of confidence in this prediction.
e) The student has provided convincing arguments based on their comparative data analysis.

Graph
Title____

Exponential Growth & Decay

Group #_____
Leader Name____________________

Growth

Don't eat the M&M's yet.

1. Gather the data.

a. Start with 4 M&M's in the cup.

b. Shake the cup and pour the M&M's onto the paper towel. Count the number of M&M's that have the M showing. (Be careful with the yellow M&M's. It is hard to see the M.)

c. Add a new M&M for each one with an M showing. Record the total number of M&M's in the table below. (Trial #0 is the starting 4, Trial #1 is 4 plus the number you added and so on...)

d. Repeat Steps b & c, recording the new total each time, until there are 7 trials on the table or you run out of M&M's.

Trial(x)	0	1	2	3	4	5	6	7
Number (y)	4							

2. Graph the data on a piece of graph paper: Create a scatterplot of Trials (x) and Total Number (y). Draw a trend line by eye. Do your best to "fit" the data.

3. Find the formula: Find a formula of the form using two points (either in the data you found or not) that fall on the line you drew.

4. Questions to be addressed and/or answered in the summary:
a. What was the exponential equation for this data?
b. Predict the number of M&M's on Trial #9.
c. Predict the number of trials needed to have 300 M&M's.
d. Explain the meaning of a and b in the equation.

Don't eat the M&M's yet.

Continue on the back of the worksheet.

Decay

Don't eat the M&M's yet.

1. Gather the data.

   a. Start with 50+ M&M's in the cup (place this number in at trial 0).

   b. Shake the cup and pour the M&M's onto the paper towel.

   c. Remove all M&Ms with an M showing. (Be careful with the yellow M&M's. It is hard to see the M.) Record the total number of remaining M&M's in the table below (as the next trial).

   d. Repeat Steps b & c, recording the new total remaining each time, until there are 7 trials on the table or you run out of M&M's.

Trial(x)	0	1	2	3	4	5	6	7
Number (y)								

2. Graph the data on a piece of graph paper: Create a scatterplot of Trials (x) and Total Number (y). Draw a trend line by eye. Do your best to "fit" the data.

3. Find the formula: Find a formula of the form using two points (either in the data you found or not) that fall on the line you drew.

4. Questions to be addressed and/or answered in the summary:
   a. What was the exponential equation for this data?
   b. Predict the number of M&M's on Trial #8.
   c. Predict the number of trials needed to run out of M&Ms.
   d. Explain the meaning of a and b in the equation.
   e. Does the equation you found ever predict you will have exactly zero M&Ms left? Explain what is going on.

You can eat the M&M's now!!

Graph
Title____

Appendix E

Final Examination Used in Face-To-Face and Blended Instruction Course

Math 112 - Final Exam

[redacted]

Directions: Read through every problem and carefully solve each problem using the mathematics we have learn in this course. **Show your work to get full credit.** Do all problems in Part 1 and in Part 2, select 3 of the 5 problems to solve. Take a deep breath and relax. Work carefully, you'll do great!

Do Not Begin Until Instructed To Do So.

Part 1

For problems 1 - 3 Let $f(x) = \frac{1}{3}x + 1$.

1) What is the slope, m, of the line $y = f(x)$? (1pt) Is $f(x)$ increasing or decreasing? (1pt)

2) Find an equation of a **linear function**, $g(x)$, that passes through $(1, 3)$ and $(3, 7)$. (2pts)

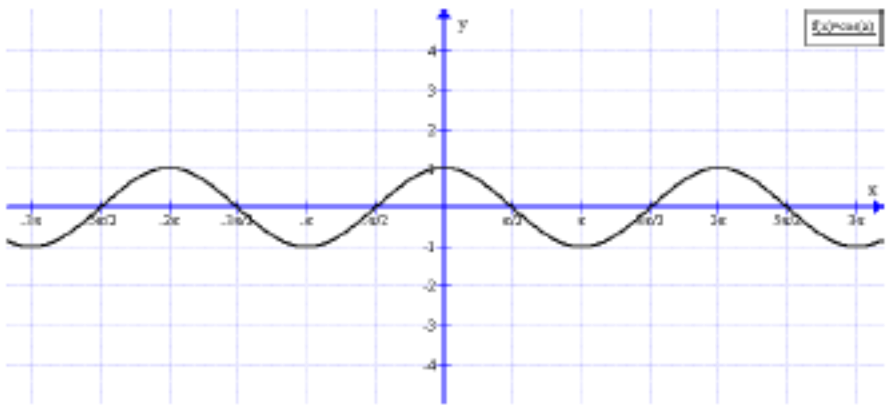
3) Find an equation for the inverse of $f(x) = \frac{1}{3}x + 1$, $f^{-1}(x)$, (2pts)

4) Find an **exponential function** which passes through the points $(0, 48)$ and $(4, 3)$. (2pts)

5) Suppose you invest \$500 in an interest bearing account with interest rate of 3% compounded quarterly. How much would you have in the account after 10 years. (2pts)

6) Suppose a radioactive substance has a half-life of 12 years. How long would it take for a 100 mg sample take to decay to 70 mg. (4pts)

7) Below is the graph of $y = \cos(t)$. On the same axes sketch the graph of $y = -2\cos(2x) + 1$. (2pts)



8) Let $f(x) = e^{2x}$ and $g(x) = x^2$. Find and simplify $f(g(x))$ and $g(f(x))$. (2pts each)

9) Suppose that $(3, 4)$ is a point on a circle centered at $(0, 0)$. What is the radius, r of the circle? (2pts)

10) What is the angle, θ, that this point makes with the x-axis? (2pts)

11) What point on this circle makes an angle, $\theta = 135^\circ$ with the x-axis? (2pts)

12) Let $f(x) = \frac{x+3}{x-2}$. Find $f^{-1}(y)$ (2pts). What is the range and domain of $f^{-1}(y)$? (2pts).

For 13 - 16, Let $f(x) = x^2 - 4$ and $g(x) = \ln(x+1)$.

13) Find $(f+g)(0)$ (1pt)

14) Find $(fg)(2)$ (1pt)

15) Find the formula for $(f/g)(x)$ (2pt). State the domain of $(f/g)(x)$ (2pts)

16) Is either f or g invertible? If no, say why, if yes, give the inverse. (4pts)

17) Suppose that y is **inversely proportional** to x. Suppose that when $x = 3$, $y = 6$. Find the constant of proportionality, k. (2pt) What is y when $x = 2$?(1pt)

18) Find an equation for a **power function** that satisfies $f(2) = 16$, $f(3) = 54$, $f(4) = 128$, $f(5) = 250$.(2pts)

19) Let $p(x) = 6x^5 + 3x^2 - \frac{x}{3}$. Is $p(x)$ a polynomial?(1pt) What are the coefficients a_1 and a_0? (2pts)

20) Find the x-values where $x^3 - 4x = 0$. (2pts)

5

Part 2

Select 3 of the following 5 problems to solve. Indicate (on each extra sheet) which problem you are solving and staple all three to the back of this exam. Within each problem, be sure to answer **all** parts.

1) Suppose you are standing 100 feet away from a building and you measure the angle between the ground and the top of the building as 60°. Find the **height** of the building. (Hint: First find the distance between the place that you are standing and the top of the building. Pictures help too.) (5pts)

2) A company believes that consumer demand is inversley proportional to the square of the price of a product. When the price is set at $p = \$5$ the demand is $D = 4$ thousand units. Find a formula for **demand**, $D(p)$ as a function of price, p. (Hint: First find the constant of proportionality, k.) Revenue is equal to the price of a product, times the number sold (demanded by the consumer). Given a fixed price, p, write down a **revenue function**, $R(x)$ which takes as input, number of units sold (thousands) and ouputs revenue (in \$). Find the **composition**, $R(D(p))$. Interpret this new functions **input and output**. (5pts)

3) The cost of producing x units of a commodity is given by $C(x) = x^2 + 20x + 50$, where x is in thousands and $C(x)$ is in thousands of dollars. Suppose further that the company can sell each unit for \$40. Write a **revenue function**, $R(x)$ which takes in the number of units produced (and sold) and outputs revenue in thousands of dollars. The profit function, $P(x)$ is defined to be revenue minus cost. **Find** $P(x) = (R - C)(x)$. Using what you know about quadratic functions, **find the production level where** $P(x)$ **is maximized.** (Hint: think about the shape of the graph of $P(x)$ and the location of the vertex.) What is the **maximum profit**?(5pts)

4) Suppose that the stock market value of a share in a certain company can be described by a sinusoidal function. Let $t = 0$ represents December 31st and $t = 1$ represents January 31st and so on. Assume that the stock price reaches a maximum of 80 points on October 31st. and a minimum of 20 points on April 31st. Also, assume that on average the company stock value is 50 points. What are the **amplitude, period and midline** of this function? **Find a sinusoidal function**, $f(t)$, which model's this company's stock value (in points) at time t (in months as described previously). (5pts)

5) Let $p(x) = -(x^2 + x - 6)(x^2 - 1)$. Determine the **long run behavior** of p, that is, determine $\lim_{x\to\infty} p(x)$ and $\lim_{x\to-\infty} p(x)$. Also, determine the **short run behavior** of p, that is, find the zeroes of p and where $p > 0$ and $p < 0$. (5pts)

Appendix F

Permission to Use Attitudes Toward Mathematics Inventory

Subject:RE: use ATMI in research
From: Tapia, Martha (mtapia@berry.edu)
To: czap0011@umn.edu;
Date: Tuesday, May 15, 2012 12:54 PM

Dear John,

You have permission to use the Attitudes Toward Mathematics Inventory (ATMI) in your dissertation. If you have any question, please do not hesitate to ask me.

Please let me know of the findings in your study.

Sincerely,

Martha Tapia

Martha Tapia, Ph.D.
Associate Professor
Department of Mathematics and Computer Science
Berry College
P.O. Box 495014
Mount. Berry, Georgia 30149-5014

From: John Czaplewski [czap0011@umn.edu]
Sent: Sunday, April 15, 2012 1:00 PM
To: Tapia, Martha
Subject: use ATMI in research

Dr. Tapia,

I am a doctoral candidate at the University of Minnesota and I am writing my dissertation on evaluating traditional and blended learning methods of instruction in terms of student attitude, retention, and achievement in an introductory college mathematics course. I would like to use your Attitudes Towards Mathematics Inventory as part of a pretest – posttest analysis on changes in attitudes throughout a semester. May I have your permission to do so?

Thank you.

John Czaplewski
Doctoral Candidate
University of Minnesota

Appendix G

Consent Form

CONSENT FORM

An Evaluation of Blended Learning Method of Instruction in Terms of Knowledge Acquisition and Attitude in an Introductory Mathematics Course

You are invited to participate in a research study designed to compare knowledge acquisition, as measured by final exam grades, and student attitude based on observations and interviews, in an introductory mathematics course taught in a blended learning instructional format. We hope to learn whether student knowledge acquisition and attitude in a mathematics course are impacted by the method of instruction at [redacted]. There are no appreciable risks or benefits from participating in this study.

The study will begin approximately January 2013 and end approximately April 2013. We estimate participating in the study will require two hours of your time outside the classroom. If you decide to participate, you will be asked to complete a 40-question inventory of your attitude towards mathematics at the beginning and again near the end of the semester, each taking approximately 10 minutes to complete, along with interviews, each taking approximately 15 minutes to complete, conducted after classroom observations to answer questions regarding your understanding of the content of the course along with attitudes towards mathematics during the activities.

Data collected during the course of this study will be kept confidential through the use of random number identifiers, kept in a secured room with restricted access, and will be destroyed within one year of the completion of the study. If the results of this study are published or presented, no names will be associated with the data cited. Any information that is obtained in connection with this study and that can be identified with you will be disclosed only with your permission.

For questions about this research project, contact John Czaplewski, Researcher at [redacted]. Advisor's contact information: Dr. Terrence Wyberg, University of Minnesota, [redacted] or [redacted] and Dr. Tamara Moore, University of Minnesota, [redacted] or [redacted]. For question about research subjects' rights or research-related injuries, contact the Human Protections Administrator [redacted].

Participation in this study is voluntary. A decision not to participate will involve no penalty or loss of benefits to which you are entitled. You may discontinue participation at any time without penalty or loss of benefits. A decision not to participate or a decision to withdraw from the study will not affect your current or future relationship with the investigators, [redacted], or the University of Minnesota. You will be offered a copy of this form to keep.

AGREEMENT TO PARTICIPATE

You are making a decision whether or not to participate in the study described above. Participation is voluntary. You may withdraw at any time without prejudice after signing this form. Your signature indicates that you have read the information provided above, had an opportunity to ask questions about the study, and have decided to participate.

__________________________________ ____________________

Signature | Date

__________________________________ ____________________

Signature of Principal Investigator | Date

Appendix H

University of Minnesota Institutional Review Board Approval

Subject:1207E17541 - PI Czaplewski - IRB - Exempt Study Notification
From: irb@umn.edu (irb@umn.edu)
To: czap0011@umn.edu;
Date: Wednesday, August 1, 2012 1:56 PM

The IRB: Human Subjects Committee determined that the referenced study is exempt from review under federal guidelines 45 CFR Part 46.101(b) category #2 SURVEYS/INTERVIEWS; STANDARDIZED EDUCATIONAL TESTS; OBSERVATION OF PUBLIC BEHAVIOR.

Study Number: 1207E17541

Principal Investigator: John Czaplewski

Title(s):
An Evaluation of Traditional and Blended Learning Methods of Instruction in Terms of Student Achievement, Retention, and Attitude in an Introductory Mathematics Course

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This e-mail confirmation is your official University of Minnesota HRPP notification of exemption from full committee review. You will not receive a hard copy or letter.

This secure electronic notification between password protected authentications has been deemed by the University of Minnesota to constitute a legal signature.

The study number above is assigned to your research. That number and the title of your study must be used in all communication with the IRB office.

Research that involves observation can be approved under this category without obtaining consent.

SURVEY OR INTERVIEW RESEARCH APPROVED AS EXEMPT UNDER THIS CATEGORY IS LIMITED TO ADULT SUBJECTS.

This exemption is valid for five years from the date of this correspondence and will be filed inactive at that time. You will receive a notification prior to inactivation. If this research will extend beyond five years, you must submit a new application to the IRB before the study's expiration date.

Upon receipt of this email, you may begin your research. If you have questions, please call the IRB office at (612) 626-5654.

You may go to the View Completed section of eResearch Central at http://eresearch.umn.edu/ to view further details on your study.

The IRB wishes you success with this research.

We have created a short survey that will only take a couple of minutes to complete. The questions are basic but will give us guidance on what areas are showing improvement and what areas we need to focus on:
https://umsurvey.umn.edu/index.php?sid=94693&lang=um

Appendix I

Public University Institutional Review Board Approval

Subject: IRBNet message from Jay Palmer
Date: Thursday, July 19, 2012 12:32:39 PM CT
From: Jay Palmer
To: Czaplewski, John R, Peterson, Nancy K, Kjorlien, Chad L

Message from Jay Palmer:

Re: [350905-1] An Evaluation of Traditional and Blended Learning Methods of Instruction in Terms of Student Achievement, Retention, and Attitude in an Introductory Mathematics Course

Protocol is approved as submitted. Good luck John.

Regards,
Jay Palmer

Subject: IRBNet Board Action
Date: Friday, July 20, 2012 1:09:10 PM CT
From: [redacted]
To: Czaplewski, John R

Please note that [redacted] University IRB has taken the following action on IRBNet:

Project Title: [350905-1] An Evaluation of Traditional and Blended Learning Methods of Instruction in Terms of Student Achievement, Retention, and Attitude in an Introductory Mathematics Course
Principal Investigator: John Czaplewski, M.Ed.

Submission Type: New Project
Date Submitted: July 16, 2012

Action: APPROVED
Effective Date: July 20, 2012
Review Type: Exempt Review

Should you have any questions you may contact Chad Kjorlien at [redacted]

Thank you,
The IRBNet Support Team

www.irbnet.org

Appendix J

Interview Protocols

Directions:

The purpose of this interview is to help me understand what students think about and do while working on precalculus tasks. During the interview, I will ask you questions related to two themes.

First, I will ask you questions that deal specifically with the collaborative assignment that you were most recently working on in class.

Secondly, you will be asked questions related to how you felt and your general attitude towards mathematics as a result of the nature of this course being that of a blended learning format.

The following questions will be asked after the group assignment is completed:

1) When you first saw the lab assignment, did you think it was an easy or difficult problem?
   Why do you think so? <or> What made the problem easy/difficult for you?
   What did you notice about the problem when you first saw or read it?

2) Tell me what helped you understand the problem?
   What did you do to help you understand the problem?
   How did this/these help you understand the problem?

3) Did you have any difficulty in understanding the problem?
   (If yes, what did you do in order to overcome the difficulty?)
   (If he/she tells you that they did not 'get it' ask, "What part did you not understand? <or> What could you have done in order to understand it?"

4) Tell me what you did to solve the problem?
   (As they explain what was done, ask "Why did you do that? <or> How did you know that you needed to … ?")

5) What was the most difficult part about solving this problem?
   Did you have a difficulty in solving the problem?
   (If yes, "What did you do in order to overcome the difficulty?")

6) When you solved the problem, did you do anything to make sure that you were on the right track in solving the problem?
   (If yes, "What were some of the things that you did?")
   (If no, "Why did you not do anything? <or> Was there a reason to not do anything? <or> I noticed that you … Why did you do that?"

7) If the student made adjustments to the work that they were doing, "I noticed that you made changes to your answer as you were working on the problem. Why did you adjust your way of solving? How did you know that you needed to change it? How did this/these help you solve the problem?

Semi-structured interview questions:

1) How would you rate your overall educational experience in taking this course?
(Poor, Satisfactory, Good, Very Good, Excellent)
Why did you rate in that way?

2) How would you compare the value of the online versus the face-to-face component of the course to date?
(Online is more successful, about the same, the face-to-face is more successful)
What specifically lead you to say that?

3) Compared to "traditional" face-to-face courses, how effective is this blended course?
(1) Much less (2) (3) (4) About the same (5) (6) (7) Much more

4) What has helped you learn the most in this course so far?
Have you seen that more or less in comparison to a "traditional" course?

5) What is least helpful to your learning in this course?
Has this been occurring more or less in comparison to a "traditional" course?

6) How is the mathematics that you do in this class different from the mathematics that you have previously done?

7) Have you changed the way in which you learn or study math? How?

8) Talk to me about the activities or things that you do in this mathematics course:

a. What do you think about the cooperative learning activities and their impact on…
   i. Self-confidence or anxiety
   ii. Value of math for your personal or professional growth
   iii. Motivation to pursue math
   iv. Enjoyment
b. What do you think about the online management system in terms of your procedural knowledge acquisition and its impact on…
   i. Self-confidence or anxiety
   ii. Value of math for your personal or professional growth
   iii. Motivation to pursue math
   iv. Enjoyment
c. What do you think is the purpose of the online homework?
d. What do you do when you are struggling with the homework assignments?
e. What do you think about the online management system in terms of assessing your comprehension and its impact on…
   i. Self-confidence or anxiety
   ii. Value of math for your personal or professional growth
   iii. Motivation to pursue math
   iv. Enjoyment
f. What do you do to prepare for assessments?
g. Are there structures in place in the course that help you deal with difficult situations?

Appendix K

Syllabi from Spring 2012 and Spring 2013

[redacted]

MATH 112: Modeling with Functions
Spring, 2012

Instructor: [redacted]
Email: [redacted]
Office: [redacted]
Office Phone: [redacted]

Dates: 1/16/2012 - 5/4/2012 **Days:** M W F **Time:** 9:00am - 9:50am **Room:** Maxwell Hall 369

Credits: 3.0 **Text:** Functions Modeling Change (3rd), Connally – ISBN 978-0-471-79302-1

Section: 01 **ID:** 001294

Description: This course will help students learn to mathematically model real-world applications, with emphasis on business applications, by developing algebraic and problem-solving skills. Topics include linear and quadratic functions, exponential and logarithmic functions, trigonometric functions, polynomial and rational functions, inverses and compositions of functions, and transformations of functions and their graphs. In addition, the course will emphasize unit analysis, changing representations (graphical, tabular, formulaic, and verbal) of data, estimation, and interpretation of solutions. Prerequisite: MATH 050 or mathematics placement.

(All information on this syllabus is subject to change at the discretion of the instructor)

SCHEDULE:	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
9:00 AM	MATH 112 01		MATH 112 01		MATH 112 01
9:30 AM	Maxwell Hall 369		Maxwell Hall 369		Maxwell Hall 369
10:00 AM	Office Hour	Office Hour	Office Hour	Office Hour	Office Hour
10:30 AM	201A	201A	201A	201A	201A
11:00 AM					
11:30 AM					
12:00 PM					
12:30 PM	Department	Department	Department	Department	Department
1:00 PM	Meetings	Meetings	Meetings	Meetings	Meetings
1:30 PM					
2:00 PM	MATH 140 04	MATH 112 02	MATH 140 04	MATH 112 02	MATH 140 04
2:30 PM	Pasteur Hall 237	Stark Hall B8	Pasteur Hall 237	Stark Hall B8	Pasteur Hall 237
3:00 PM	Office Hour		Office Hour		Office Hour
3:30 PM	201A	MATH 140 01	201A	MATH 140 01	201A
[redacted]					

Grade Breakdown: (The standard 90%(A), 80%(B), 70%(C), … applies)

Homework / Quizzes	**40%**
Exam 1	**15%**
Exam 2	**15%**
Final Exam	**30%**

Math 112 - Modeling with Functions

Spring 2013

Home
_ Schedule Grading Course Info

Instructor Info [redacted]

Office(s): [redacted]

Email: [redacted]

My Website: [redacted]

Office Phone: [redacted]
Please no messages, email me .

Grading Breakdown

Homework	20%
Participation	10%

[redacted]

Labs (2)	20%
Quizzes	20%
Exams (2)	20%
Final Exam	10%

[redacted]
change at the discretion of the instructor)
Individual grades (exams, quizzes, etc...) will **not** be curved.

WebAssign Homework: Homework will be assigned daily, even if not specifically mentioned in class. As course materials, students purchased access codes to WebAssign Software. Once installed, students will be able to logon to the WebAssign website and see assignments, due dates, practice problems, and explinations of solutions of some problems. Most notably students will complete homework assignments using WebAssign. The due dates of each assignment is clealy posted on WebAssign and it is up to the student to submit them before the deadline.

Labs: Students will form small groups and complete two labs which involve collecting data and using mathematics to create a model. Students will then make predictions and draw conclusions.. Each lab is worth 10% of the total grade for the course and each group will submit formal write up to be graded.

Quizzes: We will have a short quiz almost every week and will be announced in class. The lowest quiz score will be dropped from your grade and thus, makup quizzes will not be necessary or allowed.

Participation: Woody Allen is credited with saying, "Eighty percent of success is showing up." This is not true in our course. By simply showing up for class every day you will earn 6% not 80%. In addition, students are required to spend a certain amount of time every week working on course work in the MAC. Students will log in with their IDs and work through assignments and other course requirements. For this the student will earn the other 4% of the total 10% of participation. At present **students will be requred to spend 100 minutes, outside of class in the MAC**. Failure to log this time, even by 10 minutes, will result in a loss of points. The lowest week will be dropped from the final computation of the participation grade.

Quizzes: We will have a short quiz almost every week and will be announced in class. The lowest quiz score will be dropped from your grade and thus, makup quizzes will not be necessary or allowed.

Exams: There will be two in-class exams and one comprehensive final exam. Exam dates (see the schedule) are tentative until officially announced in class.

- ## Section Info
    -

Math 112 - 01
Mon / Wed / Fri
1:35pm - 2:25pm
Tau 314

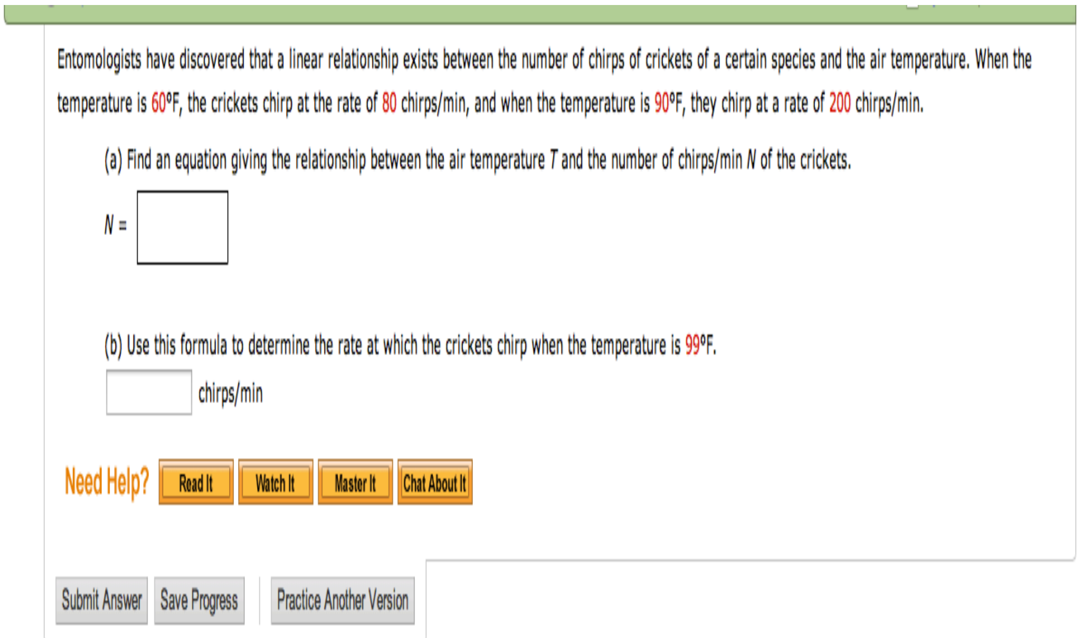
- **Math 112 - 02**
  Mon / Wed / Fri
  2:35pm - 3:25pm
  Tau 314

Final Exams

Section 01 (MWF 1:35 to 2:25) - Final: Monday May 6 from 1pm to 3pm
Section 02 (MWF 2:35 to 3:25) - Final: Wednesday May 8 from 10:30am to 12:30pm

Appendix L

Screen Shots of WebAssign© Utilized in Blended Instruction Format



Entomologists have discovered that a linear relationship exists between the number of chirps of crickets of a certain species and the air temperature. When the temperature is 60°F, the crickets chirp at the rate of 80 chirps/min, and when the temperature is 90°F, they chirp at a rate of 200 chirps/min.

(a) Find an equation giving the relationship between the air temperature *T* and the number of chirps/min *N* of the crickets.

N =

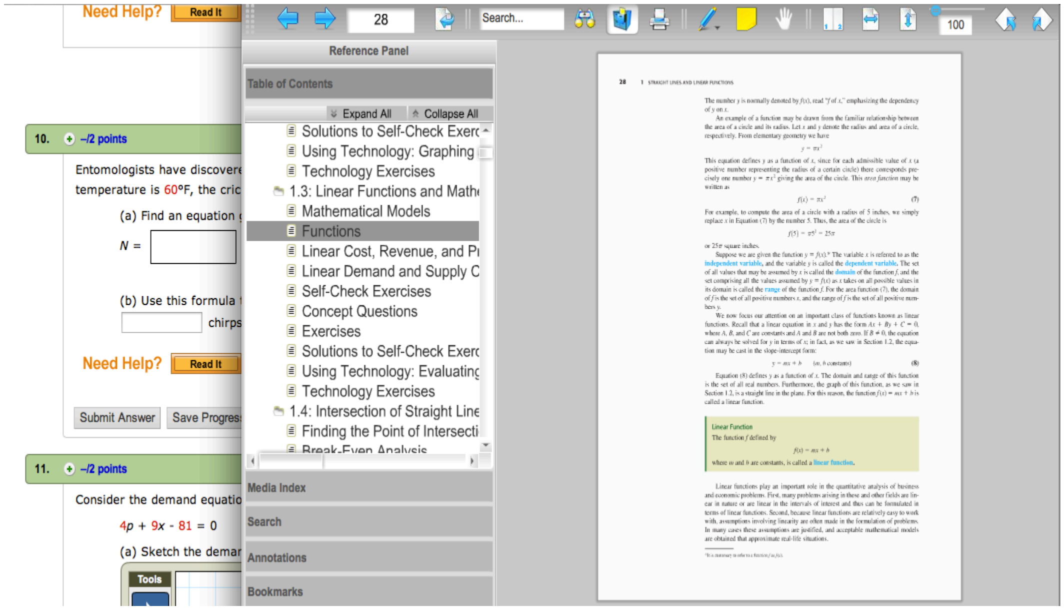
(b) Use this formula to determine the rate at which the crickets chirp when the temperature is 99°F.

chirps/min

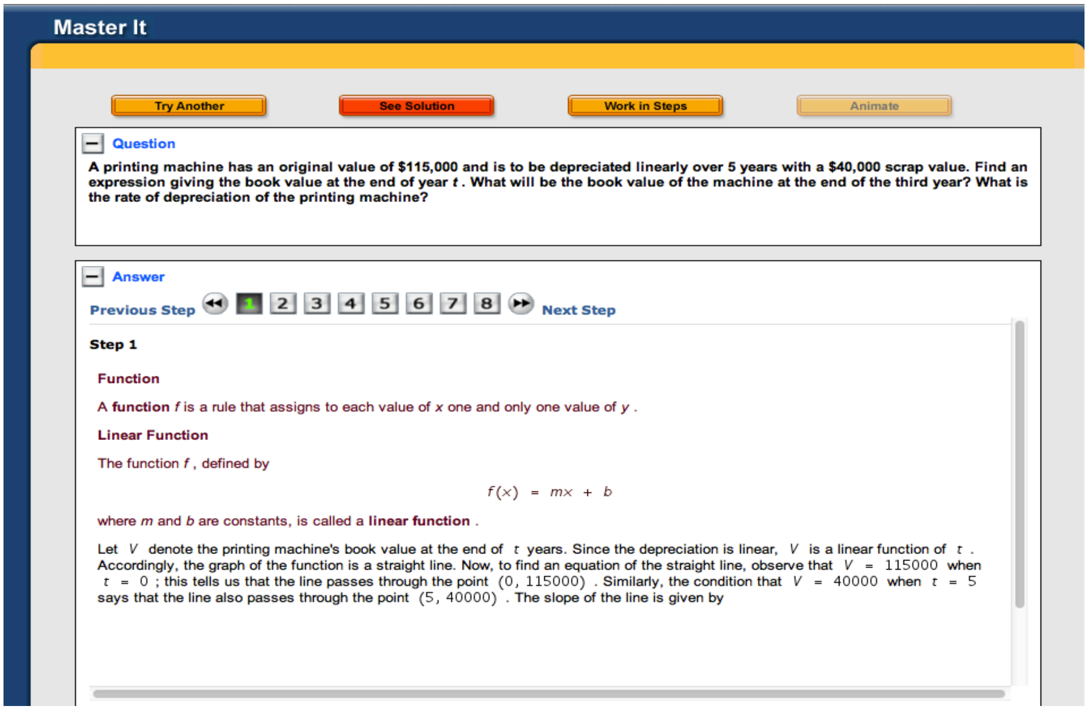
Need Help? Read It Watch It Master It Chat About It

Submit Answer Save Progress Practice Another Version

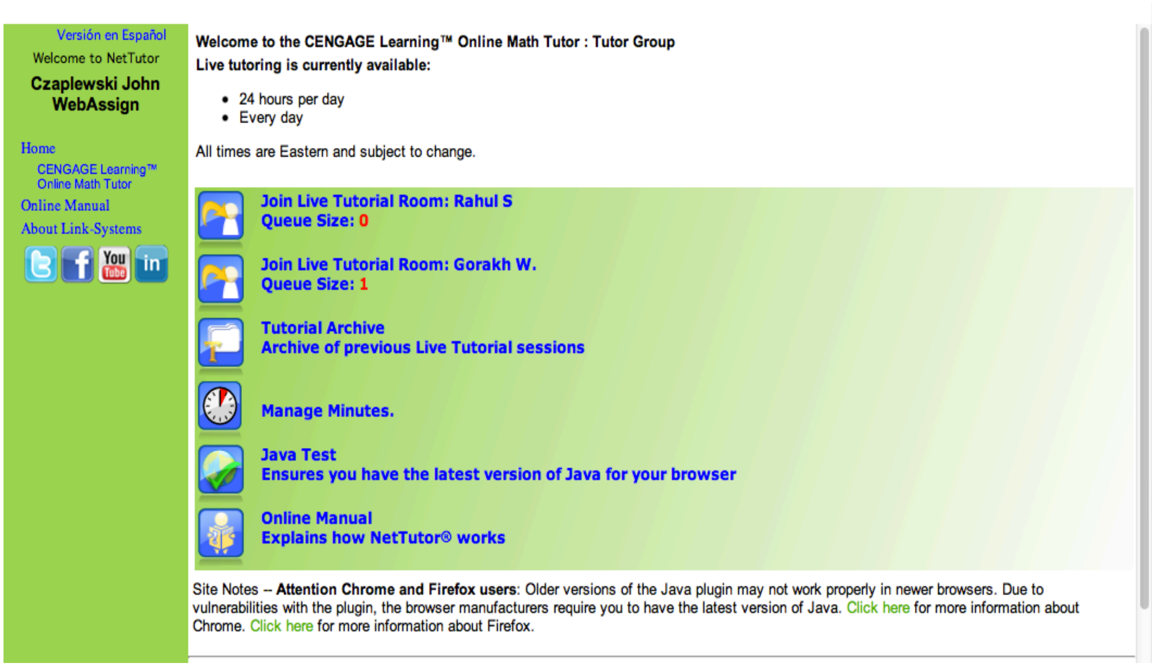
This is a sample of the types of problems that student access on the online management system.



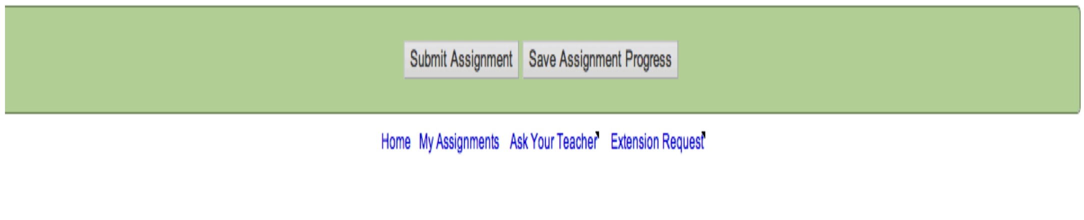
The READ IT link takes the student to the location in the electronic textbook related to the exercise.



The MASTER IT link allows students to view the entire solution, attempt another similar exercise, or have the solution shown in steps.



The CHAT ABOUT IT section allows students to link to the corporate/national online support if the student requires immediate online assistance.



Students can also contact their instructor and ask questions specific to their example – the instructor can see the exact question the student is working on and the response(s) that the student has given. In addition, students can request an extension on the due date.