5-2009

The Effects of Online Homework on Achievement and Self-efficacy of College Algebra Students

David Shane Brewer
Utah State University

THE EFFECTS OF ONLINE HOMEWORK ON ACHIEVEMENT

AND SELF-EFFICACY OF COLLEGE ALGEBRA STUDENTS

by

David Shane Brewer

A dissertation submitted in partial fulfillment
of the requirements for the degree

of

DOCTOR OF EDUCATION

in

Education
(Curriculum and Instruction)

Approved:

_____   _____
Kurt Becker, Ph.D.   Jim Dorward, Ph.D.
Major Professor   Committee Member

_____   _____
Joanne Bentley, Ph.D   Gary Straquadine, Ph.D.
Committee Member   Committee Member

_____   _____
Lisa Boyce, Ph.D   Byron Burnham, Ed.D.
Committee Member   Dean of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

2009

ABSTRACT

The Effects of Online Homework on Achievement

and Self-efficacy of College Algebra Students

by

David Shane Brewer, Doctor of Education

Utah State University, 2009

Major Professor: Dr. Kurt Becker
Department: Engineering and Technology Education

This study compared the effectiveness, in terms of mathematical achievement and mathematics self-efficacy, of online homework to textbook homework over an entire semester for 145 students enrolled in multiple sections of college algebra at a large community college. A quasi-experimental, posttest design was used to analyze the effect on mathematical achievement, as measured by a final exam. A pretest-posttest design was used to analyze the effect on mathematics self-efficacy, as measured by the Mathematics Self-efficacy Scale. The control group completed their homework using the textbook and the treatment group completed similar homework using an online homework system developed by the textbook publisher. All class sections followed a common syllabus, schedule, and homework list and completed a common, departmental final exam. Classroom observations were also used as a way to establish the similarity between groups.

The results of the study found that while the treatment group generally scored higher on the final exam, no significant difference existed between the mathematical achievement of the control and treatment groups. Both the control and treatment group did experience significant improvements in their mathematics self-efficacy, but neither group demonstrated more improvement than the other. When students were divided based on incoming math skill level, analysis showed that low-skilled students who used online homework exhibited significantly higher mathematical achievement than low-skilled students who used textbook homework. Exploratory analysis also showed that more students with low incoming skill levels and more repeating students received a passing grade when using online homework than did their higher-skilled, first-time counterparts, although the differences were not significant.

Based on this study it appears as if online homework is just as effective as textbook homework in helping students learn college algebra and in improving students' mathematics self-efficacy. Online homework may be even more effective for helping the large population of college algebra students who enroll in the course with inadequate prerequisite math skills. Instructors and researchers should consider the possibility that online homework can successfully help certain populations of students develop understanding better than traditional approaches. This study has implications for mathematics instructors and for online homework system developers.

(239 pages)

ACKNOWLEDGMENTS

It did not take me very long into the process of completing this degree to realize that I would need to rely on many people along the way. An undertaking of this size and scope cannot be done without help from others. I have been more than fortunate to associate with many people who freely gave of their time and wisdom throughout this process. I cannot list them all because I will undoubtedly miss someone. For those that are not listed by name here, you know who you are, and you have my full gratitude.

I would first and foremost like to thank my family. My wife, Marti, was always encouraging and supportive and my kids, Kelland, Jens, Britton, and Kennedy, who endured many nights, weekends, and vacations with me absent while I attended some class session or worked on some paper. I look forward to returning to them as a husband/father instead of a husband/father/doctoral student – there is a big difference.

I give special thanks to the chair of my committee, Dr. Kurt Becker. Throughout the process he provided me with sound and timely advice. I thank him for editing and re-editing many chapters of the proposal and dissertation and helping me find my way through some significant challenges related to this study.

I would also like to thank the rest of my committee, Dr. Joanne Bentley, Dr. Lisa Boyce, Dr. Jim Dorward, and Dr. Gary Straquadine, for their expertise, good advice, and willingness to devote their time to help me.

This study would not have been possible without the faculty members and students at Salt Lake Community College. They willingly did everything I asked of them

and always made me feel welcome during my many visits to their campus and classrooms.

I owe a special debt of gratitude to Lynn Lee and Gail Glover, among others, who made it possible for me to participate in this educational journey.

I am very appreciative of my sister, Josi Russell, for the many ways in which she helped with this study, in particular her ability to offer suggestions to help keep me moving and to inspire my thinking and creativity.

I am also grateful for the many friends that I made with the other students in my cohort. The late-night classes, the online discussions, and the breakneck summers will always be fond memories.

Lastly, special thanks go to Randy Larose, with whom I shared many jogs, basketball games, laughs, and fast food over the last five years. It was incredibly helpful to have someone to rely on and keep pace with throughout the process.

David Shane Brewer

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Many issues have been identified in collegiate mathematics education. The concerns expressed by national experts include student readiness and success rates, curriculum demands and instructor time constraints, national standards movements, individualized instruction, on-campus delivery and distance delivery, reform approaches and traditional approaches, and personal instruction and computer-assisted instruction (Baxter Hastings, Gordon, Gordon, Narayan, & Mathematical Association of America, 2006). The purpose of this study was to answer one of the questions drawn from these issues: how does online homework affect mathematical achievement (as measured by exam scores) and mathematics self-efficacy (as measured by a self-report survey) of students. This study also attempted to determine whether the student's incoming mathematical skill level (as measured by a mathematics prerequisite skills pretest) and experience with college algebra (first-time compared to repeating) acted as moderating variables between the independent variable, homework type, and the dependent variables, achievement and self-efficacy.

Context of the Problem

Based on high school grades, ACT scores, SAT scores, and institutional placement tests more and more students are entering post-secondary education unprepared to complete college level math courses such as college algebra (Hodges & Kennedy, 2004). Underprepared students are forced to enroll in remedial math courses. Hoyt and Sorensen (2001) found that institutions are reporting that between 30-90% of

all incoming freshmen need mathematical remediation before they can enroll in college-level math classes. Since 1980, the enrollment in remedial math courses has increased 73% and in the fall of 2000 57% of all math classes at two-year colleges and 12% of all math classes at four-year colleges were remedial (McGowen, 2006). Despite extensive remediation efforts many students ultimately enroll in college algebra unprepared to succeed, as evidenced by the percentage of students who earn D, W, or F grades – the DWF rate. The national DWF rate for college algebra is somewhere between 40-50% and has been found to be as high as 90% for some populations (Benford & Gess-Newsome, 2006; Herriott, 2006). It is critical for educators to explore every possible path to change this dismal momentum (Baxter Hastings et al., 2006; Hoyt & Sorensen, 2001).

While there are many possible avenues to pursue in trying to improve these sobering statistics, practical realities often preclude drastic changes to programs and curriculum. Large-scale efforts to reform college algebra may not be possible in universities and colleges that base their programs on certain theoretical and practical considerations (Baxter Hastings et al., 2006). Therefore, efforts to solve the problem of helping students succeed need to focus on interventions that can be implemented within the framework of existing programs. The traditional framework of most college algebra classes includes lectures provided by the instructor and homework completed by the student. If effective pedagogical changes can be made that fit within this traditional lecture-based framework then it is more likely that these changes will be accepted and consistently used by the collegiate mathematics education community. This study

attempted to identify one approach to help students succeed and become more confident in their mathematics skills while working within this traditional framework.

Homework has always been a staple of mathematics classes (Trautwein & Koller, 2003). Students need the opportunity to practice the skills and concepts demonstrated by their instructors. Theories of learning, such as constructivism (Davis, Maher, & Noddings, 1990) and social cognitive theory (Schunk, Pintrich, & Meece, 2008), state that student practice needs to be followed by instructor feedback in order for students to verify their understanding. Once feedback has been obtained, students are then able to adjust their approaches as necessary. Within mathematics education, this attempt-feedback-reattempt loop (Zerr, 2007) should occur when students complete their homework, receive feedback from their instructor on the correctness of their homework, and then reevaluate their approaches and learning. However, this attempt-feedback-reattempt loop rarely achieves its theoretical potential in college algebra courses because students may not attempt their homework because it is not required or instructors may not be able to grade the homework because of time constraints. Finally, even if the first attempt has been graded, students often fail to receive the feedback in a timely fashion or they fail to reevaluate their understanding (Davidson, 2004; Jacobson, 2006). In short, the theoretical benefits of homework in a college algebra class are often not obtained to the maximum degree by the student.

One way to improve the effectiveness of the attempt-feedback-reattempt loop is through the use of online homework. Online homework (OHW), in general, is defined to be a complete system of computerized homework problems that are available online, may

or may not correlate closely with a particular text, are most often automatically graded to provide immediate feedback regarding the correctness of answers, and may be accompanied by varying degrees of diagnostic instructional hints and/or tutorial assistance (Jacobson, 2006; Kinney, 2001). The particular OHW system used in this study conforms to each aspect of this definition. The system correlates closely with a specific math textbook and contains homework problems that are similar in type, difficulty level, and conceptual scope to those found in the text. Questions are multiple-choice, short answer, and true/false, with the majority falling into the short answer category. The computer software is able to immediately grade each question and make the results available to the student along with rejoinders that provide diagnostic direction regarding what the student may have done wrong. In addition, the software is able to produce a large selection of similar questions based on simple algorithmic programming which allows the student to practice as many similarly-structured problems as they wish until they are satisfied with the results. Each problem is accompanied with tutorials that are customized to that specific problem such as a step-by-step interactive walkthrough of the particular problem or a completely solved similar problem. Other generic (not specific to the individual problem) tutorial assistance is available such as access to an online version of the textbook, access to video lectures, access to graphical animations, or access to a variety of conceptual and procedural study guides. The system is more fully described later in this study.

Most major college algebra textbooks are currently accompanied by an OHW system similar to the one described above. These OHW systems are being developed both

by major textbook publishers and commercial organizations. National mathematics education organizations such as the National Council of Teachers of Mathematics (NCTM) and the American Mathematical Association of Two-Year Colleges (AMATYC) are promoting the appropriate use of technology in their respective sets of standards (American Mathematical Association of Two-Year Colleges, 2006; National Council of Teachers of Mathematics, 2000).

The use of technology in mathematics education has been the subject of much research. An ERIC search using the keywords "technology" and "mathematics educations" turns up 2532 results. However, the body of research examining online homework or computer-assisted homework has just started to develop as online homework systems and computer-assisted homework systems have started to become advanced enough for research and educational consideration (Davidson, 2004; Hurn, 2006; Jacobson, 2006). The flurry of research activity regarding OHW is likely due to the fact that these systems are improving as technology improves and with these improvements, there is a desire to see if the perceived benefits are, in fact, real.

The primary research question that needs to be answered is "does OHW improve mathematical achievement?" This question has received the most attention in the literature (Davidson, 2004; Jacobson, 2006). The findings of this achievement research have been mixed, although generally the results have shown that OHW is at least as effective as traditional textbook homework in improving mathematical understanding. Some results regarding achievement have been significant (Hirsch & Weibel, 2003; Zerr, 2007), while other results have failed to reach significance (Carter, 2004; Jacobson,

2006). In addition, Jacobson also found that students reported high levels of perceived learning, yet failed to demonstrate significant increases in exam scores. As more research is completed which examines this question a more complete understanding of the effectiveness of OHW may emerge.

The mixed results also suggest that a more focused approach is needed which considers other variables that may confound the effectiveness of OHW systems. Two possible moderating variables include *student's incoming mathematical skill level* and the *number of times students have previously attempted college algebra* (Jacobson, 2006; Zerr, 2007). Grouping participants based on these variables may help to identify circumstances in which OHW is most effective and help to explain previous inconsistent results.

In addition to mathematical achievement, researchers should also work to determine if OHW produces other beneficial educational outcomes. One such outcome, *increasing mathematics self-efficacy*, is important in mathematics education because of its relationship to mathematical achievement, persistence in learning mathematics, and career choice (Hackett & Betz, 1982). If OHW can help increase student's mathematics self-efficacy then it offers educators an important and effective alternative to textbook homework.

Mathematics (MSE) self-efficacy is defined as students' beliefs about their abilities to learn and perform mathematical tasks (Bandura, 1997) and has been found to act as a precursor to academic success (Linnenbrink & Pintrich, 2002). If students believe they can learn mathematics and complete mathematical tasks, then they are much more

likely to do so. In addition to self-efficacy influencing successful learning, it has been found that successful learning can also influence self-efficacy (Hurn, 2006; Middleton & Spanias, 1999). Thus, self-efficacy and successful learning form a reciprocating loop. It is desirable that students who use OHW should not only improve their mathematical learning but they should also experience an increase in their beliefs about their ability to learn mathematics, i.e. self-efficacy.

This study contributes to the growing body of research literature examining the effects of OHW on mathematics achievement for all college algebra students. In addition, this study attempted to determine if OHW, as incorporated by the specific OHW system used in this research, is more effective than traditional textbook homework in improving mathematical achievement for those students who enter college algebra under-prepared or who are retaking college algebra. It was hypothesized that these students would benefit more from OHW than from textbook homework because of the immediate feedback and the opportunity to reattempt problems with tutorial assistance in order to improve their understanding (Hidi & Harackiewicz, 2000; Linnenbrink & Pintrich, 2002; Middleton & Spanias, 1999). The beneficial effects of OHW were measured by examining achievement test performance of underprepared and repeating students.

Additionally, this study examined the effect that OHW has on mathematics self-efficacy for all students taken together, students matched on their incoming skill levels, and repeating students. Mathematics self-efficacy was measured using the Mathematics Self-Efficacy Scale (MSES) (Betz & Hackett, 1983b), which is a common instrument for

assessing students' beliefs about their abilities to learn mathematics and complete mathematical tasks.

Purpose and Objectives

The purpose of this quasi-experimental study was to examine the effect of using online homework on college algebra students, with an additional examination of the interaction effect on under-prepared college algebra students and repeating college algebra students who were retaking the class. This study examined the mathematical achievement (as measured by final exam scores) and the change in mathematics self-efficacy (as measured by the Mathematics Self-Efficacy Scale) of these students.

The following objectives were pursued to address the purpose of this study.

1. Determine if there were significant differences in mean final exam scores for the students who completed online homework and the students who completed textbook homework.

2. Determine if there were significant differences in mathematics self-efficacy scores over one semester for the students who completed online homework and the students who completed textbook homework.

3. Determine if there was a differential effect of the treatment on the mathematical achievement and mathematics self-efficacy for students with different incoming skill levels.

4. Determine if there was a differential effect of the treatment on the mathematical achievement and mathematics self-efficacy for first-time and repeating students.

Research Questions

This study was guided by the following research questions:

Research Question 1

Is there a significant difference in mathematical achievement between college algebra students who complete online homework and students who complete traditional textbook-based homework?

Research Question 1a. Is there a differential effect of the online homework treatment, in terms of mathematical achievement, for college algebra students with different incoming skill levels?

Research Question 1b. Is there a differential effect of the online homework treatment, in terms of mathematical achievement, for first-time and repeating college algebra students?

Research Question 2

Is there a significant difference in mathematics self-efficacy change over one semester between college algebra students who complete online homework and students who complete traditional textbook-based homework?

Research Question 2a. Is there a differential effect of the online homework treatment, in terms of mathematics self-efficacy change over one semester, for college algebra students with different incoming skill levels?

Research Question 2b. Is there a differential effect of the online homework treatment, in terms of mathematical self-efficacy change over one semester, for first-time and repeating college algebra students?

Research Method

This study used a quasi-experimental pretest/posttest factorial design to answer the research questions. The participants in this study were college algebra students at a moderately-sized, western community college. Four sections of college algebra served as the treatment group and completed their homework using an online homework system throughout the course of a sixteen-week semester. Five additional sections of college algebra served as the control group and completed traditional paper-and-pencil homework assigned from the textbook throughout the semester. Because of institutional circumstances, multiple instructors were involved in teaching the participating sections. To help control for instructor effects, efforts were made to make each of the sections as similar as possible: both the treatment and control groups were lecture-based, followed the same syllabus covering the same material at the same pace, and completed the same departmental final exam.

The independent variables were measured as follows. A self-report survey was administered to determine whether students were taking college algebra for the first time or were repeating the course. For each student, a mathematical skills pretest was used to determine the initial equality-level of the treatment and control groups and to categorize students based on their incoming skill level. Results from the pretest were used to divide

the students into two groups. This division operationalized the Incoming Skill Level independent variable into two categories: Low Level of Preparedness (LP) or High Level of Preparedness (HP). These classifications were used to answer the research questions pertaining to interaction effects between the treatment and the incoming skill level. Pre-treatment Mathematics Self-Efficacy was measured using the Mathematics Self-Efficacy Scale (MSES) pretest.

The dependent variable, Mathematical Achievement, was measured using a common final exam. Post-treatment Mathematics Self-Efficacy was measured using the MSES.

Definitions of Terms

This section contains the operational definition for each of the independent and dependent variables in addition to definitions of specific terms used in this study.

Homework Type

There are two homework types in this study – online homework (OHW) and textbook homework (THW).

Online Homework

OHW is homework that is delivered over the internet via a complete homework system that includes the individual homework problems, tutorial assistance for each problem (step-by-step interactive solutions, similar examples, online electronic textbook, and video lectures), immediate correct/incorrect feedback with accompanying diagnostic

directional hints, and algorithmically-generated similar problems that can be accessed for repeated practice.

Textbook Homework

THW is homework that consists of printed lists of problems found at the end of each section of the college algebra textbook. Solutions to the odd-numbered, textbook homework problems are available in the appendix section of the textbook. Additionally, completely worked-out solutions to the odd-numbered problems are available in the Student Solutions Manual.

Incoming Skill Level

Conceptually, this dependent variable is defined as the amount of college algebra prerequisite mathematical knowledge possessed by a student. Operationally, the incoming skill level was measured using a mathematics skills pretest derived from the intermediate algebra final exam. Pretest scores were sorted and two groups were created. The group of students receiving scores that were below the approximate median score was classified as having a Low Level of Preparation (LP). The group of students receiving scores that were above the approximate median score was classified as having a High Level of Preparation (HP). A similar method of categorization, using percentiles, has been used in another study examining the differentiated effects of an experimental treatment (Jackson, 2002).

College Algebra Attempts

This independent variable is conceptualized as the number of times a student has previously attempted college algebra either at the participating community college or at another institution. This variable was operationalized using a self-report survey which asked students to report whether they were first-time college algebra students or repeating college algebra students. This variable has two categories: First Time Student (FS), and Repeating Student (RS).

Repeating Student

This is a student that has previously taken college algebra at the participating community college or elsewhere and is currently retaking the course because of previous failure or dissatisfaction with previous results.

Mathematical Achievement

This dependent variable was operationalized and measured by the score obtained on a common departmental final exam.

Mathematics Self-Efficacy

Conceptually, this dependent variable is defined as one's perceptions and beliefs about their abilities to learn mathematics and to complete mathematical tasks (Bandura, 1997; Schunk et al., 2008). Operationally, mathematics self-efficacy was measured using the Mathematics Self-Efficacy Scale (MSES) (Betz & Hackett, 1983a). Because self-efficacy is domain specific it is critical to use an instrument that is designed to measure

the self-efficacy of college math students. The MSES is a 34-item Likert-scaled survey that is designed to measure this particular construct for the college population.

Assumptions of the Study

This study relied on several assumptions related to mathematical understanding: (a) mathematical understanding can be measured using a paper-and-pencil test, (b) mathematical understanding can be improved through the completion of homework, and (c) improvements in mathematical understanding are dependent on previous levels of mathematical understanding.

This study relied on several assumptions related to mathematics self-efficacy: (a) mathematics self-efficacy can be measured using a self-report survey, (b) mathematics self-efficacy can be changed over the course of a semester, (c) this change in self-efficacy can be identified using a pretest-posttest design, (d) students will honestly report their levels of mathematics self-efficacy on both the pretest and the posttest and (e) mathematics self-efficacy is influenced by level of achievement.

Delimitations of the Study

A delimitation of this study pertained to the specific OHW system used. The online homework system employed in this study has certain features, certain functions, and even a certain format that may not be available in other online homework systems. Not only is there often a significant difference between different systems, but there are likely to be significant differences between different versions of the same system. This

study is delimited by the fact that the results which were obtained may only apply to this specific OHW system or a different system that is similar in design and functionality.

This study is also delimited by the choice of population. College algebra students at a community college may differ from students at large and small public and private universities.

Limitations of the Study

A limitation of this study is due to the fact that multiple instructors are involved. Although efforts, such as a common syllabus, a common pace of instruction, common objectives addressed in the homework, a common final, and classroom observations were made in the design of the study to control for instructor differences it is impossible to completely remove instructor-related differences.

Additionally, while the treatment group completed homework online and the control group completed homework from the textbook, it was not possible to prevent the online homework group from accessing the textbook homework and encountering a diffusion of treatment effect.

Mortality was also an expected limitation. Because the withdraw rate from college algebra courses is traditionally high (Hauk & Segalla, 2005) it was anticipated that the initial sample would decrease. Efforts were made to choose a sufficiently large initial sample in order to account for participants withdrawing.

Significance of the Study

Online homework systems are coming to prominence in terms of use, functionality, and availability. These homework systems seem to offer many benefits to both students and teachers of mathematics. These perceived benefits are attractive to mathematics departments that are struggling to successfully help their students learn. In addition, these benefits seem to be available to math departments without having to overburden an already busy faculty body and without requiring broad programmatic changes. More research is needed to determine whether these systems can be used to improve the mathematical learning for all students and, in particular, for under-prepared and repeating students.

While learning should be the primary objective of any pedagogical program, other beneficial outcomes may also develop. Online homework systems have been shown to be effective in engaging students in the attempt-feedback-reattempt loop (Zerr, 2007). This engagement may help under-prepared and repeating students persist during the course of a semester and more students pass college algebra on their first attempt. Research is needed to determine if online homework systems can be used to help improve the typical pass/fail rates in college algebra.

Upon completion of any educational endeavor, students should feel as if they have improved their abilities. As students work within the OHW system environment they should not only be learning mathematics but they should also be developing more confidence in their abilities to learn mathematics in the future. In other words, OHW systems should foster the development of mathematics self-efficacy (Ponton, 2002).

Research is needed to determine if the use of OHW systems can help improve the

mathematics self-efficacy of all students, with special attention given to under-prepared

and repeating students.

In summary, by using software that is technologically and pedagogically

advanced, this study contributes important results pertaining to the effectiveness of OHW

systems in improving mathematics education. This research not only examined the effects

of OHW on mathematical achievement, it examined the effects of OHW on mathematics

self-efficacy. With the results of this study, in conjunction with existing research,

educational decision makers will be armed with more information regarding when, why,

and where to use OHW systems.

CHAPTER II

REVIEW OF THE LITERATURE

Problem Statement

Mathematics education at the college level is facing many challenges. These challenges are occurring at a time when most experts believe that students are going to need stronger mathematical skills than ever before in order to compete in the workforce (American Mathematical Association of Two-Year Colleges, 2006; National Council of Teachers of Mathematics, 2000). Many students are unprepared for collegiate-level mathematics and efforts are being made to find better ways to help all students learn the mathematics they need to pursue their educational and occupational goals.

Innovations in mathematics education are being explored which may offer many advantages. Online homework (OHW), as a replacement for traditional textbook homework, may offer a more effective alternative to help students learn mathematics. The use of OHW is growing, largely based on anecdotal reports of its effectiveness. However, the research literature fails to provide definite empirical evidence for or against the use of an online version of homework (Carter, 2004; Hirsch & Weibel, 2003; Kodippili & Senaratne, 2008; Zerr, 2007). The mixed results from existing research suggest that more research is needed and more variables need to be examined when considering the effectiveness of OHW (Davidson, 2004). More research needs to be performed that attempts to determine which populations might benefit the most from

OHW and more research needs to examine the effects of OHW on other important educational outcomes (Hurn, 2006; Packard & Holmes, 2006).

Challenges for Collegiate Mathematics Education

The literature pertaining to collegiate mathematics education is full of examples of the challenges in the field. The challenges exist on the student level, instructor level, and institutional level. Several of these challenges, related to student preparation, teacher preparation, and open enrollment, are described in this review in order to put into context the ultimate purpose of this study – the need to find more effective ways to help students learn mathematics.

Students are enrolling in college unprepared and unmotivated to do collegiate level math. There are more than 15 million undergraduates in the United States and 85% of them take some type of mathematics course to meet degree requirements (Chen & Zimbler, 2002). Many of these students are taking college mathematics simply because they are required to by their institution and not because they are intrinsically interested in the subject. The large number of students results in many classes with large enrollments. This makes it difficult for instructors to provide the level of scaffolding support that is necessary for many struggling students (Trautwein & Koller, 2003). Specifically, teachers are often not able to adequately provide feedback on the most basic component of every math class – homework (Davidson, 2004; Jacobson, 2006; Mendoza-Spencer & Hauk, 2008).

Many students must take remedial or developmental math classes before they are able to enroll in the math courses which count toward their degree (Hoyt & Sorensen, 2001). Since 1980, the enrollment in remedial math courses has increased 73%. In the year 2000, 57% of all math classes at two-year colleges were remedial while 12% of all math classes were remedial at four year colleges (McGowen, 2006). One study found that 61% of all first-year students at two-year colleges take at least one remedial class (National Center for Educational Statistics, 2004). These remedial classes often cover material that should have been learned in the early years of high school. Consequently, college math teachers are faced with the challenge of helping these unprepared students learn several years of difficult mathematics in only one or two semesters afterwhich, the students are supposed to be ready for college level math. The large percentage (estimated to be between 40-50%) of students who fail to pass their first college-level math class suggests that the remediation efforts need improvement (Benford & Gess-Newsome, 2006; Herriott, 2006). Even if they do pass, nearly half of all math and physical science majors switch majors, suggesting that the students are not being inspired to continue in their mathematical studies (Mendoza-Spencer & Hauk, 2008).

The level of instructor preparation also poses another challenge for college math education. The instructors who teach the undergraduate precalculus courses are often not trained specifically in teaching mathematics (Brilleslyper, 2002; Mendoza-Spencer & Hauk, 2008). At four-year institutions, graduate students teach a significant portion of the courses and often do so while they are completing significant course loads. Inexperience, lack of interest in teaching, and language issues often make it difficult for these

instructors to be effective. At two-year colleges, where instruction is supposed to be favored over research, full-time faculty members are often hired without having any educational training or coursework (Grubb, 1999). These instructors are often required to possess a master's degree in mathematics but are not expected to have taken any educational coursework. Institutional professional development programs can often help in these situations but these programs are often nonexistent or insufficient (Grubb; Mendoza-Spencer & Hauk, 2008).

For community colleges, open enrollment presents its own sets of issues. Because all students are allowed to enroll, math classes are full of students who vary greatly in age, ability, interest, and motivation (Miller, 1974). These students have often had unsuccessful previous experiences with math, have often forgot whatever math they did learn earlier in their school careers, have developed significant math anxiety, and have developed large-scale math avoidance (Arriola, 1993).

Approaches for Meeting the Challenges

The need to meet the challenges found in mathematics education has led to the experimentation with many different approaches. Traditionally, collegiate mathematics education has been built around the lecture model (Miller, 1974; Snider, 2006). In this highly teacher-centered approach, the instructor spends most of the time lecturing, answering homework questions, explaining rules, and working through numerous examples. This method has earned its current prominence because of the nature and amount of mathematics content covered in the classroom (Arriola, 1993).

However, other pedagogical methods are being explored, largely because of the perceived failures and shortcomings of the traditional approach (Baxter Hastings et al., 2006). More student-centered approaches are being advocated which promote more student engagement and less passivity (Becker & Shimada, 1997; Huba & Freed, 2000). Standards-based philosophies, which identify ideal standards and objectives, are being advocated by large national organizations such as the National Council of Teachers of Mathematics (National Council of Teachers of Mathematics, 2000) and the American Mathematical Association of Two-Year Colleges (American Mathematical Association of Two-Year Colleges, 2006). Most of these newer approaches advocate student understanding and are critical of the traditional approach because of its perceived emphasis on rote memorization (Roth-McDuffie, 1996).

Some proposed changes to collegiate mathematics education are not so much pedagogical as they are systemic. For instance, the National Center for Academic Transformation is an independent, not-for-profit organization which is promoting the use of technology to improve learning outcomes and decrease institutional costs (National Center for Academic Transformation, 2008). Because of the funding provided from this organization, many math departments are significantly changing how they teach their precalculus courses. Instead of teaching the traditional, face-to-face, lecture-based math courses, other models are being developed which include the use of online courses, hybrid courses, and lab-based courses. These approaches offer the potential of better educational outcomes, higher enrollments, and lower costs. Some anecdotal, non-research

based evidence is being produced using these alternatives and many schools are considering their adoption (Speckler, 2008).

However, regardless of which method, philosophy, or systemic structure is used, there is one constant component of each mathematics course – the use of homework to develop students' understanding. Students must attempt problems in order to learn; they then need feedback on the correctness of their solutions; and then it is ideal if they can reattempt the problems equipped with new understanding. This fundamental component is common to all types of math instruction (Cooper, Robinson, & Patall, 2006; Lefcort & Eiger, 2003; Trautwein & Koller, 2003).

Advantages of Online Homework

Employing an online homework system within a mathematics classroom should be done for more pedagogical reasons that simply providing additional drill and practice (Linnenbrink & Pintrich, 2002). Certainly the technology is capable of providing students with an unending collection of homework problems; however, if this is the only advantage then nothing has been accomplished that could not have been accomplished by using a larger textbook with a larger collection of problems.

Technology has the potential to be "empowering, productive, and motivational" (Gaines & Johnson, 1996, p. 74). Used in the educational setting, technology can help "move the act of learning from hearing (and forgetting), from seeing (and remembering), to doing (and understanding)…[helping] to bring about the active learning we educators all encourage, but find difficult to do" (Gaines & Johnson, p. 76). OHW systems, when

designed well, may offer benefits to both instructors and students (Hake, 1998). Packard

and Holmes (2006) have described the features and resulting benefits of a hypothetical

ideal online homework system. Their description is given in Table 1.

Table 1

Online Homework System Features and Benefits

System Features (Fixed and/or Customizable	Potential Benefits to	
	Instructors	Students
Multimodal content delivery mechanism	Provides variety of presentation options; accommodates student learning preferences and/or styles	Mediates connectivity and/or band-width problems; provides options for learners
Random problem generator	Offer variety and flexibility in testing situations; facilitates individualized assignments and/or assessments	Increased opportunity to practice in novel settings
Instructor-defined system configuration	(e.g. practice vs. test mode, fixed vs. variable response etc.)	N/A
Study pattern tracking	Behavioral (e.g. time-management patterns)	Self regulation
Problem solving tracking	Concept formation	Cognition levels (recall, synthesis, etc.)
Misconception detection and/or reporting	Early detection of student problems	Informs learner about where help is needed
Relative amount of guessing	Early warning signs of students in "trouble"	Puts student on notice

	Potential Benefits to	
System Features (Fixed and/or Customizable	Instructors	Students
Lag time between responses	Clues about student guessing	N/A
Number of attempts per problem	Guessing; mastery of subject matter	Tends to alter approaches to problem-solving
Procrastination pattern	At-risk student identification	Self regulation; relative comparison against norm; behavior modification
Problem difficulty	Allows for simple to complex	Incremental learning
Time on task	Aggregate data suggest problem spots requiring additional instruction or remediation	Time management; self regulation
Concept mastery level	Planning; remediation requirements	Predicts test/exam preparedness level

While it is possible to enumerate these desirable features, there does not seem to exist one particular OHW system that possesses all of these features. However, the current increasing use of and demand for effective systems will likely result in better systems which more closely approximate the ideal.

Zerr (2007) argued that the true pedagogical value of using an advanced online homework system lies in the system's capabilities to "more thoroughly engage students

when not in the classroom" (p. 60). By allowing students to attempt a problem, receive

feedback and tutorial assistance, and then reattempt the problem equipped with their new

understanding, the online homework system simulates the learning activities students

might experience when a teacher is present to evaluate their work and assist them.

Advanced online homework systems can act as a surrogate teacher when students are out

of class and working on their homework alone.

The two most critical components of the attempt-feedback-reattempt loop, which

are made more efficacious by online homework systems, are the feedback and reattempt

portions. Regarding feedback, practically every theory of learning requires a form of

instructor feedback so that students are aware of their own level of understanding (Cobb,

1988; Cooper et al., 2006; Davis et al., 1990; Steffe, 1996; Zemke & Zemke, 1995).

Feedback is critical so that students might make adjustments in their learning strategies

(Bandura, 1997; Zimmerman, 1990). Once students know that they do not understand,

they are able to do what is necessary to achieve understanding. Feedback also prevents

students from either underestimating or overestimating their own abilities (Linnenbrink &

Pintrich, 2002; Zimmerman). The miscalculation of one's understanding often leads to

inappropriate learning strategies.

Mathematics teachers are certainly aware, both theoretically and practically, of

the importance of providing feedback to their students (Trautwein & Koller, 2003).

However, for a variety of reasons, math instructors often fail to provide this feedback

through the grading of homework. Both Davidson (2004) and Jacobson (2006) have

described the variety of homework grading approaches that are commonly taken by math

teachers. These approaches include everything from situations where the instructor gives absolutely no feedback all the way up to the very rare situation where the instructor grades every problem (Lefcort & Eiger, 2003; Packard & Holmes, 2006). Instructors often rationalize not providing feedback because the problem solutions are already available, or the students can receive help from other students or tutors. Advanced online homework systems tirelessly grade each homework problem, and not only inform students as to whether they are correct or incorrect, but the systems also attempt to guide students to correct approaches through the use of diagnostic rejoinders (Allain & Williams, 2006). If more help is needed, then the availability of tutorial assistance serves as scaffolding for student learning.

The other important component of the attempt-feedback-reattempt loop is the reattempt portion (Pitcher, 2002). Within an OHW system, after each homework problem is graded, students are able to reattempt the problem armed with a new understanding of their approaches. This opportunity is often completely unavailable to students when they complete textbook homework in a traditional college math class. Typically, students work alone and outside of class to complete their homework problems. The homework assignment is then turned in and students rarely give it a second thought (Mavrikis & Maciocia, 2003). The OHW system makes it possible for students to follow up on the feedback they receive and reattempt similar versions of their incorrect problems as many times as they wish until they are satisfied with their results. This opportunity to demonstrate mastery is often an important motivational factor for many students (Hidi &

Harackiewicz, 2000; Linnenbrink & Pintrich, 2002) because they can, based on their own level of commitment, work until they achieve satisfactory results.

Zerr (2007) attempted to determine if students were more engaged and active in their learning as a result of the attempt-feedback-reattempt loop. He examined the OHW scores of 27 calculus students. To measure their level of engagement, he qualitatively analyzed the percentage of online homework assignments that received an almost perfect score. He hypothesized that a larger percentage of near-perfect homework scores would indicate that students were more engaged with the material and more active in their learning. He found that 65% of the homework grades were higher than 90% and argued that this result is vastly different from what would be expected from a normal distribution of homework scores and indicates that the students are much more engaged with the material outside of class.

Bonham, Beichner, and Deardorff (2001) also hypothesized that the attempt-feedback-reattempt loop offered an important advantage to OHW systems over traditional paper-and-pencil homework. They argued that the advantages of OHW systems include the ability to offer more practice, the instantaneous feedback which enables students to develop mastery by correcting their errors, and the elimination of certain common types of cheating because of the randomly generated questions. They also noted some disadvantages which include lack of feedback as to why a solution is incorrect, the susceptibility to trial-and-error approaches because of the availability of multiple submissions, and the emphasis on getting the right answer without understanding the process. In their quasi-experimental study of approximately 170 students enrolled in

introductory calculus-based physics courses, they found that the students who completed OHW reported spending substantially more time on homework than the students who completed textbook homework. Not only did students spend more time doing OHW, they also reported, overwhelmingly (about 75%), that they would like to continue to use the OHW system. On the other hand, less than half of the students who completed textbook homework indicated they would like to continue with textbook homework.

Overall, it can be said that an OHW system gives students a "greater degree of control over how, what, when, and where their learning occurs" (Granger & Bowman, 2003, p. 175). This autonomy, with the built-in support of the system, is hypothesized to be preferable to the traditional textbook homework approach.

Online Homework and Achievement

The literature examining the effects of replacing traditional textbook homework with modern online homework systems in collegiate mathematics classes reports mixed results. Because these online homework systems have recently increased in both their capability and their availability, many institutions are considering their adoption. A great deal of anecdotal evidence is accumulating which demonstrates the benefits of these OHW systems (Speckler, 2007, 2008; Testone, 2005). More rigorous research is needed to determine if using OHW offers a more effective learning experience to students than traditional textbook homework.

The primary purpose of existing studies has been to determine if online homework can be implemented effectively within the traditional lecture-based framework

of collegiate mathematics education. The primary research question in most of these studies is "does online homework improve mathematical achievement, as measured by test scores, more than traditional textbook homework?" The results of these studies have largely indicated that online homework is at least as effective as textbook homework in improving achievement, although more research is needed to identify the factors that lead to significance (Hirsch & Weibel, 2003; Hurn, 2006; Zerr, 2007).

Zerr (2007) used quantitative and qualitative techniques to analyze the effects of OHW on a small sample of calculus students. Twenty-seven students enrolled in first-semester calculus were the subjects for his study. The students in this class were asked to complete all of their homework online. The OHW system consisted of questions and diagnostic feedback created by the researcher and was used within the Blackboard classroom management system. The automatic feedback given in the rejoinders of the OHW system provided students with direction when they answered a question incorrectly. He found that the students who completed a greater percentage of their OHW also received higher exam and quiz scores.

Hirsch and Weibel (2003) also found that the use of OHW positively affected achievement. Using a quasi-experimental design, they studied 1,175 general calculus students at a large university. Eight-hundred and seven students completed a portion of their homework online using software that only told them whether their answers were correct or incorrect without offering any diagnostic feedback. The 368 students in the control group completed tradition textbook homework. The researchers found that the

students who completed OHW scored 4% higher on their final exams. This was found to be a statistically significant improvement.

Hurn (2006) found that OHW, in the form of practice quizzes, was at least as effective as textbook homework in helping students acquire basic algebra skills. His participants included 111 (64 treatment and 47 control) community college students enrolled in college algebra. He used a counter-balanced pretest-posttest design in which the treatment group completed online practice quizzes to learn the material and the control group completed paper-and-pencil practice quizzes. The online quizzes were automatically graded by computer and the computer gave instructive feedback to the students about the problems they missed. The paper-and-pencil quizzes were self-graded by the students. His analysis revealed that students in the treatment group who completed their practice quizzes online performed at least as well on a basic algebraic skills posttest as those students in the control group who completed paper-and-pencil practice quizzes.

Hauk and Segalla (2005) studied the effectiveness of OHW in comparison to traditional textbook homework (THW) for college algebra students enrolled at a large university. The participants in the study included 444 treatment students who completed OHW and 285 students who completed THW. The OHW system told students whether their answers were correct or incorrect without providing any explanatory feedback. Their study found that the OHW students did marginally better on a posttest achievement exam than THW students, although the results were not statistically different.

Williams (1996) reported finding positive effects on achievement and pass/fail rates for students receiving minimal levels of computer-assisted homework. The

participants in the study were developmental math students at a community college. One-hundred and sixty-nine students used the computer to develop and practice their skills, while 144 students participated in the traditional textbook-based drill and practice. The computer system in this study provided some corrective feedback but was limited in its capabilities.

Kodippili and Senaratne (2008) studied the effectiveness of OHW for 72 students enrolled in college algebra at a state university. The OHW system used in their study offered algorithmically-generated homework problems, immediate diagnostic feedback, and a variety of tutorial help. Using a quasi-experimental approach, they found that the OHW treatment group did slightly better than the THW control group although the results failed to reach significance. However, they did find that 70% of the students in the OHW group received an A, B, or C as their final grade as compared with only 49% of the students in the THW group.

Davidson (2004) used a case study design to examine the effect of OHW on mathematics achievement in three different instructional settings. Within each case, he used a quasi-experimental design. The participants in the study included 236 students who were asked to complete OHW and 296 students who were asked to complete THW. All students were calculus students enrolled in one of two universities. The online homework system used in this study automatically graded each problem and told students whether they were right or wrong without providing corrective feedback. Improvements in achievement on the final exam were observed in two of the three cases for the OHW students although the differences failed to reach statistical significance.

Carter (2004) reported the effects of using OHW in conjunction with traditional lecture-based instruction. Using an experimental design, she studied 55 developmental math students. The OHW system used in the study offered students diagnostic help as they worked homework problems. The software automatically tracked their progress and directed them to areas of study. The students who received the OHW treatment did perform better on a mathematics achievement posttest; however, the difference was not statistically significant.

Jacobson (2006) examined the effect of OHW on exam scores. Using a quasi-experimental approach, students enrolled in a college prealgebra course at a moderate-sized university were assigned either OHW or THW over a four-week period. The study made use of an online homework system that offered automatic grading, corrective feedback, and several other tutorial aides. No statistically significant difference was found in exam performance between the treatment and control groups. However, the students who completed the majority of their OHW assignments performed comparably to those students who were assigned THW.

The effectiveness of OHW has also been studied in other academic disciplines. As with the math-related studies listed above, most of the research in other disciplines has focused on determining if OHW improves achievement as measured by test scores. Studies have examined students taking calculus-based physics (Bonham et al., 2001), radiotherapy physics (Bridge & Appleyard, 2008), international marketing (Johnston, 2004), and introductory astronomy (Allain & Williams, 2006). The results from each of these studies indicate that OHW is at least as effective as THW in preparing students to

perform on tests. Additional beneficial outcomes of OHW are also reported in these studies: improved pass-fail rates, more time spent working on OHW than THW, more time saved by having assignments handled electronically, and a desire to continue to use OHW in future classes.

Special note should be made of the results described in the literature created by the developers of one particular OHW system (Speckler, 2007, 2008). This literature does contain many results that highlight the potential benefits of using OHW. The data contained in these documents shows increases in success rates, retention rates, success in subsequent math classes, final grades, and exam averages. Most of this data is observational and based on historic comparisons. The methods of comparison and the details of the educational circumstances are most often not provided. In addition the results were gathered largely through the convenience sampling of institutions who wanted to report how OHW was helping their institutions and the results are reported by the system developer. All of these factors make it difficult to gauge the value of their conclusions.

Need for Further Research of Online Homework and Achievement

The research results examining the effect that OHW has on mathematics achievement are generally positive even when the results fail to reach statistical significance. The inconclusive nature of these results suggests that more research is needed in order to identify the circumstances that produce significant results. Future

research needs to be explicit in describing the capabilities and features of OHW systems so that trends may become apparent.

While most of the studies that have been reviewed have replaced THW with OHW, they have often varied in important ways that may ultimately account for the differing results. The variety of research results may be attributable to the capabilities of the particular OHW system used, the duration of treatment, the amount of diagnostic and tutorial assistance provided within the software, or the students themselves. Many of the studies lack in-depth descriptions of the technological functions and pedagogical assumptions of their particular OHW system. The OHW system employed in this study is described in-depth so that effective commonalities can begin to be meta-analytically identified.

This study contributes to the body of OHW literature with the hope of helping to determine which variables play a significant role. The OHW system used in this study offered extensive diagnostic feedback for each question attempted by a student in conjunction with a variety of tutorial assistance (Hauk & Segalla, 2005). This study extended over an entire semester in order to help alleviate issues (e.g. how to navigate the OHW system and how to enter mathematical notation) relating to students' learning and using the computer interface (Jacobson, 2006). In addition, this study examined the effects of OHW on the populations of under-prepared and repeating students.

Online Homework and Self-Efficacy

Self-efficacy is an aspect of motivation that is defined as an individual's "judgments of their capabilities to organize and execute courses of action required to attain designated types of performances" (Bandura, 1997, p. 391). Self-efficacy refers to how confident a person is in their abilities to organize their mental, behavioral, and environmental resources in order to successfully accomplish a particular task. It is important to note that self-efficacy takes into consideration not only the individual's beliefs about their mental capabilities, but also the individual's beliefs about their abilities to control their environment in order to accomplish the task and their individual beliefs about their abilities to control their behaviors in order to accomplish the task. This idea is consistent with Social Cognitive Learning Theory (Bandura, 1977). Therefore, self-efficacy strongly influences the choices that students make, how much effort they expend, and how they persist when obstacles arise (Linnenbrink & Pintrich, 2002).

The effect of self-efficacy on achievement, as demonstrated in the literature, is mediated by students' choices, their effort levels, and their persistence. Multon and Brown (1991) completed a meta-analysis examining the relationship between self-efficacy and academic performance and self-efficacy and persistence. They examined 38 studies which involved participants ranging from elementary age to college age and included normal and low-achieving students. They found that the overall effect size of self-efficacy on performance was .38, thus students' self-efficacy beliefs accounted for about 14% of the variance in their academic performance. Similarly, the effect size of self-efficacy on persistence was found to be .34, thus accounting for approximately 12%

of the variance in students' persistence. Other reviews of the literature on motivation and self-efficacy have also reported relationships between self-efficacy and achievement (Linnenbrink & Pintrich, 2002; Middleton & Spanias, 1999).

Self-efficacy beliefs are conceptualized to be task-specific and situational (Schunk et al., 2008). Students may believe they can accomplish tasks in one academic area and yet have little confidence in their ability to accomplish tasks in a different area. An individual's belief about their ability to accomplish mathematical tasks is known as mathematics self-efficacy. Betz and Hackett (1983b) were the first to study mathematics self-efficacy as it related to career choices for males and females and reported a significant positive relationship between the variables (Hackett, 1981; Hackett & Betz, 1982). Later, they examined the relationship between mathematics self-efficacy and mathematics achievement and also found a positive correlation (Hackett & Betz, 1989).

Even within mathematics, self-efficacy beliefs are often specific to particular types of mathematical tasks, such as the ability solve certain types of problems or the ability to succeed in certain math or math-related courses (Pajares & Miller, 1995). Consequently, students may have confidence that they can solve certain types of math problems but may not have confidence in their ability to pass a certain math class. Measures of self-efficacy should be designed to measure the confidence levels related to specific tasks and not assume that mathematics self-efficacy is global in nature (Schunk et al., 2008).

Measuring Self-Efficacy

Betz and Hackett (1983a) created an instrument designed to measure the mathematics self-efficacy of community college students (Hall, 2002; Hodge, 2002; Hurn, 2006). This Mathematics Self-Efficacy Scale (MSES) consists of two sections: an 18-question section that asks students to indicate how much confidence they have to successfully complete specific everyday math tasks and a 16-question section that asks students to indicate how much confidence they have to complete several math-related courses with a final grade of "A" or "B". Students respond to each question based on a ten-point Likert scale with responses ranging from "No Confidence At All" to "Complete Confidence."

The scale was developed over a ten year period by first identifying three domains that were potentially relevant to mathematics self-efficacy. The developers created questions designed to measure student's self-perceived capabilities to: (a) solve math problems that might typically be found on standardized tests, (b) solve math problems that were considered common in everyday life, and (c) complete math and math-related courses with satisfactory results (Betz & Hackett, 1993). The current version of the instrument groups questions about both types of math problems (test problems and everyday problems) into the first section and questions about math and math-related courses into the second section.

Betz and Hackett (1983b) found solid evidence for the reliability of the MSES and reported an internal consistency reliability value (coefficient alpha) of .96 resulting from the administration of the instrument to 261 college students. Lent and Lopez (1991)

also reported a high coefficient alpha of .92 along with a two-week test-retest reliability of .94 in a study involving 138 introductory psychology students.

The validity of the instrument was demonstrated by comparing the results of the MSES to the results of other psychometric instruments designed to measure constructs that were deemed to be related to mathematics self-efficacy. Betz and Hacket (1983b) found that MSES scores were correlated with math anxiety ($r = .56$), confidence in doing math ($r = .66$), perceived usefulness of math ($r = .47$) and effectance motivation in math ($r = .46$) (Betz & Hackett, 1993). Content validity was also determined by comparing the MSES scores with actual educational and vocational behaviors. MSES scores were found to contribute to the selection of science-based college majors (Hackett, 1985). Mathematics self-efficacy scores were also found to be strong predictors of mathematical performance (Siegel, 1985).

Changing Self-Efficacy

Self-efficacy is conceptualized to be a task-specific personal characteristic rather than a characteristic that is global (Schunk et al., 2008). This conceptualization leads to measurement instruments with questions asking how confident individuals are to successfully complete particular tasks. For example, questions may be constructed which ask students how confident they are in their ability to solve linear equations or to pass a particular math class. On the other hand, questions asking individuals how confident they are in their math skills would be too broad.

Because of the task-specific nature of self-efficacy, and in particular mathematics self-efficacy, it can fluctuate and be influenced by environmental and personal circumstances (Middleton & Spanias, 1999). A student may feel confident to solve equations that do not involve fractions but may feel completely incapable of solving equations that do involve fractions. However, after receiving instruction, students may then feel more confident in their abilities thus demonstrating the changing nature of self-efficacy. Personal circumstances may also influence students' self-efficacy level. A student may feel very confident in their ability to pass a math test because of their past efforts and levels of preparation. The same student may lower their confidence levels for the next test because they judge the material to be difficult or because they have been unable to adequately prepare (Schunk et al., 2008).

Bandura (1977) hypothesized that self-efficacy can be influenced in the classroom and suggested four ways in which it can be enhanced: performance accomplishments (successfully completing tasks), vicarious experience (observing others successfully completing tasks), verbal persuasion (receiving feedback in the form of encouragement and reassurance), and physiological states (reducing the effects of anxiety). This study examined the effects of two of these influences: performance accomplishments (in the form of being able to reattempt homework tasks until they are judged to be successfully completed) and verbal persuasion (in the form of automatic feedback from the OHW system).

Students benefit from being given the opportunity to develop mastery (Linnenbrink & Pintrich, 2002). Whether they are intrinsically motivated and desire to

learn the material for its own sake or whether they are extrinsically motivated and desire

to achieve the best possible comparative scores, they benefit from the opportunity to

attempt and reattempt homework until they are satisfied (Carter, 2004; Pintrich &

DeGroot, 1990). This mastery helps students gain confidence in their math skills. Hurn

(2006) reported increases in self-efficacy for students using an online learning system

that allowed them to reattempt their work and hypothesized these increases were due to

the software helping the students manage their knowledge gaps relating to basic algebraic

skills. Multon and Brown's (1991) metaanalysis found that self-efficacy accounted for

approximately 14% or the variance in mathematical achievement and hypothesized that

self-efficacy and performance accomplishments possessed a reciprocal relationship, with

each positively affecting the other (Schunk et al., 2008). If the mathematics course is

designed in such a way as to allow students to achieve positive learning results, then

mathematics self-efficacy should improve (Hall & Ponton, 2005).

Students' mathematics self-efficacy may also be enhanced through verbal

persuasion in the form of motivational and instructional feedback (Bandura, 1977).

Students often have difficulty in accurately assessing their actual academic abilities and

need feedback in order to make more accurate assessments of their performance

accomplishments (Ley & Young, 1998; Slemon & Shafrir, 1997; Young & Ley, 2000,

2001; Zimmerman, 1990). Feedback allows students to identify any discrepancies that

might exist in their understanding. Instructors should work to provide feedback that is

timely and accurate. As students receive feedback and match that feedback to their

performance they are able to adjust their self-efficacy beliefs accordingly.

Students' self-efficacy is also influenced by any encouragement they receive as they attempt academic tasks. Jackson (2002) reported that efficacy beliefs were enhanced when students received efficacy-enhancing encouragement via email in an introductory psychology class. Tuckman (2007) also found that efficacy beliefs could be improved by providing motivational scaffolding in the form of study skills support groups and instructor office hours. Encouragement can take almost any form and can have a positive effect on self-efficacy.

<div style="text-align:center">Self-Efficacy and Student Ability Levels</div>

Students who struggle academically because of motivational, educational, or even physiological challenges often demonstrate low and inaccurate levels of self-efficacy, often as a result of a misunderstanding of the value of persistence and hard work (Linnenbrink & Pintrich, 2002). These difficulties with self-efficacy have adverse effects on student adjustment, learning, and success. Saracoglu, Minden, and Wilchesky (1989) examined 34 students with learning disabilities and found that they had lower levels of self-esteem and self-efficacy than students without these classifications. These students also reported more difficulties in adjusting to the university setting. The researchers hypothesized that increasing student self-esteem and efficacy may help to serve as a "buffer" against the environmental stresses which the students may encounter. It is unknown if college algebra students who are underprepared or who are repeating the course suffer from the same lack of self-efficacy.

Jackson (2002) examined the effects of a self-efficacy enhancing treatment on below average, average, and above average performing college students. The participants in his study were 123 introductory psychology students. These students were divided into roughly equal ability groups based on exam scores. Part of the students were sent an "efficacy-enhancing email" that was structured to improve efficacy based on Bandura's four influencing factors (Bandura, 1977). Jackson found that the feedback and encouragement contained in the email had a significant impact on improving students' self-efficacy. He was unable to identify differences in improvement based on skill level but hypothesized that more research was needed. No research exists that examines the differential effects based on skill-level of efficacy-enhancing interventions. This study provides insight into this area.

Hurn (2006) examined the effect of online practice quizzes on college algebra students' self-efficacy but did not try and identify differing effects based on incoming skill level. Using a separate-sample pretest-posttest control group design involving 111 college algebra students at a community college, he found a significant difference in self-efficacy improvement favoring the treatment group. Hurn's research influenced this study which attempted to determine if changes in self-efficacy were a function of incoming skill level and the type of homework used.

Need for Further Research of Mathematics Self-Efficacy

Researchers, noticing the positive effects of self-efficacy on achievement, advocate educational approaches that not only help students increase their mathematical

knowledge but also help students increase their mathematics self-efficacy (Jackson, 2002; Ponton, 2002). Young and Ley (2002) have advocated "providing support for maintaining this high level of self-efficacy, while reducing the dissonance between the efficacy beliefs and performance level" (p. 27). In order to reduce the dissonance between perceived capabilities and actual capabilities, it is critical for students to receive feedback on their work. This study used an advanced online homework system that provided immediate detailed feedback on every problem a student attempts. This study examined the effect which an advanced online homework system had on mathematics self-efficacy, an area of research that needs more attention.

In addition, researchers have found that students who struggle in various academic areas for motivational, educational, or even physiological reasons have difficulties with their self-efficacy. Feedback and encouragement, designed to improve self-efficacy, may be critical to helping underprepared students succeed. Students who are well-prepared for college algebra may not see a marked improvement in their mathematics self-efficacy because they already feel confident in their skills, or as Pintrich and De Groot (1990) stated, these students already have the "skill and the will to be successful in classrooms" (p. 38). Students who are very unprepared may also fail to see an improvement in their self-efficacy because they know they are already lacking the prerequisite skills. However, students who enter the classroom with an average level of preparedness may see the most benefit from self-efficacy enhancing feedback and encouragement (Jackson, 2002). This study examined the effects of such feedback and encouragement, available through the OHW system, based on student's incoming skill

level. In addition, this study examined whether the mathematics self-efficacy of repeating students is impacted at a different level than the self-efficacy of first-time college algebra students.

The literature which has been reviewed provides evidence for the reciprocating relationship between mathematics self-efficacy and achievement. In addition, it has been shown that self-efficacy can be influenced by providing feedback and persuasion to students as they attempt academic tasks. Lastly, students who struggle academically demonstrate low and inaccurate levels of self-efficacy. Modern online homework systems offer students immediate and unending feedback and encouragement related to their educational efforts. This feedback may not only improve understanding but it may improve self-efficacy (Hall & Ponton, 2005). This study extends the literature related to mathematics self-efficacy and achievement of all students, and, in particular, underprepared and repeating students.

CHAPTER III

RESEARCH METHOD

The purpose of this study was to determine if students who complete their homework online demonstrate significantly different levels of mathematical achievement and mathematics self-efficacy gain than students who complete their homework using traditional textbook approaches. This section describes the research questions, null hypotheses, research design, online homework system, instructional setting, participating instructors, study participants, institutional review board, variables, data-collection methods, instrumentation, procedures, and statistical analyses that were employed in this study.

Research Questions

This study was guided by the following research questions:

Research Question 1

Is there a significant difference in mathematical achievement between college algebra students who complete online homework and students who complete traditional textbook-based homework?

Research Question 1a. Is there a differential effect of the online homework treatment, in terms of mathematical achievement, for college algebra students with different incoming skill levels?

Research Question 1b. Is there a differential effect of the online homework treatment, in terms of mathematical achievement, for first-time and repeating college algebra students?

Research Question 2

Is there a significant difference in mathematics self-efficacy change over one semester between college algebra students who complete online homework and students who complete traditional textbook-based homework?

Research Question 2a. Is there a differential effect of the online homework treatment, in terms of mathematics self-efficacy change over one semester, for college algebra students with different incoming skill levels?

Research Question 2b. Is there a differential effect of the online homework treatment, in terms of mathematics self-efficacy change over one semester, for first-time and repeating college algebra students?

Null Hypotheses

This study tested the following null hypotheses which were derived from the primary research questions:

Null hypothesis 1

The mean final exam score of college algebra students who complete online homework is not significantly larger than the mean final exam score of college algebra students who complete textbook homework.

Null hypothesis 2

The mean difference between posttest and pretest mathematics self-efficacy scores over one semester of college algebra of students who complete online homework is not significantly larger than the mean difference between posttest and pretest mathematics self-efficacy scores over one semester of students who complete textbook-based homework.

Design

This study used a quasi-experimental pretest/posttest factorial design to answer the research questions. The quasi-experimental design was necessary because it was not possible to randomly assign individual participants to either the treatment or the control group (Creswell, 2002). Nine sections (four treatment sections and five control sections) of college algebra were involved in the study. The participating college algebra sections were the result of the course coordinator actively recruiting instructors to participate. It was not possible to randomly assign students to either of these groups because they were able to enroll in any section of college algebra which they chose. On the first day of classes, all students were made aware of whether they were enrolled in an OHW or a THW section and had the option of remaining enrolled in the section or dropping the section, regardless of whether they wished to participate in the study or not.

The pretest/posttest design was used because some of the research questions pertained to changes over time. The pretest/posttest design is an effective method for determining change over time (Creswell, 2002). The pretest/posttest design was only

used to answer the questions relating to mathematics self-efficacy. This type of design must guard against threats to internal validity related to instrumentation. The self-report MSES was used for both the pretest and the posttest. However, the pretest asked students about their beliefs prior to the treatment and the posttest asked students about their beliefs after the treatment. Because mathematics self-efficacy has been found to be affected by educational experiences (Middleton & Spanias, 1999), it was expected that this pretest/posttest design would measure any changes that might occur.

The factorial design was necessary because this study involved three categorical independent variables (Homework Type, Incoming Skill Level, and College Algebra Attempts), each with two levels (Homework Type: Online Homework (OHW) and Textbook Homework (THW); Incoming Skill Level: Low (LP) and High (HP); College Algebra Attempts: First-time Student (FS), and Repeating Student (RS)). Not only did this design make it possible to determine if the treatment (Homework Type) had a main effect on achievement and self-efficacy, but the factorial design also made it possible to determine if there were any interaction effects between Homework Type and Incoming Skill Level and to determine if there were any interaction effects between Homework Type and College Algebra Attempts (Cohen, 2001).

The Online Homework System

Irregularities in previous research results regarding the effectiveness of online homework may be partly attributable to the different pedagogical capabilities of the systems being examined. In order to be able to determine why some systems are

significantly effective while others are not, it is important for current and future

researchers to provide in-depth descriptions of the online homework systems that are

being employed. With such descriptions it may then be possible to identify trends in

software functionality that would be helpful to designers and educators. The following is

a description of the online homework system used in this study, which was created by the

textbook publisher to match a particular textbook. This description will describe how the

online homework system employs the attempt-feedback-reattempt loop (Zerr, 2007). The

topics covered include how the online homework problems were created, what types of

feedback and assistance were available, how were students able to reattempt their

homework, what technological considerations were part of the system, and what access

did students have to results. Screenshots (Appendix A) of the software are provided.

Problem Creation

The first component of the attempt-feedback-reattempt loop is the attempt phase

where students first try to solve mathematical problems. The online homework problems

were created so that they matched, inasmuch as possible, the textbook homework

problems. Each odd-numbered textbook problem had an online counterpart such that the

two problems matched procedurally and conceptually. Each online homework problem

was created to match its corresponding textbook problem in terms of type (e.g. both

problems asked students to solve a linear equation); they were matched in terms of

difficulty level (e.g. both problems asked students to solve a linear equation that involved

approximately the same number of steps); and they were matched in terms of conceptual

scope (e.g. both problems asked students to solve linear equations that involved fractional

coefficients and produced a fractional solution). For example, one randomly chosen

homework problem from the textbook is:

$$\text{Solve: } 7(3x+6) = 11 - (x+2)$$

and the corresponding online homework problem (with the same section and problem

number) is:

$$\text{Solve: } 7(3x+9) = 11 - (x+3).$$

Both problems ask students to solve linear equations, involve multiple steps, and result in

fractional solutions.

This level of correlation was important because it strongly tied the online

homework system to the textbook, thus making it possible for students to use the

textbook as a resource while they were completing their homework online. This

correlation represented a significant strength of this particular online homework system

as it related to this study which was meant to compare the effectiveness of the online

homework to the textbook homework.

Each online homework problem was algorithmically generated. For each

individual problem, the software generated any number of problems that were of the

same type, difficulty level, and conceptual scope. This allowed students to practice the

same type of problem as many times as they wished until they were satisfied with their

results. For instance, one time a student would be asked to solve $7(3x+9) = 11 - (x+3)$

and the next time (if they answered this question incorrectly or if they just wanted

additional practice) the student would be asked to solve $7(5x+9) = 18 - (x+9)$. These

two problems are of the same type, difficulty, and scope. The algorithmic programming was capable of producing as many new similar problems as the student needed.

Feedback and Assistance

After attempting problems, students need feedback on their efforts. The types of feedback that are available vary from system to system. The most basic, and almost universal, type of feedback tells the student whether they have answered the problem correctly or not. The system used in this study offers this type of feedback along with encouraging remarks such as "Good Job" or "Way to Go".

The next level of feedback, which is referred to as diagnostic feedback, provides students with instructional directions when they provide incorrect answers (Appendix A). This type of feedback can range from very simple to very complex. The simplest forms of diagnostic feedback result when the software is programmed to respond to one or two of the most common mistakes students often commit for a given problem. For instance, when solving equations involving square roots it is common for students to omit one of the solutions because they forgot the negative case. The software would watch for this omission and then, upon identifying it, would provide students with the hint to "remember to include the negative case." More complex forms of diagnostic feedback try to offer feedback on all types of mistakes and offer this feedback in a sequential and directive fashion. The online homework system used in this study tried to identify several of the most common mistakes and then tried to provide students with instructional hints to help them understand and correct their errors.

The online homework system used in this study offered students a variety of tutorial options. Each homework problem within the system was accompanied, via hyperlink, by an interactive "Help Me Solve This Problem" option and a descriptive "Show Me a Similar Problem" option. The "Help Me Solve This Problem" option directed students through the problem and asked them to answer intermediate questions that led to the solution of the problem. Using this option, students could have the computer help them solve the problem for zero homework credit. To get credit, they must then solve a similar problem on their own. The "Show Me a Similar Problem" option showed students a completely worked out solution to a problem that was similar in type, difficulty, and scope. Each homework problem was also accompanied by a hyperlink that allowed students to immediately send email questions to the instructor and a hyperlink that automatically took students to the proper section in an electronic version of the textbook. Finally, selected questions were accompanied by hyperlinks which took students to digital video lectures and animations that described the concepts found in a particular homework problem. A screenshot of a typical online homework problem (Appendix A) shows the tutorial options that are available.

The feedback and tutorial assistance that are available within an online homework system are critical in helping students gauge their level of understanding and find ways to improve their level of understanding (Tuckman & Sexton, 1992; Zerr, 2007). A strength of the online homework system used in this study was that it provided prescriptive feedback to students along with resources they could use to increase their understanding.

Students were given information and the opportunity to control their learning based on that information.

Reattempt the Homework Problems

The OHW system used in this study immediately graded each individual homework problem within a homework set. If a student got a problem incorrect they were able to rework different versions (see *Problem Creation* section for an example of different versions of the same problem) of that problem as many times as they wished and still receive credit for a correct answer as long as the homework deadline had not passed. Essentially, the OHW system allowed the students to achieve and demonstrate mastery if they wished. They were not forced to rework incorrect problems if they did not want to. This aspect of the OHW system gave students more control over their learning, especially when compared to traditional textbook based approaches.

Technological Considerations

As with any technological tool used in education, there are issues that must be dealt with. For mathematics, one issue relates to the input of mathematical symbols and notation. This is no small hurdle and has been found to be problematic in other research studies (Jacobson, 2006). The OHW system used in this study made use of a palette of common symbols. This palette included the most common symbols relating to algebraic computations: exponents, fractions, ordered pairs, radicals, etc. Using a palette-based approach is preferable to using a command-line approach because students are able to see

their mathematical objects as they would appear in math textbooks. The screenshots (Appendix A) show the typical palette used in the system.

Graphing is another challenge for online learning systems. Graphing tools were provided within the current OHW system. These tools made it easy for students to complete the most common graphical tasks found in algebra. Students were able to graphs individual points, lines, and curves.

How the OHW system handled equivalent expressions is another challenge. In algebra, it is not uncommon for a problem solution to be represented in multiple forms. Usually there exists a preferred standard form that is the "best". The OHW system used in this study attempted to identify equivalent forms. If one form was preferred over another, then the system informed students that they had the correct answer but it was not in the correct form and then gave them the opportunity to resubmit.

Access to Grades

While using the OHW system, students had electronic access to their overall course grades and their individual assignment grades. In this way, students were always aware of their academic standing within the class. This information allowed them to make immediate adjustments to their learning strategies. A screenshot of a partial student grade report is provided (Appendix A).

Instructors were able to manually edit any score within the system. This made it easier for instructors to compensate for grading limitations within the software.

Instructional Setting

Organization of Classes

This study took place during the Fall 2008 semester at Salt Lake Community

College (SLCC), a large, western community college with enrollment of nearly 25,000.

The institution awards nearly 3,000 Associates Degrees and 200 certificates and diplomas

annually. Students take an average of 8.5 credit hours per semester, with 13% of the

students taking more than 13 credit hours per semester. The institution has a student to

faculty ratio of 21.4 and an average class size of 19.13 (SLCC Institutional Research,

2006).

During a typical Fall semester the math department teaches more than 30 sections

of college algebra, each with a maximum of 35 students. Four sections of college algebra

formed the treatment group and completed OHW and five sections of college algebra

formed the control group and completed THW. All participating instructors volunteered

to be part of this study, but were not randomly assigned to either the treatment or control

group. If the instructor was already using OHW in their class they were included in the

treatment group and if the instructor was already using THW in their class then they were

included in the control group.

All sections of college algebra at this community college were supervised and

organized by a departmental course coordinator. The coordinator created a common

course syllabus and schedule (Appendix B) that included a day-to-day content schedule, a

testing schedule, and a detailed list of homework problems that were to be assigned in

each section. This common syllabus/schedule created homogeneity between all of the

sections of college algebra on campus, ensuring that the same material was taught at the same pace of instruction in each section. The traditional college algebra topics were covered: solving equations, graphing functions, factoring polynomials, using exponential and logarithmic functions, solving systems of equations, and matrices. All of the treatment and control sections participating in this study followed this common syllabus and schedule.

The treatment and control sections of this study were lecture-based. Instructors spent four contact hours each week delivering content to students in the traditional lecture format. Most of the class time was devoted to lecture where the instructor taught concepts and provided examples; however, some class time was available to answer student questions. Some class periods were also used for chapter reviews and exams. Overall, the course was traditional in its practices toward delivering and assessing college algebra content.

Homework

The activities that took place during class time were similar for both the treatment and control groups. The one area that was different was the mode of delivery for the homework problems, the subject of this study. While both the treatment and control groups were assigned homework after each textbook section, the treatment group accessed their homework using an online homework system and the control group completed problems directly from the textbook. The assigned problems consisted of traditional skill-based and concept-based questions. The homework problems that were assigned to the control and treatment groups were similar in degree of difficulty, depth of

content coverage, and breadth of content coverage as has been previously described. The textbook and online homework problems were chosen by the course coordinator by going through the problems one-by-one in order to make sure that the same types of problems were present in both the online and textbook homework assignments.

The online homework system used by the treatment group presented problems to the students, offered them some tutorial assistance if needed, and immediately graded the problems. These problems consisted of multiple-choice, short-answer, and true-false questions, with a majority falling into the short answer category. The computer system automatically graded each homework assignment and kept track of how much time a student spent working a particular assignment. If the student got a problem incorrect, they were given the option to rework a similar version of the problem for full credit. They could rework as many similar versions of the problem as they wished before the homework due date until they were satisfied. However, they were not required to rework any problems if they so chose. The OHW system allowed students to develop mastery at their discretion. The homework grade was the percentage of correct problems. The homework grade, overall course grade, and the time spent on the assignment were always accessible, via the internet, to the instructor and the student.

The control group completed their homework out of the text using an assigned list of problems. The solution to each odd-numbered problem was available to the student in the appendices of the textbook so that they might self-grade their work. A solution manual was also available that showed students the complete, worked-out solutions to each odd-numbered problem. Students were able to rework the problem as many times as

they wished before the homework due date until they were satisfied with their results and level of understanding. This opportunity to rework the problems until they got the correct answer was completely optional to the student. Graded homework, which consisted of teacher comments on a small subset of the homework problems, was returned to the students 5 to 7 days after it had been submitted. The homework grade was sometimes calculated based on the percentage of correct problems and other times calculated based on the percentage of completed problems.

The homework grade did contribute to the final course grade. The final course grade was calculated using homework and exam scores. The exam problems were similar to the homework problems. Students were told that the best way to do well on the exams was to complete and understand the assigned homework. Because of the departmental course coordination, students in both the treatment and control groups took the same number of exams covering the same material. The final exam was the same for all students in all sections of college algebra.

Participating Instructors

The instructors who taught the treatment and control sections of this study were fulltime and adjunct faculty that had been assigned, trained, and supervised by the mathematics department. Four instructors taught the treatment sections and three instructors taught the control sections. The participating instructors each had at least a master's degree in mathematics and between 5 and 25 years of college algebra teaching experience. The instructors teaching the OHW sections all had previous experience with

the software and were familiar with its capabilities and limitations. In addition, they were experienced in introducing students to the system and helping them learn to use it effectively.

Controlling and Identifying Instructor-related Effects

Because of the institutional circumstances of the mathematics department, multiple instructors were involved in teaching the control and treatment sections. While this imposed some limitations on the study and may have introduced an instructor-related effect, efforts were made to minimize and control for this effect by having all instructors work from a common syllabus, a common schedule, and administer a common final exam. Therefore, each instructor covered the same material at approximately the same pace.

The researcher attempted to control and/or identify instructor-related effects by conducting classroom observations of all treatment and control sections during weeks 6 and 10 of the semester. The purpose of these observations was to confirm that the course content was similar in structure and approach and, if not similar, identify ways in which they were different. A modified version (omitting the sections on Description of Room and Reference Made To Science Related Topics) of the Case Studies in Science Education Classroom Observation Checklist (Stake, 2006) was used (Appendix C). This checklist contained questions pertaining to various pedagogical approaches, teacher aims, and use of knowledge and consisted of 19 Likert-style questions scored on a scale from one to four. After completing the observations, member checking with the instructors was used to confirm or clarify the checklist scoring. The researcher discussed the checklist

scoring with each instructor following the class period in order to determine if the typical

characteristics of the day-to-day classroom environment were being identified.

Study Participants

The participants in this study were college algebra students at SLCC, a large,

western community college. Students were allowed to enroll in college algebra if they

passed the prerequisite math course (Intermediate Algebra) with at least a C grade or

better, or if they achieved an acceptable score on the college placement test or the ACT.

If students failed to meet these requirements they were strongly discouraged from

enrolling in college algebra. However, students who did not meet these minimal

requirements were still allowed to enroll because the institution did not have a mandatory

prerequisite policy in place. It was not possible to determine how many, if any,

participating students fit into this category.

For the 2005-2006 academic year (the most recent statistics available), the

participating community college reported 14.2% of their students classified as minority,

51% of the students were male, and 61.3% of their students were below 25 years of age

(SLCC Institutional Research, 2006).

Nine total sections of college algebra participated in this study. The classes were

held at various times throughout the day. As per the quasi-experimental design of the

study, students were not randomly assigned to the treatment and control sections. Rather,

students enrolled in sections of college algebra that fit their schedule or other preferences.

Some students may have enrolled in sections of college algebra with or without the prior

knowledge that either OHW or THW was to be used. No students were aware of the

research study until the first day of class. However, on the first day of class all students

learned that they were either in an OHW or a THW section. At this point they had three

options: remain in the class and participate in the study, remain in the class and not

participate in the study, or switch to a different section of their choice. Students choosing

to switch sections could then choose from nearly thirty other regular sections of college

algebra offered at various times. As far as the researcher could determine, based on initial

enrollment data and conversations with instructors, no students switched to different

sections after the beginning of class to avoid one type of homework or the other.

Institutional Review Board

Approval from the appropriate institutional review board was obtained prior to the

beginning of this study. The community college Mathematics Department was given a

letter of information (Appendix D) describing the purposes, procedures, expectations, and

risks of the study and agreed to assist with this study contingent upon IRB approval. The

participating instructors were given letters of information (Appendix E) describing the

purposes, procedures, expectations, and risks pertaining to their role in the study.

Students were also given an informed consent document to complete and sign to signify

their understanding and willingness to participate in this study (Appendix F).

Variables and Data Collection

The independent variables in this study were Homework Type which had two

levels: *Online Homework* (OHW) and *Textbook Homework* (THW); Incoming Skill Level

which had two levels: *Low* (LP) and *High* (HP); and, finally, College Algebra Attempts

which had two levels: *First-time Student* (FS) and *Repeating Student* (RS).

Homework Type

Students were assigned a Homework Type as described above.

Incoming Skill Level

Skill level was conceptualized as the amount of college algebra prerequisite

knowledge which a student possessed at the beginning of the semester. Incoming skill

level was determined using a math skills pretest. This pretest was meant to determine

each student's knowledge of the mathematical skills that were considered to be

prerequisite to college algebra. Select questions were taken from the intermediate algebra

(the prerequisite course to college algebra) final exam and were used by the researcher to

create the pretest. Based on the scores from this pretest, students were divided into two

groups. The median pretest score was calculated and the pretest scores were divided into

two, roughly equal groups based on a near approximation of the median. The group of

students receiving scores below the approximate median dividing point was classified as

having a Low Level of Preparation (LP). The group of students receiving scores above

the approximate median dividing point was classified as having a High Level of

Preparation (HP). This categorization method was inspired by another study examining

the differentiated effects of an experimental treatment on self-efficacy (Jackson, 2002). Jackson divided his experimental groups into three equal-sized groups based on pretest scores. These groups were then given a treatment designed to improved self-efficacy. Self-efficacy was then measured and the results were compared to see if differential effects existed.

College Algebra Attempts

A short demographic survey was given at the beginning of the semester to determine, among other things, the number of attempts each student had previously made to pass college algebra. Based on the survey results, students were classified as a First-time Student (FS) or as a Repeating Student (RS).

The dependent variables in this study were Mathematical Achievement and Mathematics Self-Efficacy.

Mathematical Achievement

This variable was measured using a paper-and-pencil final exam. All participants in both treatment and control groups completed the same departmental final exam. The math skills pretest scores were used to establish a baseline for the control and treatment groups so that the final exam scores could be used to measure the relative rate of gain of mathematical achievement for both groups.

Mathematics Self-Efficacy

This variable was conceptualized as a student's beliefs about their abilities to successfully complete math problems, everyday math tasks, and tasks related to

collegiate math courses. This variable was measured using the Mathematics Self-Efficacy

Scale (MSES) (Betz & Hackett, 1983a) at the beginning of the semester using a pretest

and again at the end of the semester using a posttest.

Instrumentation

The instruments used in this study included a demographic survey (included with

the MSES pretest), a college algebra prerequisite skills pretest, the mathematics self-

efficacy survey (pretest and posttest), a classroom observation checklist, and the common

departmental final exam.

Demographic Survey

A short demographic survey was included with the MSES pretest and was

administered during the first week of the semester in order to gather basic information

from each student. A critical part of this survey asked students to report how many times

they have taken college algebra. When the MSES was administered as a posttest at the

end of the semester, the demographic survey was replaced by a self-report question

asking students to estimate average number of hours per week spent doing homework.

College Algebra Prerequisite Skills Pretest

The purposes of the pretest were to identify initial differences, if any, between the

treatment and control sections in this study and to measure student's incoming

prerequisite mathematics skills. Based on the scores of the pretest, students were divided

into two ability groups. These ability groups formed the basis for answering the

secondary research questions. The prerequisite course for college algebra is intermediate algebra; therefore, the questions on the pretest were all taken from the common departmental final exam for intermediate algebra. The questions on the pretest were selected based on the results from pilot testing the pretest with college algebra and intermediate algebra students and with the assistance from members of the mathematics department. This pretest included 20 questions and was administered during week two of the semester (Appendix G).

Mathematics Self-Efficacy Survey

The Mathematics Self-Efficacy Survey (Betz & Hackett, 1983a) was used to measure self-efficacy (Appendix H). This is an instrument designed to measure the mathematics self-efficacy of community college students. This scale contained 34 questions and used Likert-style responses, ranging from 0 to 9, based on degrees of disagreement and agreement. This instrument was designed to assess students' confidence in their abilities to successfully complete math problems, everyday math tasks, and tasks related to collegiate math courses. The self-efficacy pretest asked students to assess their confidence levels prior to taking the college algebra course. The self-efficacy posttest asked students to assess their confidence levels after taking the college algebra course. The purpose of the pretest was to identify any initial differences in mathematics self-efficacy that might exist between the treatment and control sections. The purpose of the posttest was to measure the changes in self-efficacy that have resulted from the online homework treatment. The MSES was administered at the beginning of

the semester during week one of the semester and at the end of the semester during week fifteen.

Classroom Observation Checklist

Twice during the semester, once during week 6 and once during week 10, the researcher visited each participating classroom and made informal observations. The Classroom Observation Checklist was used to guide this visit and to identify the basic functioning of the class. The checklist was adapted from the CSSE Classroom Observation Checklist and used a 4-point Likert response scale to identify the basic pedagogies, teacher aims, knowledge use, and time allocation of each class. The results of the observations were used to help control instructor-related effects by identifying any significant differences that existed in the classes.

Common Departmental Final Exam

At the end of the semester all college algebra students were given a common departmental final examination. The purpose of this exam was to measure the mathematical achievement of college algebra students. This exam consisted of 10 multiple choice questions and 15 "show-your-work" open-ended questions (Appendix I). The "show-your-work" questions were graded using a common grading rubric in order to facilitate consistency. The exam was developed by the mathematics department over the course of several years. The questions of the exam were chosen in order to assess students' understanding of the essential concepts of college algebra. Through trial-and-error the department refined to exam to be as comprehensive and discriminatory as

possible. The department has not kept year to year statistics on the effectiveness of the exam but believes that it represents an adequate measure of college algebra learning.

Procedures

During the first two weeks of class all students completed an informed consent document, a short demographic survey to determine if they were first-time or repeating students, a mathematics self-efficacy pretest, and a mathematical prerequisite (intermediate algebra) skills pretest. Exploratory analysis of the results of both pretests was performed to determine the initial equality of the treatment and control groups.

The mathematical prerequisite skills pretest was used to categorize students according to their incoming skill level. The pretest scores were sorted and divided into two groups. Based on this division, students were categorized as having either a low (below the approximate median) or high (above the approximate median) level of preparation.

Additionally, during the first two weeks of class, students in the treatment group were introduced to the online homework system and trained in its use. Students were shown how to log in to the system and access their homework assignments. Students were also shown how to understand the automated feedback, make use of the tutorial assistance, and access their online homework grades.

Throughout the sixteen-week semester, students in the treatment group completed their homework using the online homework system. Students in the control group completed their homework directly from the textbook. Both groups had a common list of

problems that they were expected to complete. The online homework problems that were assigned were similar in number, difficulty, and scope to the homework problems found in the textbook.

During weeks 6 and 10 of the semester the researcher completed classroom observation visits of each section in order to identify similarities or differences in teaching approaches. During these visits the researcher completed the Classroom Observation Checklist in order to assess the various pedagogical approaches used during the class period, the aims of the teacher, and the use of knowledge. The results of these observations were compared in order to identify possible instructor effects. If significant differences between classes were found the researcher planned to report and discuss these differences in order to allow for a proper interpretation of the results of the study.

Two weeks before the end of the semester all students completed a mathematics self-efficacy posttest. Finally, during the last week of the semester all students completed the common, departmental final exam.

Statistical Analyses

Independent samples *t* tests and factorial analysis were used to test each null hypothesis and to explore the secondary research questions. A significance level of .05 was used throughout this study. This level is common in many educational research studies (Cohen, 2001). In order to answer Research Question 1 an independent samples *t*-test was used to compare the mean final exam scores of the treatment and control groups. In order to answer Research Questions 1a and 1b, a 2 x 2 x 2 (Homework Type: OHW,

THW x Incoming Skill Level: LP, HP x College Algebra Attempts: FS, RS) factorial three-way ANOVA was used to compare the mean final exam scores of each design group. This three-way ANOVA identified the significance of any main effects, identified the significance level of the Homework Type x Incoming Skill Level interaction effect, and identified the significance level of the Homework Type x College Algebra Attempts interaction effect as it related to mean final exam scores.

In order to answer Research Question 2 independent samples *t* tests were used to first determine if mathematics self-efficacy changed significantly for the treatment and control groups and then to compare the pretest to posttest changes in mathematics self-efficacy of the treatment and control groups. In order to answer Research Questions 2a and 2b, a 2 x 2 x 2 (Homework Type: OHW, THW x Incoming Skill Level: LP, HP x College Algebra Attempts: FS, RS) factorial three-way ANOVA was used to compare the pretest to posttest changes in mathematics self-efficacy scores of each design group. This three-way ANOVA identified the significance of any main effects, identified the significance level of the Homework Type x Incoming Skill Level interaction effect, and identified the significance level of the Homework Type x College Algebra Attempts interaction effect as it related to changes over time in mathematics self-efficacy scores.

Null Hypothesis 1

The results from an independent samples *t* test were used to test this hypothesis. However, the literature suggested that interaction effects on mathematics achievement may exist between Homework Type, Incoming Skill Level, and College Algebra Attempts (Jacobson, 2006; Pintrich & DeGroot, 1990). If interaction effects did exist then

they would make it difficult to interpret the main effects of Homework Type on Mathematics Achievement. Therefore, a three-way ANOVA was used to identify any interaction effects. If significant interaction effects were not found, then the results from the *t* test and the Homework Type main effect results from the three-way ANOVA could be interpreted without concern, leading to a rejection or a failure to reject Null hypothesis 1.

Null Hypothesis 2

The results from an independent samples *t* test were used to test this hypothesis. However, the literature suggested that interaction effects on mathematics self-efficacy may exist between Homework Type, Incoming Skill Level, and College Algebra Attempts (Jackson, 2002). If interaction effects did exist then they would make it difficult to interpret the main effects of Homework Type on Mathematics Self-Efficacy. Therefore, a three-way ANOVA was used to identify any interaction effects. If significant interaction effects were not found, then the results from the *t* test and the Homework Type main effect results from the three-way ANOVA could be interpreted without concern, leading to a rejection or a failure to reject Null hypothesis 2.

Secondary Research Questions

The secondary research questions (1a, 1b, 2a, and 2b) were answered using the interaction results of both of the previous three-way ANOVAs.

To determine if there was a differential effect of the treatment, in terms of mathematical achievement, on students of different skill levels (Research Question 1a)

the significance of the interaction between Homework Type and Skill Level was identified from the three-way ANOVA. If this interaction was significant or marginally significant, then *a priori* post-hoc *t* tests (comparing LP OHW to LP THW and HP OHW to HP THW) were performed to determine which means were significantly different and which incoming skill-level group received the most benefit from the treatment.

To determine if there was a differential effect of the treatment, in terms of mathematical achievement, on students with different numbers of college algebra attempts (Research Question 1b) the significance of the interaction between Homework Type and College Algebra Attempts was identified from the three-way ANOVA. If this interaction was significant or marginally significant, then *a priori* post-hoc *t* tests (comparing FS OHW to FS THW and RS OHW to RS THW) were performed to determine which means are significantly different and which college algebra attempts group received the most benefit from the treatment.

To determine if there was a differential effect of the treatment, in terms of mathematics self-efficacy change over time, on students of different skill levels (Research Question 2a) the significance of the interaction between Homework Type and Skill Level was identified from the three-way ANOVA. If this interaction was significant or marginally significant, then *a priori* post-hoc *t* tests (comparing LP OHW to LP THW and HP OHW to HP THW) were performed to determine which score changes were significantly different and which incoming skill-level group received the most benefit from the treatment.

To determine if there was a differential effect of the treatment, in terms of mathematics self-efficacy change over time, on students with different numbers of college algebra attempts (Research Question 2b) the significance of the interaction between Homework Type and College Algebra Attempts was identified from the three-way ANOVA. If this interaction was significant or marginally significant, then *a priori* post-hoc *t* tests (comparing FS OHW to FS THW and RS OHW to RS THW) were performed to determine which score changes were significantly different and which college algebra attempts group received the most benefit from the treatment.

CHAPTER IV

RESULTS

This study examined the effectiveness of online homework (OHW) as compared to textbook homework (THW) relating to mathematical achievement and mathematics self-efficacy. Two primary research questions were answered: (a) how did mathematical achievement compare for students who completed OHW and for students who completed THW and (b) how did the change in mathematics self-efficacy over one semester compare for students who completed OHW and for students who completed THW. Secondary research questions, which considered differential effects for groups with different skill levels and groups of first-time and repeating students, were also answered.

This chapter describes the demographics of the students participating in this quasi-experiment. Attrition analysis is performed to establish the similarity of the students who withdrew from the study and the students who completed the study. The similarity of the control (THW) and treatment (OHW) groups is established, in terms of math prerequisite knowledge and mathematics self-efficacy, using independent *t* tests. The similarity between the participating class sections of college algebra is established, in terms of math prerequisite knowledge and mathematics self-efficacy, using one-way ANOVA analysis. Additionally, the similarity between the participating class sections of college algebra is discussed in terms of data gathered during classroom observations.

The research questions are answered using comparative analysis of final exam scores and changes in mathematics self-efficacy (SEC). Incoming skill level and number of college algebra attempts are controlled for in order to answer the secondary research

questions. Results relating to other key data collected from the students at the end of the semester are explored. This additional data includes (a) the self-reported, average time spent on homework each week, (b) the final letter grades earned by each student who completed the course, and (c) responses from students in the treatment (OHW) group regarding their willingness to take another course which uses OHW and their suggestions for improvements.

Comparisons of Participants

At the beginning of the Fall 2008 semester, 203 students agreed to participate in the study, 122 in the control (THW) group and 81 in the treatment (OHW) group. Consistent with the quasi-experimental design of this study, the students were not randomly assigned to either the control or treatment groups. The control (THW) and treatment (OHW) groups were similar in demographic makeup. The ratio of males to females was approximately 1:1 for both groups and the ratio of first time to repeating students was approximately 2:1 for both groups. The demographic distribution of the all participating students who began the study is presented in Table 2.

Table 2

Distribution of All Participating Students Who Began the Study

Group	n	Male	Female	First Time	Repeating
Control (THW)	122	60	62	81	41
Treatment (OHW)	81	45	36	53	28

During the semester, attrition occurred when students either officially or unofficially withdrew from the college algebra section in which they were enrolled. Therefore, at the end of the semester 85 students had completed the course and the study in the THW group and 60 students had completed the course and the study in the OHW group.

The following comparisons are meant to establish the initial similarity of the groups involved in the study and are divided into three main subsections: (a) the students who withdrew from the study are compared to the students who remained in the study, (b) the students who completed the study in the control group are compared to the students who completed the study in the treatment group, and (c) the students who completed the study are compared based on their individual class sections.

Comparison of Students Who Withdrew from
and Students Who Completed the Study

Some attrition occurred during the study. Approximately 28% of the students who began the study withdrew from class and, therefore, withdrew from the study. According to the best knowledge of the class instructors, none of the students withdrew from class because of the research study. Instead, the students seemed to withdraw for a variety of reasons, ranging from academics to scheduling, unrelated to the study. Other students unofficially withdrew and stopped coming to class and turning in assignments. In the following analysis, all of these students who withdrew from the class are referred to as having withdrawn from the study.

Comparisons were made between the students who withdrew from the study and the students who completed the study. These comparisons were meant to determine if there was a difference between these groups that might be related to and affect the research study. For instance, if many students dropped out of the online homework sections then that might indicate a personal preference held by these students for a class that used textbook homework or a class that did not have the distractions of an ongoing research study. It could also be possible that the withdrawal of students significantly changed the characteristics of the sample. For instance, if many high-skilled students dropped out then that might lead to changes in the final exam comparisons which could skew the study results. Therefore, the researcher compared the students who withdrew from the study and the students who completed the study by first comparing the attrition rates of the THW and OHW groups and then comparing their math skills pretest and mathematics self-efficacy pretest means.

Comparison of attrition rates of the THW and OHW groups. Overall, the attrition rate was 28.6%, with the THW group experiencing an attrition rate of 30.3% and the OHW group experiencing an attrition rate of 25.9%. A two-sample proportion z-test was performed to determine if one group experienced more attrition than the other. The analysis yielded $z = 0.68$ and $p = 0.50$, indicating that the two attrition rates were not significantly different. Therefore it does not appear that students made their choice to withdraw from class based on the homework type used in the class.

Comparison of prerequisite math skills. The College Algebra Prerequisite Skills Pretest scores were used to establish that similar levels of prerequisite math skills existed

between the students who withdrew from the study and the students who completed the study.

An independent samples *t* test was conducted to compare the initial math skills of the two groups. The results from the test provided evidence supporting the assumption that the withdrawing and completing students possessed similar levels of prerequisite math skill at the beginning of the semester. Table 3 reports the math skills pretest means and standard deviations for these groups. Analysis of the *t* test follows the table.

Table 3

Math Skills Pretest Scores for Withdrawing and Completing Students

Group	*n*	Mean	*SD*
Withdrawing Students	58	53.79	15.76
Completing Students	145	56.14	16.88

Prior to the independent samples *t* test, Levine's Test was used to test the equality of variances. This test yielded an $F(57, 144) = 0.446$ and $p = 0.505$. Since the *p*-value was greater than 0.05, it was assumed that the variances were equal and the appropriate *t*-test results were calculated.

The *t*-test comparison of the math skills pretest means yielded a calculated $t(201) = -0.911$ and $p = 0.364$ which was not significant at $\alpha = 0.05$. This result indicated that the withdrawing and completing students possessed approximately equal prerequisite skills at the beginning of the study.

Comparison of mathematics self-efficacy. The Mathematics Self-Efficacy Survey

Pretest scores were used to evaluate the degree of similarity of mathematics self-efficacy

that existed between the withdrawing and completing students.

An independent samples *t* test was conducted to compare the initial mathematics

self-efficacy of the two groups. The results from the test indicated that the groups did not

possess statistically significant different levels of mathematics self-efficacy. Table 4

reports the mathematics self-efficacy pretest data for all withdrawing and completing

students. Analysis of the *t* test follows the table.

Table 4

Mathematics Self-Efficacy Pretest Scores for Withdrawing and Completing Students

Group	*n*	Mean	*SD*
Withdrawing Students	57	209.54	39.14
Completing Students	143	213.34	44.85

Some students failed to answer more than three of the survey questions and, thus,

their individual survey was invalidated as indicated in the instruction manual that

accompanies the mathematics self-efficacy instrument (Betz & Hackett, 1993). The

invalidation of these scores led to a slightly smaller sample size for this comparison. Prior

to the independent samples *t* test, Levine's Test was used to test the equality of variances.

This test yielded an $F(56, 142) = 3.547$ and $p = 0.061$. Since the *p*-value was greater than

0.05, it was assumed that the variances were equal and the appropriate *t*-test results were

calculated.

The *t*-test comparison of the mathematics self-efficacy survey pretest means yielded a calculated $t(198) = -0.559$ and $p = 0.577$ which was not significant at $\alpha = 0.05$. This result indicates that there was not a statistically significant difference between the two self-efficacy pretest means.

Comparison of Students Who Completed the Study

During the course of the semester natural attrition occurred when students withdrew from the class officially or unofficially. It was not possible to gather final exam scores and mathematics self-efficacy scores from these students; therefore, the data used to answer the research questions came from the smaller sample of students who actually finished the class and completed the study. A comparison of completing students was performed in order to determine if there were any significant differences between the control and treatment groups. After removing the withdrawn students, the ratios of male to female students and first time to repeating students remained approximately equal to what they were when all students were considered. Table 5 contains the demographic data for the students who ultimately completed the study.

Table 5

Distribution of Participating Students

Group	*n*	Male	Female	First Time	Repeating
Control (THW)	85	40	45	50	35
Treatment (OHW)	60	32	28	39	21

Math skills pretest and mathematics self-efficacy pretest means were also compared for those students who completed the study. It was felt that this was necessary in order to establish the initial similarity of the experimental groups. It was found that both the THW and OHW groups demonstrated similar levels of prerequisite math skills and mathematics self-efficacy. Tables 6 and 7 display the pretest means and standard deviations for the participating students. The groups' mean scores were compared using independent samples *t* tests and the results are analyzed following the tables.

Table 6

College Algebra Prerequisite Skills Pretest Scores for Participating Students

Group	*n*	Mean	*SD*
Control (THW)	85	55.65	17.91
Treatment (OHW)	60	56.83	15.43

Prior to the *t* test, Levine's Test was used to test the equality of variances. This test yielded an $F(84, 59) = 1.205$ and $p = 0.274$. Since the *p*-value was greater than 0.05, it was assumed that the variances were equal and the appropriate *t*-test results were calculated.

The *t*-test comparison of the math skills pretest means of the experimental groups yielded a calculated $t(143) = -0.416$ and $p = 0.678$, which was not significant at $\alpha = 0.05$. This result supports the assumption that there was no statistically significant difference

between the two pretest means, and that the students in the THW and OHW groups

possessed approximately equal prerequisite math skills.

Table 7

Mathematics Self-Efficacy Pretest Scores for Participating Students

Group	n	Mean	*SD*
Control (THW)	85	208.61	45.60
Treatment (OHW)	58	220.26	43.19

Levine's Test was used to test the equality of variances. This test yielded an $F(84,$

$57) = 0.311$ and $p = 0.578$. Since the p-value was greater than 0.05, it was assumed that

the variances were equal and the appropriate t-test results were calculated.

The t-test comparison of the mathematics self-efficacy pretest means yielded a

calculated $t(141) = -1.532$ and $p = 0.128$, which was not significant at $\alpha = 0.05$. This

result supports the assumption that there was no statistically significant difference

between the two pretest means, and that the students in the THW and OHW groups

possessed approximately equal levels of beginning mathematics self-efficacy.

Comparison Between Individual Class Sections

Nine sections of college algebra, being taught by a total of seven different

instructors, were involved in this study. The large number of instructors introduced the

possibility of instructor-related effects and necessitated the following comparisons

between class sections in order to establish their initial similarity. By comparing the math

skills pretest means and the mathematics self-efficacy pretest means for each section to

Table 8

Section Enrollments and Pretest Means for Participating Students

		Prerequisite Math Skills Pretest		Mathematics Self-Efficacy Pretest	
Section	Enrollment	Mean	*SD*	Mean	*SD*
Sections Using Textbook Homework					
1	15	57.00	20.42	207.53	50.74
2	17	53.82	19.89	205.59	49.26
3	18	53.89	15.49	207.11	44.58
4	20	53.50	19.54	202.75	43.78
5	15	61.33	13.95	222.73	42.83
Sections Using Online Homework					
6	9	65.56	13.33	202.88	45.85
7	11	59.09	8.89	223.91	35.90
8	12	50.83	22.24	201.08	57.47
9	28	55.71	13.86	232.44	34.75

each of the other sections, using a one-way ANOVA, it was determined that no

significant differences existed between any sections at the beginning of the study. Table 8

shows the number of students who completed the study for each class section and the

mean scores and standard deviations for each pretest.

Comparison of math skills pretest means. A one-way ANOVA analysis was used to compare the prerequisite math skills pretest means of all the sections of college algebra. The results of the analysis showed that the pretest means were similar for all participating sections. The results of the analysis are shown in Table 9 with a narrative interpretation following.

Table 9

ANOVA for Math Skills Pretest Means Compared by Section

Source	Sum of Squares	*df*	Mean Square	*F*	Sig. (*p*)
Between Groups	.197	8	.025	.859	.553
Within Groups	3.906	136	.029		
Total	4.104	144			

The ANOVA test comparing the individual college algebra sections' math skills pretest means yielded a calculated $F(8, 136) = 0.859$ with $p = 0.553$. Since the *p*-value was greater than 0.05, this result indicated that there was no significant difference between the math skills pretest means of the different class sections. Thus, each section was comparable to each of the other sections in terms of prerequisite math skills at the beginning of the study.

Comparison of mathematics self-efficacy pretest means. A separate one-way ANOVA analysis was used to compare the mathematics self-efficacy pretest means of all the sections of college algebra. The results of the analysis showed that the pretest means

were similar for all participating sections. The results of the analysis are shown in Table

10 with a narrative interpretation following.

Table 10

ANOVA for Mathematics Self-Efficacy Pretest Means Compared by Section

Source	Sum of Squares	*df*	Mean Square	*F*	Sig. (*p*)
Between Groups	19554.209	8	2444.276	1.231	.286
Within Groups	266105.7	134	1985.863		
Total	285659.9	142			

The ANOVA test comparing the individual college algebra sections' mathematics

self-efficacy pretest means yields a calculated $F(8, 134) = 1.231$ with $p = 0.286$. Since the

p-value was greater that 0.05, this result indicated that there was no significant difference

between the mathematics self-efficacy pretest means of the different class sections. Thus,

each section was comparable to each of the other sections in terms of mathematics self-

efficacy at the beginning of the study.

Results of classroom observations. During the semester, two visits were made by

the researcher to each class section in order to observe the day-to-day instructional

approaches. The Classroom Observation Checklist (COC) was used during these visits to

document the pedagogical strategies of the instructor, the aims of the teacher, the use of

knowledge, and the allocation of time. Based on these observations it was determined

that no significant differences existed in instructional approaches that would bias the

ultimate results. A narrative discussion of the results is presented here.

In the area of pedagogical strategies, each instructor consistently employed large amounts of objective-based, problem-oriented, and operations/drill infused instruction. During each classroom visit, the researcher observed the instructors teaching basically the same material from the common syllabus, thus demonstrating a commitment to achieving the same educational objectives. All of the instructors used key math problems as a way to introduce and explore more general mathematical rules instead of declaring the rules and then letting students discover problems to fit the rules. Finally, all of the instructors expected their students to be able to learn the material through drill and practice. The other categories found in the Pedagogical Section of the COC (text orientation, test orientation, experiential learning, the rules-first approach, subject integration, and diversions) were not used at all or only a small amount of the time in each classroom.

The Teacher Aims section of the COC measured the extent to which the instructor employed didactic (lecture-based) approaches, heuristic (discovery-based) approaches, or philetic (student-centered) approaches. Overwhelmingly, each instructor employed the didactic, lecture-based approach to instruction. Basically no time was spent using discovery or student-centered approaches.

The primary method used to convey knowledge and help students learn information was measured in the Knowledge Use section of the COC. Each instructor emphasized replicative and interpretive approaches to help their students understand. Instructors provided examples and then expected their students to duplicate the problem solving approaches shown. Additionally, the instructors questioned students and encouraged them to interpret and explain their results and processes. Small amounts of

time were spent trying to help students develop associations between new knowledge and previously acquired knowledge. During the classroom visits none of the instructors tried to encourage students to solve math problems by using content from other academic disciplines.

Finally, the Time Allocation section of the COC measured how instructors spent their class time. During each observational visit, the vast majority of time was devoted to instruction and only small amounts of time were spent discussing other educational and non-educational topics.

Summary of Comparisons

Taken together, the previous comparisons indicate that there was no significant difference between the students who withdrew from the study and the students who completed the study. In addition, the control (THW) and treatment (OHW) groups were similar at the beginning of the study. Therefore, it was concluded that both groups possessed similar prerequisite math skills and similar levels of mathematics self-efficacy in addition to experiencing similar classroom environments. Establishing the similarity between the control and treatment groups in a quasi-experimental study is essential in order to be able to accurately attribute subsequent differences to the treatment employed in the study.

Research Questions

Two main research questions relating to the main effects of the treatment were answered in this study. Each of the main research questions was accompanied by a null

hypothesis that was tested using the collected data. Additionally, each main research question was accompanied by two secondary research questions relating to the interaction effects of the treatment. Additional exploratory analysis was also completed which examined select data gathered from the participants.

Research Question 1

Is there a significant difference in mathematical achievement between college algebra students who complete online homework and students who complete traditional textbook-based homework?

Null hypothesis. The null hypothesis associated with this research question claims that the mean final exam score of college algebra students who complete online homework is not significantly larger than the mean final exam score of college algebra students who complete textbook homework.

To test the null hypothesis, an independent sample *t* test was initially used which compared the final exam means of the THW and the OHW groups for all students who completed the final exam, and thus completed the study. It was found that neither group significantly outperformed the other on the common, departmental final exam. Therefore, the researcher failed to reject the null hypothesis and concluded that college algebra students who completed online homework did not outperform college algebra students who completed textbook homework. Table 11 displays the final exam means and standard deviations for both experimental groups. The results from the *t* test are reported following the table.

Table 11

Final Exam Scores

Group	n	Mean	*SD*
Control (THW)	85	60.12	21.76
Treatment (OHW)	60	65.40	19.98

Levine's Test was used to test the equality of variance and resulted in $F(84, 59) =$ 0.623 and $p = 0.431$, indicating that equal variances could be assumed. The t test resulted in a calculated $t(143) = -1.487$ and $p = 0.139$ indicating that there was no significant difference between the final exam means of the students who completed the class in the THW group and the students who completed the class in the OHW group. The effect size of the treatment was also calculated using Cohen's d and found to be $d = 0.253$. This indicated that the OHW treatment had a "small" effect, using Cohen's terminology, on the final exam scores of the OHW treatment group (Cohen, 2001).

Retrospective power analysis was performed to assess the *post-hoc* power of the *t*-test. Statistical power can be thought of as the likelihood of obtaining a significant result when, in fact, there is one. The power is related to sample size, alpha level, and effect size and can be increased by increasing any of these factors (Cohen, 2001). Assuming that the effect size cannot be manipulated by the researcher and that the alpha level is largely based on typical values, the only factor that can usually be manipulated is the sample size. However, in this study it was not possible to increase the sample size. The power of the test was calculated to be 0.32. The results of the analysis indicated that the minimum difference between the THW and OHW final exam means which could have

been detected using the given sample size was 6.99 points. The analysis also indicated

that the required sample size which would have been necessary in order for the actual

observed difference to be significant was $n = 254$. These results indicate that this study

could have benefitted from increases in any of the factors related to power

Cohen (2001) cautions that treatment effects, such as the treatment effect

examined in this study between Homework Type and Mathematics Achievement, may be

obscured by the interaction effects of moderating variables. These interactions may make

it difficult to properly interpret the main effects. The research literature relating to the

effectiveness of online homework suggests that a student's incoming skill level may be

one such moderating variable that produces an interaction effect (Jacobson, 2006). The

researcher was also interested in determining whether the number of times a student had

previously attempted the college algebra class acted as an interacting moderating

variable. This particular variable was considered important because a significant

percentage of college algebra students tend to be retaking the class.

Therefore, in light of the insignificant differences found using the previous *t* test

and because of the interest and concern over the interaction effects introduced by

moderating variables, the researcher felt that it was important to perform a three-way (2 x

2 x 2) factorial ANOVA which could both reaffirm the previous main effect results and

identify possible interaction effects. The results of the three-way ANOVA are reported in

Table 12.

Table 12

Three-Way ANOVA for Final Exam Scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig. (p)
Corrected Model	10993.048	7	1570.435	4.034	.000
Intercept	501487.294	1	501487.294	1288.297	.000
Homework Type	473.300	1	473.300	1.216	.272
Skill Level	6752.674	1	6752.674	17.347	.000
Attempts	63.993	1	63.993	.164	.686
HW Type*Skll Lvl	1194.680	1	1194.680	3.069	.082
HW Type*Attempts	69.003	1	69.003	.177	.674
Skll Lvl*Attempts	349.021	1	349.021	.897	.345
HW Type*Skll Lvl*Attempts	248.161	1	248.161	.638	.426
Error	53329.134	137	389.264		
Total	627246.300	145			
Corrected Total	64322.182	144			

The three-way (2 x 2 x 2) factorial ANOVA was used to examine the effects

which the three factors, Homework Type, Incoming Skill Level, and College Algebra

Attempts, had on the dependent variable, the final exam mean. Each of the factors had

two levels: Homework Type was divided into Textbook Homework (THW) and Online

Homework (OHW), Incoming Skill Level was divided into Low Level of Preparation

(LP) and High Level of Preparation (HP), and College Algebra Attempts was divided into

First Time Student (FS) and Repeating Student (RS). The levels for Homework Type and

College Algebra Attempts are self-explanatory. However, the levels for Incoming Skill

Level need some explanation. To determine whether a student was an LP or an HP

student, an approximate median split was used on the math skills pretest data. The

median for the math skills pretest was calculated and a number was chosen which was

close to that median which would allow for the creation of two, approximately equal-

sized, groups. This approach was considered the optimal approach given the sample size

of students involved in the study and the theoretical requirements of the factorial

ANOVA which recommend equally-sized subgroup cells. To establish that the LP and

HP groups, constructed using the median split, did possess different levels of prerequisite

math skills and, therefore, met the requirements of the study design necessary to answer

the research questions relating to skill level, an independent samples t test was used. The

mean pretest score for all of the students in the LP group was 43.07 and the mean pretest

score for all of the students in the HP group was 70.14. An independent samples t test

was used to compare these means and resulted in $t(142) = -16.269$ and $p < 0.001$. These

results suggested that the two groups had significantly different math skills at the

beginning of the study and their pretest scores were not clustered about the median. Other

methods for creating the LP and HP groups were considered but were rejected because

they led to small and unevenly distributed sample sizes. The alternative methods for

creating these skill-level groups which were considered and then rejected used z-scores

(the LP group consisted of the students with pretest z-scores less than negative one and

the HP group consisted of the students with pretest z-scores greater than positive one) and

percentiles (the LP group consisted of the students with pretest scores below the 33rd percentile and the HP group consisted of the students with pretest scores above the 66th percentile).

The results of the three-way ANOVA found no significant main effects of any of the factors on final exam means. Additionally, no significant interaction effects were found between Homework Type and Incoming Skill Level and no significant interaction effects were found between Homework Type and College Algebra Attempts. However, the interaction between Homework Type and Incoming Skill Level was marginally significant and, therefore, motivated further exploration.

The three-way ANOVA was used to identify the significance of main and interaction effects on final exam means. The main effect related to Homework Type was of primary interest and yielded a calculated $F(1, 137) = 1.216$ and $p = 0.272$, which reaffirms the previous result that the treatment did not have a significant effect on final exam scores. The significant main effect related to Incoming Skill Level, with $F(1, 137) = 17.347$, $p = 0.000$, was largely unimportant because it was completely expected that students with different incoming skill levels, regardless of homework type, would have significantly different final exam scores. If anything, this significant result suggested that students' pretest scores were highly correlated with their final exam scores and that the validity threat related to regression to the mean may have only been minor. The main effect related to College Algebra Attempts, $F(1, 137) = 0.164$ and $p = 0.686$, was insignificant and led to the interpretation that first time and repeating college algebra

students did not perform differently on the final exam when all other factor were
controlled for.

However, the proper interpretation of the main effects is influenced by the level of
significance of the interaction effects. Because none of the interaction effects (the three,
two-way interactions and the single, three-way interaction) were significant the main
effects could reliably be interpreted as insignificant. The interaction effects that were
suggested by the literature and chosen *a priori* to be relevant in this study were
Homework Type X Incoming Skill Level, with a calculated $F(1, 137) = 3.069$ and $p = 0.082$, and Homework Type X College Algebra Attempts, with a calculated $F(1, 137) = 0.177$ and $p = 0.674$. While neither interaction was significant at the 0.05 level, the
Homework Type X Incoming Skill Level interaction was considered to be marginally
significant and deserving of further exploration because it indicated that LP and HP
students might be affected differently by the OHW treatment. While both *a priori*
interactions were considered while answering the secondary research questions, 1a and
1b, the Homework Type X Incoming Skill Level interaction was more deeply explored
because of its marginal significance.

Pair-wise Groupings Necessary to Answer
Secondary Research Questions

The three-way (2 x 2 x 2) ANOVA performed previously produced many results
that could be examined further. However, it was decided *a priori* that certain results were
significant to this study and would be examined closely while other results would be
ignored. In particular, it was relevant to this study to determine how certain groups

compared to one another. These pair-wise comparisons were needed in order to answer the secondary research questions relating to the differential effects of OHW. The groups of interest are listed in Table 13 and will be subsequently be referred to by their Pair Name or Notational Name to lessen confusion.

Table 13

Pair-wise Comparison Groups Relevant to the Secondary Research Questions

Pair Name	Descriptive Name	Notational Name
Pair A	Low Skilled Students using Textbook Homework vs. Low Skilled Students using Online Homework	LP THW vs. LP OHW
Pair B	High Skilled Students using Textbook Homework vs. High Skilled Students using Online Homework	HP THW vs. HP OHW
Pair C	First Time Students using Textbook Homework vs. First Time Students using Online Homework	FS THW vs. FS OHW
Pair D	Repeating Students using Textbook Homework vs. Repeating Students using Online Homework	RS THW vs. RS OHW

The final exam means for each of these selected groups are presented in Table 14. These means form the basis for answering Research Questions 1a and 1b below.

Table 14

Mean Final Exam Scores for Select Group Comparisons

Pair		Mean	*SD*	*n*
Pair A	LP THW	51.28	19.06	47
	LP OHW	61.25	19.48	28
Pair B	HP THW	71.07	20.03	38
	HP OHW	69.03	20.01	32
Pair C	FS THW	62.03	21.49	50
	FS OHW	65.08	18.92	39
Pair D	RS THW	57.41	22.18	35
	RS OHW	66.00	22.31	21

Research Question 1a

Is there a differential effect of the online homework treatment, in terms of mathematical achievement, for college algebra students with different incoming skill levels?

To answer Research Question 1a, two questions were considered: (a) for students with low incoming skill levels was the use of OHW more beneficial than THW, in terms of final exam scores (i.e. was there a difference between the final exam means of the groups in Pair A [LP THW vs. LP OHW]) and (b) for students with high incoming skill

levels was the use of OHW more beneficial than THW, in terms of final exam scores (i.e. was there a difference between the final exam means of the groups in Pair B [HP THW vs. HP OHW]). It was felt that answering these questions would provide insight into the marginal interaction effect found in the previous factorial ANOVA where the F-score and p-value of the Homework Type x Incoming Skill Level were found to be $F(1, 137) = 3.069$ and $p = 0.082$.

Before these questions could be answered it was necessary to establish the similarity, in terms of prerequisite math skills, of the groups in Pair A. Additionally, it was necessary to establish the similarity, in terms of prerequisite math skills, of the groups in Pair B. This was necessary because the median split used to create the skill-level groups could have led to groups that were very different in terms of prerequisite math skills. This dissimilarity would have made t-test comparisons of final exam means difficult to interpret. Therefore, independent samples t tests that compared math skills pretest means were performed. The t test used to compare the pretest means of the groups in Pair A yielded $t(73) = -0.311$ and $p = 0.757$. This indicated that the groups in Pair A possessed similar prerequisite math knowledge. The t test used to compare the pretest means of the groups Pair B yielded $t(68) = 1.47$ and $p = 0.146$. This indicated that the groups in Pair B possessed similar prerequisite math knowledge. Because the groups possessed similar levels of perquisite math knowledge it was felt that their final exam means could be compared in order to answer the questions regarding interaction effects.

The final exam means for each of the groups in Pairs A and B are shown in Table 15 and Table 16. It can be seen from the tables that the LP OHW students scored higher

on the final exam than the LP THW students, by a group mean of almost ten points.

However, the HP OHW students actually scored lower on the final exam than the HP

THW students, by a group mean of approximately two points. This difference suggests

that the LP students were affected differently than the HP students by the OHW

treatment. For each pair, a *t* test was performed to identify whether the differences in

their means were significant. The results of the tests showed that there was a significant

difference between the final exam means of Pair A and there was not a significant

difference between the final exam means of Pair B. The results of each test are reported

after their respective tables.

Table 15

Final Exam Means for Pair A

	Mean	*SD*	*n*	
LP THW	51.28	19.06	47	
LP OHW	61.25	19.48	28	

Prior to the *t* test used to compare the final exam means of the LP THW and the

LP OHW groups of Pair A, Levine's Test was performed. The results of the test, $F(46,$

$27) = 0.028$ and $p = 0.867$, indicated that the equality of variances could be assumed. The

t test resulted in a $t(73) = -2.174$ and $p = 0.033$ which was significant at the 0.05 level.

This indicated that there was a significant difference, in favor of OHW, between the final

exam means of the LP THW and LP OHW groups. The effect size of the treatment was

also calculated using Cohen's *d* and found to be $d = 0.526$. This indicated that the OHW

treatment had a "medium" effect, using Cohen's terminology, on the final exam scores of

the LP OHW treatment group (Cohen, 2001).

Table 16

Final Exam Means for Pair B

	Mean	SD	n
HP THW	71.07	20.03	38
HP OHW	69.03	20.01	32

Prior to the *t* test used to compare the final exam means of the HP THW and the

HP OHW groups of Pair B, Levine's Test was performed. The results of the test, $F(37,$

$31) = 0.055$ and $p = 0.815$, indicated that the equality of variances could be assumed. The

t test resulted in a $t(68) = 0.424$ and $p = 0.673$ which was not significant at the 0.05 level.

This indicated that there was not a significant difference between the final exam means of

the HP THW and HP OHW groups. The effect size of the treatment was also calculated

using Cohen's *d* and found to be $d = -0.103$. This indicated that the OHW treatment did

not even have a "small" effect, using Cohen's terminology, on the final exam scores of

the HP OHW treatment group (Cohen, 2001).

The fact that there was a significant difference in the final exam means of Pair A

and not a significant difference in the final exam means of Pair B reinforces the

possibility of an interaction effect between Homework Type and Incoming Skill Level.

Additionally, the large differences in effect sizes indicated that the LP group seemed to

be affected differently by the OHW treatment than the HP group. Lastly, a profile plot

showing the marginal means for the Homework Type X Incoming Skill Level block was created. The plot is shown in Figure 1 and, because the lines are not parallel, provides more supporting evidence of, at least a marginal, interaction effect. Thus, to answer Research Question 1a, it was determined that there was a marginal differential effect of the online homework treatment, in terms of mathematical achievement, for college algebra students with different incoming skill levels.
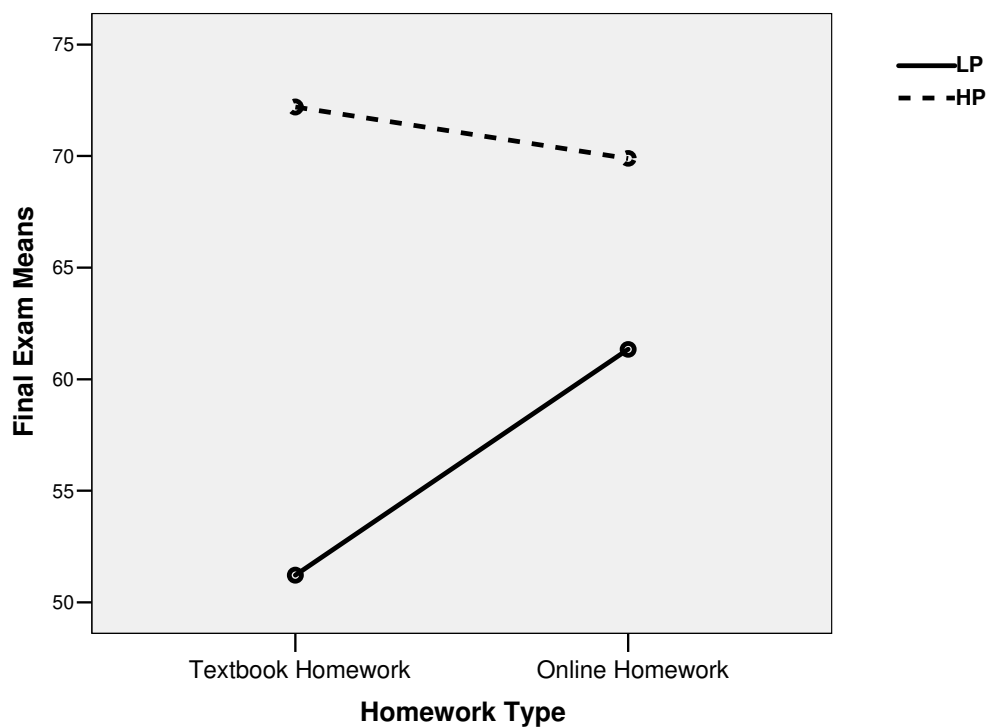

Figure 1. Profile plot for final exam means of Low Incoming Skill Level Students (LP) and High Incoming Skill Level Students (HP) who used Textbook Homework and Online Homework.

Research Question 1b

Is there a differential effect of the online homework treatment, in terms of mathematical achievement, for first-time and repeating college algebra students?

The official answer to this question, based on the previous three-way factorial ANOVA, with a calculated $F(1, 137) = 0.177$ and $p = 0.674$ for the Homework Type X College Algebra Attempts interaction related to final exam means, was determined to be that there was not a differential effect. The following analysis was performed for exploratory purposes in order to understand why no differential effect was found, despite the fact that the literature suggested that one may exist. Additionally, the researcher felt that the following analysis may indicate possible sources of interaction which could be studied in the future. While levels of significance for each of the following tests are reported, they cannot be and were not used to make declarations of significance relative to the research question because of the increased possibility of making Type I errors.

With regard to Research Question 1b, two questions were considered: (a) for first time students was the use of OHW more beneficial than THW, in terms of final exam scores (i.e. was there a difference between the final exam means of the groups in Pair C [FS THW vs. FS OHW]); and (b) for repeating students was the use of OHW more beneficial than THW, in terms of final exam scores (i.e. was there a difference between the final exam means of the groups in Pair D [RS THW vs. RS OHW]). It was felt that the answers to these questions would provide insight into the differential effects considered in Research Question 1b.

Before these questions could be answered it was necessary to establish the similarity, in terms of prerequisite math skills, of the groups in Pair C. Additionally, it was necessary to establish the similarity, in terms of prerequisite math skills, of the groups in Pair D. Therefore, independent samples *t* tests, which compared math skills pretest means, were performed. The *t* test used to compare the pretest means of the groups in Pair C yielded a $t(87) = -0.478$ and a $p = 0.634$. This indicated that the groups in Pair C possessed similar prerequisite math knowledge. The *t* test used to compare the pretest means of the groups in Pair D yielded a $t(54) = 0.117$ and a $p = 0.907$. This indicated that the groups in Pair D possessed similar prerequisite math knowledge. Because the initial similarity, in terms of prerequisite math skills, of the groups had been established it was felt that they could then be compared, in terms of final exam means, in order to further explore the interaction effects.

The final exam means for each of the groups in Pairs C and D are shown in Table 17 and Table 18. It can be seen from the tables that the FS OHW students scored higher on the final exam than the FS THW students, by a group mean of approximately 3 points. Additionally, it can be seen from the tables that the RS OHW students scored higher on the final exam than the RS THW students, by a group mean of more than 8 points. Because the OHW students in both groups outscored the THW students in both groups it appears as if the OHW treatment affected the FS and the RS students to similar degrees. For each pair, a *t* test was performed to identify whether the differences in their means were significant. The results of the tests showed that there was not a difference between

the final exam means of the groups in either Pair C or D. The results of each test are

reported after their respective tables.

Table 17

Final Exam Means for Pair C

	Mean	*SD*	*n*
FS THW	62.03	21.49	50
FS OHW	65.08	18.92	39

Prior to the *t* test used to compare the final exam means of the FS THW and the

FS OHW groups of Pair C, Levine's Test was performed. The results of the test, $F(49,$

$38) = 0.812$ and $p = 0.370$, indicated that the equality of variances could be assumed. The

t test resulted in a $t(87) = -0.699$ and $p = 0.486$ which was not significant at the 0.05

level. This indicated that there was not a difference between the final exam means of the

FS THW and FS OHW groups. The effect size of the treatment was also calculated using

Cohen's *d* and found to be $d = 0.151$. This indicated that the OHW treatment did not have

even a "small" effect, using Cohen's terminology, on the final exam scores of the FS

OHW treatment group (Cohen, 2001).

Table 18

Final Exam Means for Pair D

	Mean	*SD*	*n*
RS THW	57.41	22.18	35
RS OHW	66.00	22.31	21

Prior to the *t* test used to compare the final exam means of the RS THW and the RS OHW groups of Pair D, Levine's Test was performed. The results of the test, $F(34, 20) = 0.042$ and $p = 0.839$, indicated that the equality of variances could be assumed. The *t* test resulted in a $t(54) = -1.401$ and $p = 0.167$ which was not significant at the 0.05 level. This indicated that there was not a difference between the final exam means of the RS THW and RS OHW groups. The effect size of the treatment was also calculated using Cohen's *d* and found to be $d = 0.394$. This indicated that the OHW treatment had between a "small" and a "medium" effect, using Cohen's terminology, on the final exam scores of the RS OHW treatment group (Cohen, 2001).

The above detailed exploration largely reinforces the previous conclusion that there was not a differential effect of the online homework treatment, in terms of mathematical achievement, for first-time and repeating college algebra students. However, the calculated effect sizes seemed to indicate that the RS group may have been slightly more affected by the OHW treatment than the FS group. No peculiarities were found which might point researchers in the direction of the source of a possible hidden interaction.

Research Question 2

Is there a significant difference in mathematics self-efficacy change (SEC) over one semester between college algebra students who complete online homework and students who complete traditional textbook-based homework?

Null hypothesis. The null hypothesis associated with this research question claims that the mean difference between posttest and pretest mathematics self-efficacy scores

(SEC) over one semester of college algebra of students who complete online homework

is not significantly larger than the mean difference between posttest and pretest

mathematics self-efficacy scores (SEC) over one semester of students who complete

textbook-based homework.

Testing the null hypothesis was accomplished in two steps: (a) determine if the

mean SEC within each group was significant (e.g. did the OHW group score significantly

higher on their posttest than on their pretest) and (b) determine if the mean SEC between

each group was significantly different (e.g. was the mean SEC of the THW group

different from the mean SEC of the OHW group). The first question addressed the issue

of whether or not the mean pretest-to-posttest change in self-efficacy for the THW group

or the mean pretest-to-posttest change in self-efficacy for the OHW group was even

significant. The researcher felt that unless mathematics self-efficacy actually changed

over the course of the semester, it was of little value to determine if one group

experienced more change than the other group. The second question directly addressed

the null hypothesis related to Research Question 2. In other words, the answer to the

second question would determine which group experienced more change in their

mathematics self-efficacy.

To determine if the SEC of the THW group was actually significant, a t test was

used to compare the mathematics self-efficacy pretest mean to the mathematics self-

efficacy posttest mean of the THW group. The results, $t(71) = 4.352$ and $p < 0.001$,

indicated that the THW group did significantly improve their mathematics self-efficacy.

To determine if the SEC of the OHW group was actually significant, a *t* test was used to compare the mathematics self-efficacy pretest mean to the mathematics self-efficacy posttest mean of the OHW group. The results, $t(53) = 3.780$ and $p < 0.001$, indicated that the OHW group did significantly improve their mathematics self-efficacy.

Therefore, it was concluded that both groups experienced significant changes to their mathematics self-efficacy and, therefore, it was reasonable to try and determine which group experienced the greater change.

An independent sample *t* test was used which compared the mean SEC of the THW and the OHW groups for all students who completed the final exam, and thus completed the study. It was found that there was no significant difference between the mean SEC experienced by either group. This indicated that, although both groups experienced significant improvements in their mathematics self-efficacy, neither group improved significantly more than the other. Therefore, the researcher failed to reject the null hypothesis and concluded that college algebra students who completed online homework experienced similar levels of SEC as did college algebra students who completed textbook homework. Table 19 shows the SEC mean and standard deviations for both experimental groups. The results from the *t* test are reported following the table. It should be noted that the sample sizes in the table are smaller because some students failed to take the posttest and other students had their posttest results invalidated because they were incomplete.

Table 19

Mean Mathematics Self-Efficacy Change (SEC)

	Mean	*SD*	*n*
THW	16.89	32.93	72
OHW	12.37	24.05	54

Levine's Test was used and resulted in $F(71, 53) = 3.89$ and $p = 0.051$, indicating that equal variances could be assumed. The *t* test resulted in a calculated $t(124) = 0.852$ and $p = 0.396$, indicating that there was no significant difference in mean SEC scores for the students who completed the class in the THW group and the students who completed the class in the OHW group. The effect size of the treatment was also calculated using Cohen's *d* and found to be $d = -0.155$. This indicated that the OHW treatment did not have even a "small" effect, using Cohen's terminology, on the SEC of the OHW treatment group (Cohen, 2001).

Retrospective power analysis was performed to assess the *post-hoc* power of the *t*-test. Statistical power can be thought of as the likelihood of obtaining a significant result when, in fact, there is one. The power is related to sample size, alpha level, and effect size and can be increased by increasing any of these factors (Cohen, 2001). Assuming that the effect size cannot be manipulated by the researcher and that the alpha level is largely based on typical values, the only factor that can usually be manipulated is the sample size. However, in this study it was not possible to increase the sample size. The power of the test was calculated to be 0.13. The results of the analysis indicated that the minimum difference between the THW and OHW mean SEC that could have been

detected using the given sample size was 10.44 points. The analysis also indicated that the required sample size which would have been necessary in order for the actual observed difference to be significant was $n = 672$. These results indicate that this study could have benefitted from increases in any of the factors related to power.

To assess the internal consistency reliability of the Mathematics Self-efficacy Survey, Cronbach's α was calculated using the actual student responses from both the pretest and posttest. The alpha for the complete pretest was found to be 0.95, with the alpha for Part I being 0.92 and the alpha for Part II being 0.95. The alpha for the complete posttest was found to be 0.94, with the alpha for Part I being 0.93 and the alpha for Part II being 0.94. These values are consistent with those reported by the creators of the instrument: 0.96 for the total scale, 0.92 for Part I, and 0.92 for Part II (Betz & Hackett, 1983a).

The previous cautions, discussed when answering Research Question 1, relating to how interaction effects may obscure main effects apply to SEC as well. The researcher felt, based on the literature, that interaction effects might exist between Homework Type and Incoming Skill Level and between Homework Type and College Algebra Attempts.

Therefore, in light of the insignificant differences found between the SEC of the THW group and the SEC of the OHW group and because of the interest and concern that this insignificant difference might be the result of interaction effects, the researcher performed a three-way (2 x 2 x 2) factorial ANOVA which could both reaffirm the previous main effect results and identify possible interaction effects. The results of the three-way ANOVA are reported in Table 20 with a narrative analysis following the table.

Table 20

Three-Way ANOVA for Mean SEC

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig. (*p*)
Corrected Model	6553.958	7	936.280	1.086	.377
Intercept	22994.824	1	22994.824	26.675	.000
Homework Type	727.341	1	727.341	0.844	.360
Skill Level	326.751	1	326.751	0.379	.539
Attempts	2.811	1	2.811	0.003	.955
HW Type*Skll Lvl	413.729	1	413.729	0.480	.490
HW Type*Attempts	651.824	1	651.824	0.756	.386
Skll Lvl*Attempts	2434.429	1	2434.429	2.824	.096
HW Type*Skll Lvl* Attempts	746.184	1	746.184	0.866	.354
Error	101721.756	118	862.049		
Total	136446.000	126			
Corrected Total	108275.714	125			

The three-way (2 x 2 x 2) factorial ANOVA was used to examine the effects which the three factors, Homework Type, Incoming Skill Level, and College Algebra Attempts, had on the dependent variable, mean SEC. As with the previous factorial ANOVA used to answer Research Question 1, each factor had two levels and was coded exactly the same as before (i.e. THW, OHW, LP, HP, FS, and RS).

The results of the three-way ANOVA found no significant main effects of any of the factors on mean SEC. Additionally, no significant interaction effects surfaced. In particular there were no significant interaction effects between Homework Type and Incoming Skill Level and no significant interaction effects between Homework Type and College Algebra Attempts.

The three-way ANOVA was used to identify the significance of main and interaction effects on mean SEC. The main effect related to Homework Type was of primary interest and yielded a calculated $F(1, 118) = 0.844$ and $p = 0.360$ which reaffirms the previous result that the treatment did not have a significant effect on mean SEC. The other main effects related to Incoming Skill Level, with a calculated $F(1, 118) = 0.379$ and $p = 0.539$, and College Algebra Attempts, with a calculated $F(1, 118) = 0.003$ and $p = 0.955$, were also insignificant.

However, the proper interpretation of the main effects is influenced by the level of significance of the interaction effects. Because none of the interaction effects (the three, two-way interactions and the single, three-way interaction) were significant the main effects could reliably be interpreted as insignificant. The interaction effects that were suggested by the literature and chosen *a priori* to be relevant in this study were Homework Type X Incoming Skill Level, with a calculated $F(1, 118) = 0.480$ and $p = 0.490$, and Homework Type X College Algebra Attempts, with a calculated $F(1, 118) = 0.756$ and $p = 0.386$. Neither of these interactions was significant at the 0.05 level. Nevertheless, both of these interactions were explored in order to answer the secondary research questions, 2a and 2b.

Pair-wise Groups Necessary to Answer
Secondary Research Questions

The same pairs (Pair A, Pair B, Pair C, and Pair D) that were discussed when

answering the previous secondary research questions, 1a and 1b, were chosen *a priori*

and were applicable to answering the secondary research questions 2a and 2b. For the

Table 21

Mean SEC Scores for Select Group Comparisons

Pair	Coding	Mean	*SD*	*n*
Pair A	LP THW	16.00	36.78	40
	LP OHW	8.11	27.42	28
Pair B	HP THW	18.00	27.92	32
	HP OHW	16.96	19.29	26
Pair C	FS THW	14.05	31.90	43
	FS OHW	14.45	22.96	33
Pair D	RS THW	21.10	34.54	29
	RS OHW	9.10	25.91	21

convenience of the reader, the pairs are again briefly listed here: Pair A is LP THW vs.

LP OHW, Pair B is HP THW vs. HP OHW, Pair C is FS THW vs. FS OHW, and Pair D

is RS THW vs. RS OHW. The SEC means for each of these selected groups are presented

in Table 21. These means form the basis for answering Research Questions 2a and 2b below.

Research Question 2a

Is there a differential effect of the online homework treatment, in terms of mathematics self-efficacy change over one semester, for college algebra students with different incoming skill levels?

The official answer to this question, based on the previous three-way factorial ANOVA, with a calculated $F(1, 118) = 0.480$ and $p = 0.490$ for the Homework Type X Incoming Skill Level interaction related to SEC, was determined to be that there was not a differential effect. The following analysis was performed for exploratory purposes in order to understand why no differential effect was found, despite the fact that the literature suggested that one may exist. Additionally, the researcher felt that the following analysis may indicate possible sources of interaction which could be studied in the future. While levels of significance for each of the following tests are reported, they cannot be and were not used to make declarations of significance relative to the research question because of the increased possibility of making Type I errors.

With regard to Research Question 2a, two questions were considered: (a) for students with low incoming skill levels was the use of OHW more beneficial than THW, in terms of SEC scores (i.e. was there a difference between the SEC means of the groups in Pair A [LP THW vs. LP OHW]) and (b) for students with high incoming skill levels was the use of OHW more beneficial than THW, in terms of SEC scores (i.e. was there a difference between the SEC means of the groups in Pair B [HP THW vs. HP OHW]). It

was felt than the answers to these questions would provide some insight into the differential effects considered in Research Question 2a.

Before these questions could be answered, it was necessary to determine if each of the included subgroups (LP THW, LP OHW, HP THW, and HP OHW) actually experienced increases in their mathematics self-efficacy over the course of the semester. Independent samples *t* tests were used to compare the mathematics self-efficacy pretest mean to the mathematics self-efficacy posttest mean of each group. All group SEC means and standard deviations, as well as the *t*-test results are presented in Table 22.

Table 22

Mean SEC Within LP and HP Groups

Group	Mean	*SD*	*n*	*t*-score	*p*-value
LP THW	16.00	36.78	40	2.751	0.009
LP OHW	8.11	27.42	28	1.565	0.129
HP THW	18.00	27.92	32	3.647	0.001
HP OHW	16.96	19.29	26	4.483	<0.001

Visual analysis of the SEC means shows that the THW groups achieved higher SEC means than the OHW groups, regardless of skill level. All groups, except the LP OHW group, experienced increases that would normally be considered significant in their mathematics self-efficacy over the course of the semester. This indicated that, on average, all students except those in the LP OHW group became more confident in their abilities to successfully complete mathematical tasks. The single insignificant result was

peculiar and could be interpreted to be the source of some interaction. It is possible that

because this group still showed an increase in SEC the ANOVA analysis did not identify

an interaction. If future research was to be conducted exploring the interaction considered

here, a closer examination of students with low skill levels who were using online

homework might be warranted.

The next step in exploring Research Question 2a was to compare the mean SEC

between the groups in Pair A and the mean SEC between the groups in Pair B. A t test

was used to compare the mean SEC of the Pair A groups and resulted in $t(66) = 0.963$

and $p = 0.339$. The effect size of the treatment was also calculated using Cohen's d and

found to be $d = -0.241$. This indicated that the OHW treatment did not have even a

"small" positive effect, using Cohen's terminology, on the SEC of the OHW treatment

group (Cohen, 2001). In fact, it appears that there is a "small" detrimental effect on the

SEC of the LP OHW treatment group.

A t test was used to compare the mean SEC of the Pair B groups and resulted in

$t(56) = 0.161$ and $p = 0.873$. The effect size of the treatment was also calculated using

Cohen's d and found to be $d = -0.043$. This indicated that the OHW treatment did not

have even a "small" effect, using Cohen's terminology, on the SEC of the HP OHW

treatment group (Cohen, 2001). These results indicate no peculiarities that could point to

possible sources of differential effects.

The above detailed exploration reinforces the previous conclusion that there was

not a differential effect of the treatment on SEC means for college algebra students with

different incoming skill levels. The effect sizes do appear slightly different but it is

difficult to interpret the implications of these differences precisely. Therefore, it appears as if the online homework treatment affected both pairs similarly.

*Research Question 2*b

Is there a differential effect of the online homework treatment, in terms of mathematics self-efficacy change over one semester, for first-time and repeating college algebra students?

The official answer to this question, based on the previous three-way factorial ANOVA, with a calculated $F(1, 118) = 0.756$ and $p = 0.386$ for the Homework Type X College Algebra Attempts interaction related to SEC, was determined to be that there was not a differential effect. The following analysis was performed for exploratory purposes in order to understand why no differential effect was found, despite the fact that the literature suggested that one may exist. Additionally, the researcher felt that the following analysis may indicate possible sources of interaction which could be studied in the future. While levels of significance for each of the following tests are reported, they cannot be and were not used to make declarations of significance relative to the research question because of the increased possibility of making Type I errors.

With regard to Research Question 2b, two questions were considered: (a) for first time students was the use of OHW more beneficial than THW, in terms of SEC scores (i.e. was there a difference between the SEC means of the groups in Pair C [FS THW vs. FS OHW]), and (b) for repeating students was the use of OHW more beneficial than THW, in terms of SEC scores (i.e. was there a difference between the SEC means of the

groups in Pair D [RS THW vs. RS OHW]). It was felt that the answers to these questions would provide insight into the differential effects considered in Research Question 2b.

Before these questions could be answered, it was necessary to determine if each of the included subgroups (FS THW, FS OHW, RS THW, and RS OHW) actually experienced increases in their mathematics self-efficacy over the course of the semester. Independent samples *t* tests were used to compare the mathematics self-efficacy pretest mean to the mathematics self-efficacy posttest mean of each group. All group SEC means and standard deviations, as well as the *t*-test results are presented in Table 23.

Table 23

Mean SEC Within FS and RS Groups

Group	SEC Mean	SEC *SD*	*n*	*t*-score	*p*-value
FS THW	14.05	31.90	43	2.888	0.006
FS OHW	14.45	22.96	33	3.617	0.001
RS THW	21.10	34.54	29	3.291	0.003
RS OHW	9.10	25.91	21	1.609	0.123

Visual analysis of the SEC means shows no consistent pattern of the THW or the OHW groups outgaining the other in terms of SEC. All groups, except the RS OHW group, experienced increases that would normally be considered significant in their mathematics self-efficacy over the course of the semester. This indicated that, on average, all students except those in the RS OHW group became more confident in their abilities to successfully complete mathematical tasks. The single insignificant result was

peculiar and could be interpreted to be the source of some interaction. It is possible that

because this group still showed an increase in SEC the ANOVA analysis did not identify

an interaction. If future research was to be conducted exploring the interaction considered

here, a closer examination of repeating students who were using online homework might

be warranted.

The next step in exploring Research Question 2b was to compare the mean SEC

between the groups in Pair C and the mean SEC between the groups in Pair D. A t test

was used to compare the mean SEC of the Pair C groups and resulted in $t(74) = -0.062$

and $p = 0.951$. The effect size of the treatment was also calculated using Cohen's d and

found to be $d = 0.014$. This indicated that the OHW treatment did not have even a

"small" effect, using Cohen's terminology, on the SEC of the FS OHW treatment group

(Cohen, 2001).

A t test was used to compare the mean SEC of the Pair D groups and resulted in

$t(48) = 1.342$ and $p = 0.186$. The effect size of the treatment was also calculated using

Cohen's d and found to be $d = -0.392$. This indicated that the OHW treatment actually

had a "small" to "medium" detrimental effect, using Cohen's terminology, on the SEC of

the RS OHW treatment group (Cohen, 2001). These results indicate no peculiarities that

could point to possible sources of differential effects.

The above detailed exploration reinforces the previous conclusion that that there

was not a differential effect of the treatment on SEC means for first-time and repeating

college algebra students. The effect sizes do appear slightly different but it is difficult to

interpret the implications of these differences precisely. Therefore, it appears as if the online homework treatment affected both pairs similarly.

Mathematics Self-efficacy and Passing/Failing Final Grade

A final consideration relating to mathematics self-efficacy change concerned whether SEC was different for students who eventually passed the class as compared to students who failed the class. The literature suggested (Pajares & Miller, 1995) that self-efficacy increased when students experienced success. Therefore, the students were grouped based on whether they passed the class and were eligible for college credit (with a grade of A, B, or C) or did not receive a grade that would make them eligible from credit (D, F, or UW). A two-way ANOVA was used to compare the SEC of the groups (ABC THW, DFUW THW, ABC OHW, DFUW OHW). The results of the ANOVA

Table 24

Mean SEC Scores for Credit and Noncredit Earning Students

Final Grade	Mean	SD	n
	Textbook Homework		
ABC	15.76	33.98	49
DFUW	19.30	31.16	23
	Online Homework		
ABC	11.24	22.34	34
DFUW	14.30	26.92	20

indicated that there were no significant differences between the mean SEC of any of the groups. The ABC students actually reported slightly smaller mean SEC than the DEF groups for both the THW and OHW groups. The mean SEC for each group is presented in Table 24 and the results of the ANOVA are given in Table 25.

Table 25

ANOVA for Mean SEC for Credit and Noncredit Earning Students

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.
Corrected Model	945.466	3	315.155	.358	.783
Intercept	25622.955	1	25622.955	29.125	.000
HW Type	633.012	1	633.012	.720	.398
Final Grade	305.268	1	305.268	.347	.557
HWType * Grade	1.638	1	1.638	.002	.966
Error	107330.248	122	879.756		
Total	136446.000	126			
Corrected Total	108275.714	125			

The results, $F(1, 121) = 0.347$ and $p = 0.557$, indicated no significant difference existed between the mean SEC of ABC and DEUW students. This result may have occurred because of a ceiling effect or it may have occurred because some basic assumptions were violated, such as the assumption that student success fosters improved mathematics self-efficacy.

Other Results Critical to Exploratory Analysis

Additional data was collected from each student at the end of the semester in order to provide insight into the issues of this study: (a) how many hours per week on average did each student spend working on college algebra homework, (b) what was the final letter grade each student received for the course, and (c) students in the OHW group were asked if they would ever take another math class that used OHW. This data was used to better understand and interpret the previous results. The data is briefly summarized, without critical analysis, below.

Average Homework Hours per Week

On the mathematics self-efficacy posttest, given at the end of the semester, students were asked to self-report the average number of hours they spent per week doing homework. Students selected from six choices: 0-2 hrs/wk, 3-5 hrs/wk, 6-8 hrs/wk, 9-11 hrs/wk, 12-14 hrs/wk, or 15 or more hrs/wk. This self-reported data was dummy coded (1, 2, 3, 4, 5, or 6) and was considered to be ratio-type data, thus allowing for basic mathematical computations. The mean response for each of the main groups relevant to this study was calculated and used to aid in the interpretation of the results. The researcher did not parse the data down further in order to calculate the mean responses for each of the subgroups (e.g LP THW, LP OHW, etc.). It was felt that because the data was self-reported and because differences in the data would be hard to place practical value upon (e.g. the difference between a response of "1" and a response of "2" could be as much as 5 hours which is a 33% error relative to the scale of the survey) that

comparisons between smaller groups could not be performed reliably. Table 26 shows the mean dummy-coded response from the homework time survey question for each of the main comparison groups relevant to this study.

Table 26

Responses to the Homework Time Survey Question

Main Group	Mean Response	*SD*	*n*
Textbook Homework Group (THW)	3.08	1.26	72
Online Homework Group (OHW)	3.22	1.44	58
Low Skilled Group (LP)	3.15	1.23	68
High Skilled Group (HP)	3.15	1.47	62
First Time Group (FS)	3.39	1.36	80
Repeating Group (RS)	2.76	1.22	50

Additionally, graphs were created which showed the percentage of students in each of the main groups who responded to each category contained in the homework time survey question. Figure 2 shows the percentages for the THW and OHW groups compared to each another. Figure 3 shows the percentages for the LP and HP groups compared to each another. Figure 4 shows the percentages for the FS and RS groups compared to each other.
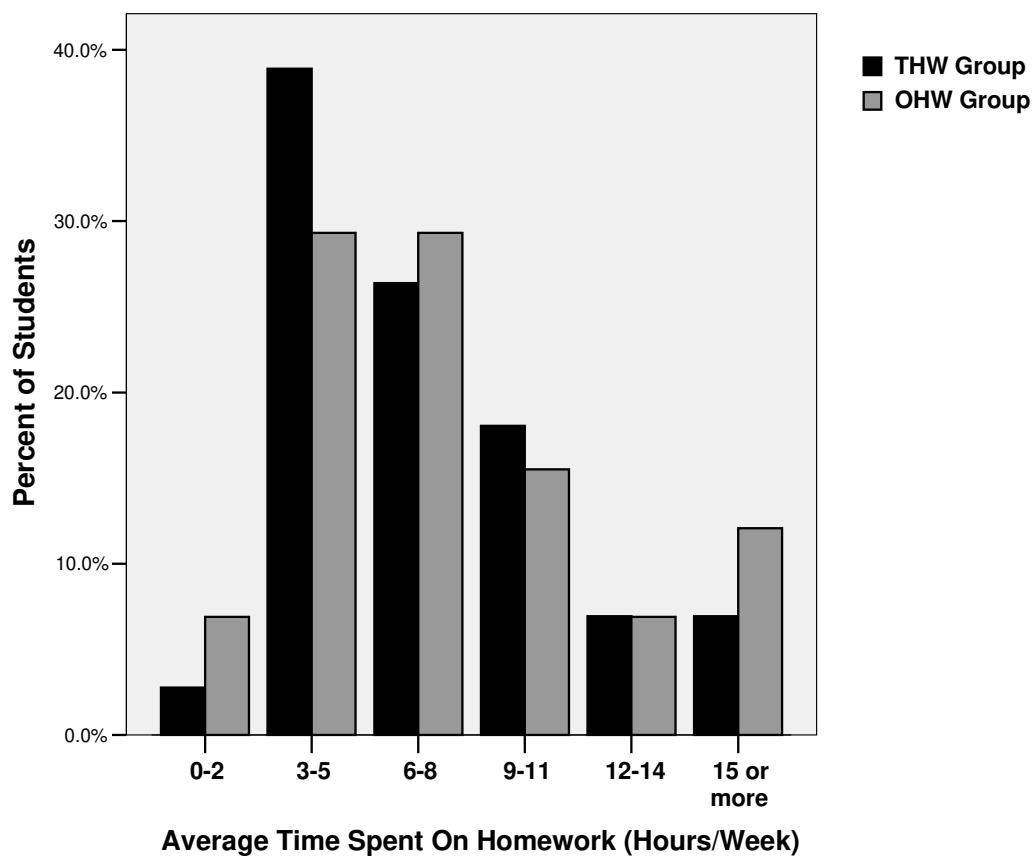
Figure 2. Percent of students from the Textbook Homework (THW) group and the Online Homework Group (OHW) reporting time spent on homework.

Final Letter Grades and ABC Rates

Participating instructors reported the final letter grades of each student at the end of the semester. The percentage of students who received an A, B, or C as their final grade (i.e. the ABC rate) was calculated for each of the main groups and subgroups relevant to this study and was used to aid in the interpretation of the results. Table 27 shows the ABC rates for each of the main groups.

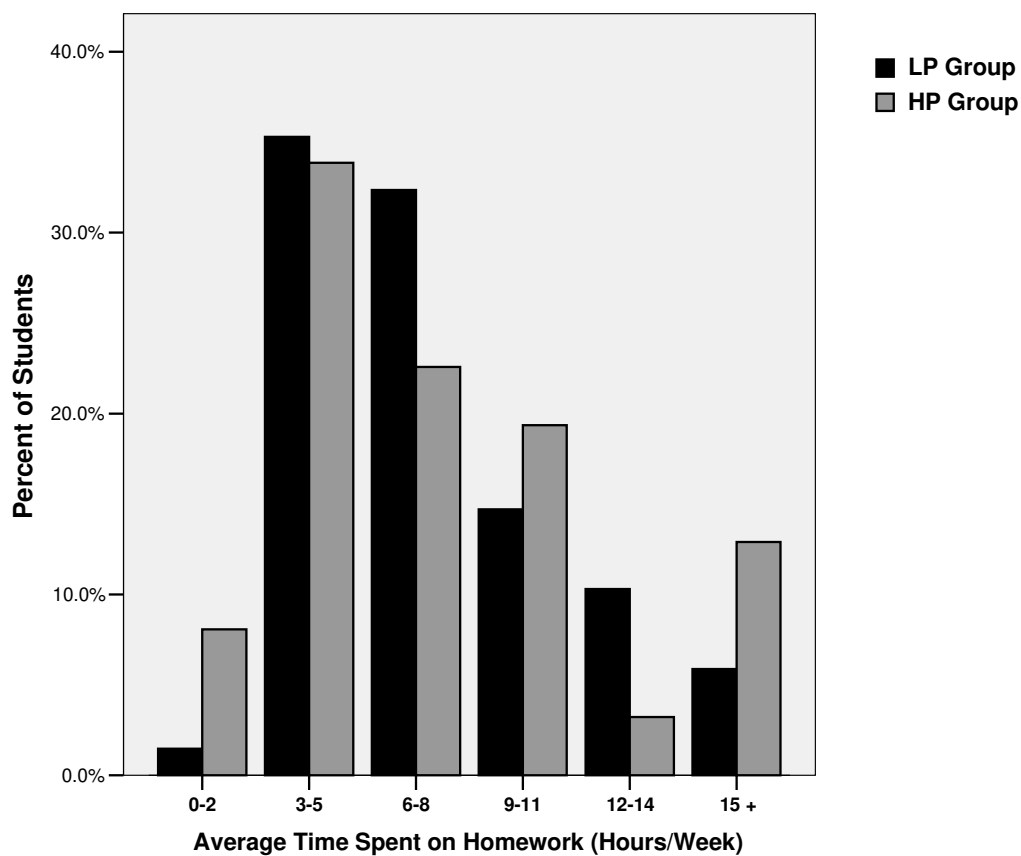*Figure 3*. Percent of students from the Low Incoming Skill Level (LP) group and the High Incoming Skill Level (HP) reporting time spent on homework.

Unlike the data related to homework time, the ABC rates were parsed down in order to describe the smaller subgroups involved in the study. It was felt that this information might aid with the interpretation of the results. Table 28 shows the ABC rates for each of the subgroups.
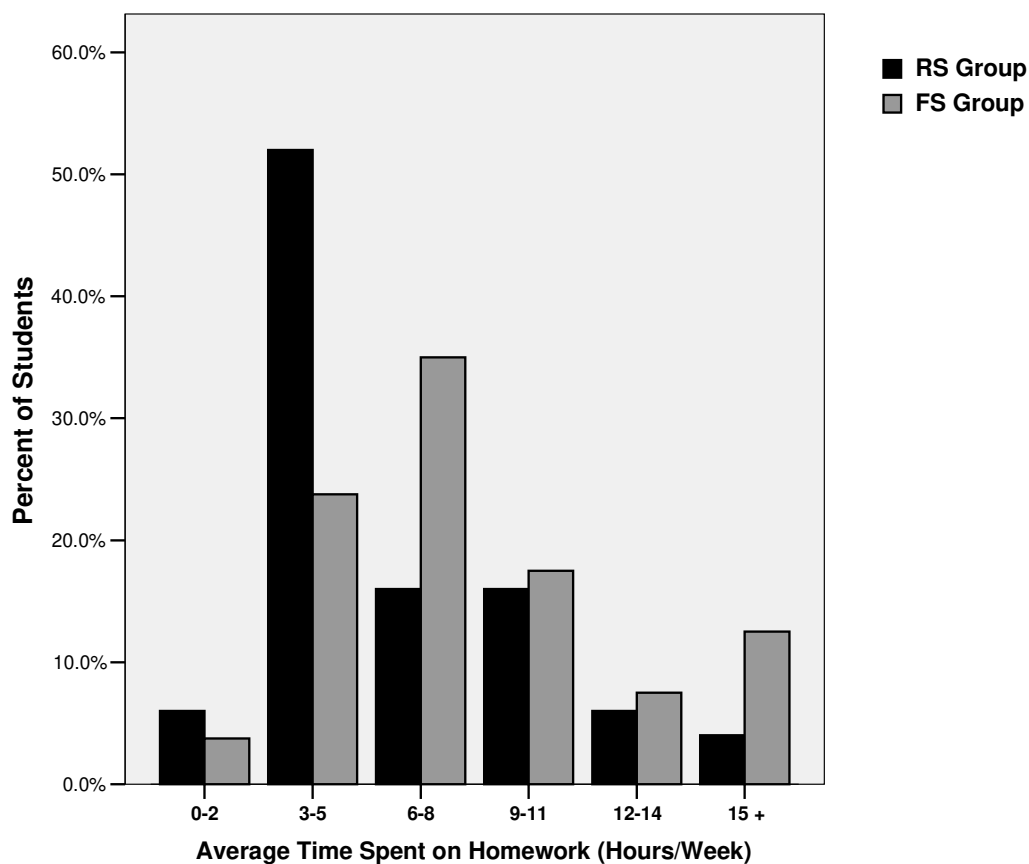
Figure 4. Percent of students from the Repeating Student (RS) group and the First Time Student (FS) group reporting time spent on homework.

Students Willing to Use OHW Again

Each student in the OHW group was asked at the end of the semester if they would ever take another math class which used OHW. Sixty percent of the students responded that they would take another class that used OHW. Twenty-five percent of the students responded that they would not take another class that used OHW.

Table 27

ABC Rates for Relevant Groups

Main Group	ABC Rate	*n*
Textbook Homework Group (THW)	63.5%	85
Online Homework Group (OHW)	65%	60
Low Skilled Group (LP)	52%	75
High Skilled Group (HP)	77.1%	70
First Time Group (FS)	68.5%	89
Repeating Group (RS)	57.1%	56

Table 28

ABC Rates for Subgroups

Subgroup	ABC Rate	*n*
LP THW	48.9%	47
LP OHW	57.1%	28
HP THW	81.6%	38
HP OHW	71.9%	32
FS THW	70%	50
FS OHW	66.7%	39
RS THW	54.3%	35
RS OHW	61.9%	21

Twelve percent of the students responded that they would take another class that used OHW if some changes were made. Three percent of the students did not respond to the question. If the categories were narrowed to only those students who did or did not possess positive attitudes toward future OHW classes, then 72% of the students who used online homework would be willing to use OHW again.

Those students who indicated that they would take another OHW class in the future if some changes were made also provided their recommended changes. Overall the largest recommended change was related to the strict way in which the computer graded homework problems. If a correct answer was entered by the student but it was not in a certain form (e.g. not simplified or not typeset correctly) then the computer would mark the answer as incorrect. Related to this was the suggestion that more partial credit be offered.

Other suggestions related to how the online homework system presented and assisted students with homework problems. These included the desire for more detailed tutorial assistance and the desire to have fewer multi-step problems which could be confusing and time consuming.

Internet access was also an issue. Some students were concerned that they did not have internet access at home which made completing assignments difficult. Others voiced concerns relating to missed assignments due to network failures. One student, who reported that they didn't buy a textbook and wanted to rely solely on the online textbook, expressed concern that using the online textbook was slow and cumbersome.

Other issues were related to how the instructor integrated the online homework system into their course. In particular, some students wanted the homework problems to more closely match the test problems. Other students suggested that if homework was going to be online then the tests should also be online. They found it frustrating to do homework online and then have to complete paper-and-pencil tests.

Summary

The results presented above indicate that using online homework as part of a college algebra class to facilitate learning and mathematics self-efficacy is at least as effective as using textbook homework. In addition, it was found that online homework may be more beneficial than textbook homework in helping students who have lower prerequisite math skills learn the subject. A more detailed discussion of these results is presented in the following chapter.

CHAPTER V

DISSCUSSION, IMPLICATIONS, AND RECOMMENDATIONS

This chapter provides a summary of the research problem, methodology, and results of the study. A discussion of the results follows, which includes discussion, limitations, implications for teachers and system developers, and recommendations for researchers.

Online learning systems, which deliver, grade, and assist with mathematics homework are becoming increasingly advanced and prevalent at the collegiate level. Online homework of this kind offers many potential advantages and may be more effective in helping students learn mathematics and in helping students increase their confidence to learn mathematics. The purpose of this study was to determine if the use of online homework helped students better learn college algebra and helped produce increases in their individual mathematics self-efficacy as compared to the use of textbook homework. In addition, further analysis was performed in order to determine if there were differential effects related to the use of online homework. In other words, the researcher worked to determine if certain students benefitted more from using online homework than from using textbook homework.

A quasi-experimental research design was used to answer the questions regarding college algebra students at Salt Lake Community College (SLCC): a large, western community college. Over the course of a semester, the treatment group (OHW) completed online homework using an online homework system which provided immediate feedback, repeated practice, and tutorial assistance. The control group (THW)

completed similar homework problems from the textbook. At the end of the semester all of the participants completed a common departmental final exam in order to measure their mathematical achievement. Additionally, pretest and posttest surveys were administered in order to measure the change in mathematics self-efficacy. The secondary objectives of the study, related to the differential effects of online homework, were accomplished by dividing the participants into groups based on their level of incoming math skills and groups based on whether the student was taking college algebra for the first time or was retaking the class. The mean final exam scores and the mean self-efficacy change scores for these groups were then compared to determine which groups experienced more benefit from using online homework instead of textbook homework.

The results of the study indicated no significant difference between the mean final exam scores and, while both main comparison groups experienced significant increases in their mathematics self-efficacy, no significant difference was found between the mean self-efficacy change of the THW and OHW groups. However, evidence was found which indicated that students with low incoming skill levels may learn more when using OHW than when using THW. Other comparisons, based on incoming skill level and number of previous college algebra attempts, showed no significant difference in final exam scores or self-efficacy changes for students using OHW compared to students using THW. Effect sizes were calculated for all of these comparisons and indicated some small to medium effects.

Discussion

Mathematical Achievement

The results related to the mathematical achievement comparisons are summarized

in Table 29.

Table 29

Summary Table of Mathematical Achievement Results

Groups Compared	Difference between Final Exam Means (OHW minus THW)	Significance	Effect Size Cohen's d
OHW vs. THW	5.28	0.139	0.253
LP OHW vs. LP THW	9.97	0.033*	0.526
HP OHW vs. HP THW	(2.04)	0.673	-0.103
FS OHW vs. FS THW	3.05	0.486	0.151
RS OHW vs. RS THW	8.59	0.167	0.394

Note. OHW = Online Homework; THW = Textbook Homework; LP = Low Level of
Preparation; HP = High Level of Preparation; FS = First Time Students; RS = Repeating
Students.
*$p < 0.05$.

Whole Group Comparisons for THW versus OHW. The results of this study

showed that there was no significant difference between the final exam means of the

control (THW) and the treatment (OHW) groups when they were compared as complete

groups. Therefore, the students who completed OHW did not perform statistically better

on the final exam than the students who completed THW. The mean final exam score of

the OHW group was slightly more than five points higher than the mean final exam score of the THW group. Under the assumption that a comprehensive final exam can reliably measure mathematical achievement, this result indicates that OHW is at least as effective as THW in improving mathematical achievement. Even though the slight improvement in exam scores experienced by the OHW group may not be statistically significant, it may still have some practical significance as indicated by the effect size. In the case of this study, an improvement of five points is roughly equivalent to one-third, or sometimes two-thirds, of a letter grade. This much improvement might be important to some students and teachers. Even if this amount of improvement is not considered to be practically significant, the results of this study do indicate that OHW is a viable alternative to THW in helping students perform on a final exam and, thus by assumption, learn college algebra.

These findings are consistent with similar research which examined the effectiveness of OHW when compared with THW (Carter, 2004; Davidson, 2004; Hauk & Segalla, 2005; Hirsch & Weibel, 2003; Hurn, 2006; Williams, 1996; Zerr, 2007). Each of these studies found that using OHW, or some form of it, resulted in small but statistically insignificant gains in test scores when compared to THW. Taken as a whole, this body of research indicates that OHW is a consistently viable alternative to THW that can be used to help students learn mathematics.

Previous studies also indicated some shortcomings in their research designs which may have interfered with obtaining significant results and may have masked the effectiveness and advantages of OHW. Some researchers suggested that using an online

homework system that contained many pedagogical and technological features, as opposed to a more basic online homework system that failed to do anything except grade the problems, might be critical in order to help students learn more effectively (Hirsch & Weibel, 2003; Hurn, 2006; Zerr, 2007). These researchers recommended the use of systems which would provide diagnostic feedback that could help students determine why they were making mistakes and allowed students to reattempt problems in order to develop mastery. In addition, systems which provided many different forms of tutorial assistance were also advocated. This variety of tutorial aids was thought to be more likely to fit the learning preferences of the many students who used the system. Other researchers suggested that an online homework system needed to be used over an entire semester, rather than for just a short period, in order to increase its effectiveness (Jacobson, 2006; Williams, 1996). When the OHW system was used for a longer period of time it was thought that students would have the opportunity to become more familiar with the capabilities of the system and the students would be able to learn how to work within the constraints and weaknesses of the system. This study was designed to implement these suggestions – an advanced online homework system was used which contained many features designed to help the student learn and the system was used for an entire semester so as to help students become familiar and comfortable with it. The results of the study found that while these factors may be necessary to achieve significant results, neither of these factors is sufficient, taken alone or together, to achieve significant results.

The effectiveness of an OHW system in improving mathematical learning, as measured by final exam scores, may also depend on how much time a student spends using the system. One possible advantage of an OHW system is that it should facilitate more student engagement with the homework. Because students were able to attempt each homework problem, receive instantaneous feedback on the correctness of the problem, and then reattempt the problem immediately it was believed in this study that OHW may improve final exam scores because students would be motivated to spend more time using the system, thus, their level of engagement with and understanding of the material would increase. To explore this hypothesis, students were asked at the end of the semester to estimate the average number of hours they spent each week working on homework. This data was examined in order to identify any noticeable differences. The data (in graphical and numeric form) did not show a significant difference in the average amount of time spent doing homework for the THW and OHW groups taken as a whole. In general, it appeared as if both groups spent about the same amount of time working on homework. This result can be interpreted several ways: (a) OHW students were able to achieve slightly higher final exam scores while spending the same amount of time working on homework, (b) the OHW system did not noticeably motivate the students to spend more time working on homework, or (c) the data gathered from this homework time survey question was too unreliable because it was self-reported at the end of the semester when students may not have provided an accurate answer. Given the available data, it is not possible to determine which of these interpretations is correct.

While the main construct used to measure Mathematical Achievement in this study was a final exam score, there are other possible ways to measure how well a student performs in a math class which uses OHW. Other research has measured the effect of OHW on mathematics achievement by examining how many students ultimately passed the math class with a grade of A, B, or C, otherwise known as the ABC rate (Carter, 2004; Speckler, 2007). The results from these other studies were mixed, with some reporting greater ABC rates for OHW students and others reporting greater ABC rates for THW students, and should be interpreted with caution because little information is provided in these other studies regarding how the final grade was calculated.

Using the ABC rate as a measure of achievement in this study was thought to be reasonable under the assumption that the learning that occurred while doing homework had an effect on everything the student did during the class, and therefore, had a substantial effect on the final grade. However, using the ABC rate to compare different classes must be done cautiously given the many variables that can typically contribute to the student's final grade in each class. Controlling, or at least accounting for these variables, is important if the ABC rate is to have any comparative meaning. Given that the students in this study all possessed similar math skills at the beginning of the semester, and given that all of the participating sections used the same syllabus (which outlined common grading schemes), the same schedule (which insured the same objectives applied to each section), the same homework (which provided all of the students with roughly the same type and amount of drill and practice), and the same final exam (which insured that instructors covered and emphasized the same material), it was

reasonable to cautiously use the ABC rate as an exploratory measure of the effect of

OHW on mathematical achievement in this study. The result of this comparison was that

there was no significant difference between the ABC rates of THW and OHW students.

This reconfirmed the previous result that mathematical achievement was not different

between the THW and OHW groups.

 Subgroup comparisons. The results discussed previously all pertained to the

comparisons made between all of the students who used OHW and all of the students

who used THW. This section discusses the results when the students were divided into

certain *a priori* subgroups. Students were divided into two groups based on the

approximate median score of the prerequisite math skills pretest. These groups were

classified as having either low incoming skill levels (LP) or high incoming skill levels

(HP). Students were also divided into two groups based on whether they were first-time

college algebra students (FS) or repeating college algebra students (RS). These groupings

were combined with the two homework type factors to obtain the cross subgroupings

which were considered in this study. Creating these groups was suggested in the literature

(Carter, 2004; Jacobson, 2006; Pintrich & DeGroot, 1990) as a possible way of

understanding why many of the previous whole-group comparisons discussed in the

literature may have resulted in insignificant results. The hypothesis put forth in these

studies was that OHW may be more effective for certain subpopulations and may not be

as effective for other subpopulations or for the entire population as a whole. The

subpopulations that are currently of interest to the college algebra education community,

because they are large and growing, are the students who enter college algebra with low

skills and the students who must retake college algebra after previously failing (Baxter Hastings et al., 2006). Additionally, no current research could be found that examined the effect of OHW on these populations. Therefore, it was deemed important in this study to determine if students who traditionally struggled in college algebra, either because they were mathematically unprepared or because they were caught in a cycle of retaking the college algebra course, might learn more from using OHW than from using THW.

Differences between HP and LP subgroups. When considering Mathematical Achievement as measured by final exam scores this study found that there was no significant difference between any of the LP/HP subgroups. However, based on the initial analysis it appeared that online homework affected the LP students differently than the HP students because a marginally significant interaction effect was found. This marginal interaction was explored more deeply and it was discovered that LP students who used OHW significantly outperformed LP students who used THW. In addition, it was found that HP students who used OHW scored slightly lower than HP students who used THW. Taken together, these results suggest that online homework, as compared to textbook homework, is more effective in helping students with low incoming skill levels succeed in college algebra. The actual difference between the final exam means of the LP OHW and LP THW was almost ten points which translates into a whole letter grade advantage for the OHW group. Therefore, not only was this difference statistically significant, it was also practically significant as evidenced by differences in point totals and effect sizes.

The researcher was concerned that this result may have been dependent on the way in which the incoming skill-level groups were created, therefore further exploration was performed which used different methods of grouping the participants based on skill level. The method used in this study and reported on here involved dividing the students into two groups based on the approximate median math skills pretest score. This method was decided upon because of the sample size and because it led to similarly-sized groups. Two other groupings were explored: (a) a grouping which used the math skills pretest raw scores to divide the participants into three, roughly equal-sized groups and (b) a grouping which used the standardized math skills pretest scores (z-scores) and divided students into groups depending on whether their z-score was greater than positive one or less than negative one. Ultimately, both of these groupings were discarded, in favor of the current grouping, because they led to groups of considerably different sizes and, in some cases, groups which were so small they could not be analyzed. Nevertheless, exploratory analysis was performed on these alternate groupings and the same differential effect between the LP and HP students was observed. Therefore, the researcher felt comfortable in drawing the conclusion that LP and HP students were affected differently, with LP students significantly benefitting, from the use of OHW, and that this difference was not necessarily an artifact of the research design.

To provide insight into why LP students achieved significantly higher final exam scores when using OHW (compared to using THW) and why HP students actually achieved slightly lower final exam scores when using OHW (compared to using THW) the average amount of time each student spent working on homework each week was

analyzed. The data collected regarding time spent on homework was not detailed or accurate enough to compare the individual subgroups (LP THW, LP OHW, HP THW, and HP OHW). However, it was found that the students in the LP, HP, OHW, and THW groups spent about the same amount of time per week doing homework. Therefore, the researcher could not attribute the higher scores reported by the LP OHW students to more time spent working on homework each week.

Other possibilities, besides more time spent on homework, exist which could explain why LP students scored higher when using online homework. Perhaps the homework helped them learn more efficiently because of the educational features that the system made available and, therefore, they did not need to spend more time doing homework in order to learn more. It could also be possible that LP students benefitted precisely because the online homework system was something quite different from previous traditional approaches that did not work in the past for these students. On the other hand, HP students may not be experiencing the same benefits as their LP counterparts for the exact opposite reasons - the OHW system provided support that they did not really need and they did not really use or the OHW system was quite different from the traditional homework system that they were already familiar with and had already been successfully using.

As further evidence that LP students benefitted more from using OHW than from using THW, the ABC rates of these two groups were compared. The ABC rate for the LP OHW students was 57.1% while the ABC rate for the LP THW students was 48.9%. There was no statistically significant difference between these two proportions. For the

students and instructors involved in this study the difference does appear to be practically significant; with just over 8 percentage points more students receiving a grade that could be counted for college credit or that was eligible for transfer between institutions if necessary. Or, put a different way, this represents an increase of about 8 percentage points in the number of students who passed the class and a decrease of about 8 percentage points in the number of students who have to retake college algebra.

When considering the ABC rates of HP students it was found that the ABC rate for the HP OHW group was 71.9% and the ABC rate for the HP THW group was 81.6%. The difference was not statistically different. For those involved in this study the results may be practically different with nearly 10 percentage points more HP students receiving a passing and transferrable grade when they used THW. This provides further evidence that OHW seems to be more effective for low-skilled students than high-skilled students.

Differences between FS and RS subgroups. The results of this study did not indicate any significant difference in the final exam means of the FS/RS subgroups. The FS OHW group did outscore the FS THW group by just over three points. Additionally, the RS OHW outscored the RS THW students by over eight points. Neither of these differences was statistically significant. Therefore, it appears that the use of online homework affected both the FS and RS groups similarly and there was not a particular advantage demonstrated for either group.

Comparing the average amount of time spent on homework by each group does raise some questions. The homework time data that was gathered was not detailed or accurate enough to compare individual subgroups (FS THW, FS OHW, RS THW, and

RS OHW) but it was possible to compare the homework time of all first-time and all repeating students. The data appeared to indicate that repeating students reported spending less time doing homework than first-time students. In fact, repeating students reported spending less time doing homework than any of the groups involved in the study. While this decrease in homework time did not result in decreased final exam means when compared with first-time students' final exam means, it did raise questions about the use and effectiveness of online homework. Did repeating students, who spent less time doing homework, score similarly on the final exam to first-time students, who spent more time doing homework, because the online homework helped them learn more efficiently? Did repeating students spend less time doing homework because they believed that they would fail the class again no matter how hard they worked to learn the material? Lastly, because repeating students spent less time doing homework did they not get a chance to experience the possible benefits that might have led to higher scores? The literature does suggest one possible explanation for why repeating students did not spend more time doing homework: the repeating students, who have already failed the class once, may not be able to accurately assess their own levels of understanding (Young & Ley, 2000, 2001). If this was the case, then the repeating students may have assumed that they already understood the concepts and felt that they did not need further homework study.

Finally, a comparison of the ABC rates of the subgroups showed no significant statistical difference. The ABC rate of the FS OHW group was nearly 4 percentage points less than the ABC rate of the FS THW group, and the ABC rate of the RS OHW was

more than 8 percentage points greater than the ABC rate of the RS THW rate. It is possible that the same explanation can be used to understand both differences: the online homework system approach was new and different from the traditional textbook approach. For first-time students, the new OHW approach may have been difficult to adjust to and they may have already experienced success with the traditional THW approach. For repeating students, who have already experienced failure with the traditional THW approach, the use of OHW may have been viewed as a positive new opportunity which could offer them the chance for success.

Mathematics Self-Efficacy

The results related to changes in mathematics self-efficacy are summarized in Table 30. Comparisons of the differences in mathematics self-efficacy change are summarized in Table 31.

Table 30

Summary Table of Mathematics Self-efficacy Changes

Group	Mean Mathematics Self-efficacy Change (SEC)	Significance
THW	16.89	<0.001
OHW	12.37	<0.001
LP THW	16.00	0.009
LP OHW	8.11	0.129
HP THW	18.00	0.001
HP OHW	16.96	<0.001

Group	Mean Mathematics Self-efficacy Change (SEC)	Significance
FS THW	14.05	0.006
FS OHW	14.45	0.001
RS THW	21.10	0.003
RS OHW	9.10	0.123

Note. OHW = Online Homework; THW = Textbook Homework; LP = Low Level of Preparation; HP = High Level of Preparation; FS = First Time Students; RS = Repeating Students.

Table 31

Summary Table of Differences Between Mathematics Self-efficacy Changes

Groups Compared	Difference between Mean Self-efficacy Change (OHW minus THW)	Sig.	Effect Size Cohen's *d*
OHW vs. THW	(4.52)	0.396	-0.155
LP OHW vs. LP THW	(7.89)	0.339	-0.241
HP OHW vs. HP THW	(1.04)	0.873	-0.043
FS OHW vs. FS THW	0.4	0.951	0.014
RS OHW vs. RS THW	(12)	0.186	-0.392

Note. OHW = Online Homework; THW = Textbook Homework; LP = Low Level of Preparation; HP = High Level of Preparation; FS = First Time Students; RS = Repeating Students.

Whole group comparisons for THW versus OHW. The results of this study showed that, while both the THW and OHW group experienced significant improvements in mathematics self-efficacy, neither group experienced a larger improvement than the other. Therefore, it does not appear that homework type made a difference in improving students' beliefs about their abilities to successfully complete mathematical tasks. The self-efficacy level of both groups was significantly increased during the semester which indicated that the students did feel that the new knowledge they were gaining throughout the semester was increasing their mathematical abilities. The THW group's self-efficacy improvement score was actually slightly higher than the OHW group's score, although it is likely that this difference does not have any practical value as further evidenced by the insignificant effect size.

The findings of the study were consistent with similar results examining changes in mathematics self-efficacy (Campbell & Hackett, 1986; Hall, 2002; Hurn, 2006; Jackson, 2002; Tuckman & Sexton, 1990). Each of these studies indicated that self-efficacy increased when students were exposed to successful learning opportunities. The results of this study also indicated that, on average, students' mathematics self-efficacy increased, although it is not possible to determine if these increases have any practical value. Because no significant differences were found to exist between either of the experimental groups (i.e. THW vs. OHW), the most likely explanation for the improvement is that the students were being exposed to new learning opportunities which had previously been unknown to them and that the students were, as a result, becoming

more confident in their math skills. As such, it is not possible to attribute this increase specifically to the use of either textbook or online homework.

Bandura (1977) hypothesized that self-efficacy could be influenced in the classroom and suggested four ways in which it could be enhanced: performance accomplishments (successfully completing tasks), vicarious experience (observing others successfully completing tasks), verbal persuasion (receiving feedback in the form of encouragement and reassurance), and physiological states (reducing the effects of anxiety). In this study it was hypothesized that online homework would be more effective than textbook homework in changing self-efficacy because it offered students more opportunities to experience successful performance accomplishments and more opportunities to receive positive and directive persuasion. Online homework was thought to provide more opportunities for successful performance accomplishments because students were given the opportunity to rework any homework problem they missed after receiving tutorial assistance. Thus, students could work on each homework assignment until they had mastered it and received a score indicating that they had successfully completed the task. Online homework was also thought to be more effective in enhancing self-efficacy because it provided feedback, in the form a correct/incorrect grading and insight into what error had occurred when an answer was wrong. Both of these advantages were thought to be in contrast to the typical approaches used with textbook homework where the student rarely received quality feedback on the homework and, even more rarely, got a second chance to complete a homework assignment for a higher grade.

In the end, neither of these hypothesized advantages seemed to make a difference. It is not known, and could not be determined from the data, whether students did value the opportunity for mastery and whether thy gained from the abundance of feedback. It is possible that when students were allowed to keep reworking homework problems they attributed their high grades to getting many chances to get the problems correct instead of attributing their high grades to actually learning and mastering the concepts. This could be a possible explanation of why mathematics self-efficacy was not increased substantially for OHW students compared to THW students. It is also possible that students did not place any value or credence in the feedback they were receiving because they did not feel like the feedback really had relevance to their personal understanding of college algebra. They may have already formed such solid perceptions of their mathematical abilities that they were not affected at all by the feedback in the form of perfect homework grades.

In order to further explore the hypothesis that mathematics self-efficacy was increased as students experienced success, the researcher divided the students into two groups – students who received a final grade of A, B, or C (the ABC group) and students who received a final grade of D, F, or UW (DFUW group). It was found that the DFUW group actually experienced greater changes in their mathematics self-efficacy than the ABC group. It could be that this discrepancy is the result of a ceiling effect acting on the A, B, and C students. This discrepancy could also be the result of violations of the assumptions used in this study related to mathematics self-efficacy.

The assumptions made when designing the mathematics self-efficacy portion of this study were based on the literature (Bandura, 1977; Betz & Hackett, 1983b; Campbell & Hackett, 1986; Hackett & Betz, 1982) and are discussed next. Three main assumptions were made: (a) mathematics self-efficacy could be measured by a self-report survey, (b) mathematics self-efficacy could be changed over one semester, and (c) a pretest-posttest design could be used to measure this change. While the literature supports these assumptions, it is possible that they were violated in this study and led to the inconsistent results relative to the final grades mentioned above. Nothing in the data, as is evidenced by the high internal consistency levels of the mathematics self-efficacy pretest and posttest, indicated that any of these assumptions was violated, but the possibility needs to be considered.

A violation of the first assumption could have occurred if the students were not honest or thoughtful as they answered the questions on either of the mathematics self-efficacy surveys. There is always the danger of this occurring when self-report surveys are used. Perhaps the students did not take the time to reflect on their answers or perhaps the students wanted to give the impression that they were more confident that they really were.

The second assumption, that mathematics self-efficacy could be changed over one semester, was also based in the literature. Once again, the literature pointed strongly to the belief that self-efficacy can change as students experience success. However, the literature also indicated that self-efficacy can fluctuate from day to day and from chapter to chapter. It may be that students experienced this day to day fluctuation as they received

high and low grades, but their overall self-efficacy belief remained unchanged. Without experiencing success over a period of time longer than a semester, students' mathematics self-efficacy may be too solidified to change.

Finally, the last assumption that a pretest-posttest design could be used to measure self-efficacy change, could be violated if, when students completed the pretest and posttest surveys they chose their answers based on their performance over their entire mathematical career instead of based on how they felt about their math skills at the beginning and end of the semester. Because the students were asked to answer the same questions on the pretest and posttest it may be that they were unable or unwilling to thoughtfully answer the questions based on how they were currently feeling.

In the end, almost all groups did experience significant improvements in their mathematics self-efficacy and the mathematics self-efficacy change of the OHW group did prove to be statistically equal to the mathematics self-efficacy change of the THW group. Therefore, it can at least be said that the treatment did no harm to the mathematics self-efficacy of the OHW students and that the treatment facilitated a similar change in the mathematics self-efficacy of the OHW and the THW groups.

Subgroup comparisons. The same *a priori* subgroups (HP, LP, FS, and RS) were also used to explore the possible differential effects of the treatment on mathematics self-efficacy.

Differences between HP and LP students. For the most part, the previous discussion regarding the interpretation of the whole-group comparisons could be repeated for the comparisons between the HP and LP students. In particular, three out of the four

HP and LP subgroups (HP THW, HP OHW, and LP THW) demonstrated significant

improvements in their mathematics self-efficacy (i.e. they demonstrated a significant

SEC). Only the LP OHW group did not experience significant SEC. However, when the

SEC of the particular groups were compared (e.g. HP THW vs. HP OHW and LP THW

vs. LP OHW) no significant differences were found. Additionally, the calculated effect

sizes indicated that there was a small detrimental effect of the treatment on the SEC of

the LP group although it is difficult to interpret this small effect in terms of practical

value. The collected data provided no insight beyond what has already been discussed

into this singular result.

 Differences between FS and RS students. Once again, the previous discussion

regarding the interpretation of the whole-group comparisons could be repeated for the

comparisons between the FS and RS students. In particular, three out of the four FS and

RS subgroups (FS THW, FS OHW, and RS THW) demonstrated significant

improvements in their mathematics self-efficacy (i.e. they demonstrated a significant

SEC). Only the RS OHW group did not experience significant SEC. However, when the

SEC of the particular groups were compared (e.g. FS THW vs. FS OHW and RS THW

vs. RS OHW) no significant differences were found. Additionally, the calculated effect

sizes indicated that there was a small to medium detrimental effect of the treatment on the

SEC of the RS group although it is difficult to interpret this small effect in terms of

practical value. The collected data provided no insight beyond what has already been

discussed into this singular result.

Limitations

The results of this study should be interpreted within the framework of several limitations. Understanding these limitations may be useful to other researchers who wish to replicate this study or who wish to perform similar research relating to online homework. The limitations related to sample size and multiple instructors were anticipated in the design of the study. Because some natural attrition was expected, the researcher attempted to choose a sufficiently large initial sample so that the effects of mortality could be countered. Using multiple instructors also posed some limitations due to the possibility of instructor-related effects. Anticipating this, the design made use of common course materials and also included classroom observations by the researcher.

A separate limitation, relating to how students actually used the online homework system, was identified during the analysis and interpretation phase of the study. Had the researcher been able to directly observe students as they used the online homework system then it may have been possible to make stronger correlations between online homework use and mathematical achievement or mathematics self-efficacy.

Finally, it is also a possibility that the students involved in this study altered their academic behavior because they were aware they were involved in a research study. Nothing in the collected data indicated that this was the case, but it remains a possibility that future researchers may need to consider.

Implications for Teachers

The findings from this study demonstrated that college algebra students who used online homework experienced similar levels of mathematical achievement and mathematics self-efficacy change when compared with students who used textbook homework. Therefore, it appears that online homework is likely to be an effective learning tool when used for the college algebra population. Although the results from one study cannot be considered definitive, the results of this study, when taken together with the results of other similar studies, provide evidence that online homework can be considered a viable alternative to textbook homework. For the many teachers who are currently using online homework as part of their classes, whether in face-to-face, hybrid, or online classes, this result may not be surprising. In fact, it may partially explain the recent rise in use of online homework systems that has been seen in higher education (Speckler, 2007). For other teachers who have been under the assumption that technology-heavy approaches often interfere with, instead of increasing, learning this result may or may not be sufficient to change their minds and convince them that the disadvantages are outweighed by the advantages.

A common concern from undergraduate math instructors is that many of the students who enroll in their classes are mathematically unprepared to succeed. This study indicated that online homework may be more effective than textbook homework in helping this particular population learn college algebra. It is possible that these students learned more when they used online homework because it provided the scaffolding they needed in order to make up for any knowledge deficits which they possessed. It may also

be possible that these students learned more because the approach was substantially different from the traditional approaches which they were already used to and which had been ineffective for them in the past. Regardless of the explanation, if instructors had the tools necessary to help this large population of students, it would represent a significant step forward for college-level mathematics education.

The other population of students that concern college math instructors is the population of students who are retaking the class. In this study, nearly one-third of the students were retaking the class after previously failing. The results relating to first-time and repeating students did not indicate that the use of online homework significantly increased final exam scores. However, teachers may be more interested in the result which showed that more repeating students passed the class when they used online homework than when they used textbook homework. It may be that the repeating students learned more while using online homework and demonstrated that increase in knowledge on the many chapter tests and quizzes that were spread throughout the semester. On the whole, these chapter tests and quizzes contributed more to the final letter grade than did the lone final exam, thus the number of repeating students who passed the class increased. This represents a positive result which would be of value to any teacher concerned with helping students who have had past difficulties with math. Another possible explanation of the larger passing rate could be that the repeating students were more motivated to learn using an approach that was different from the previous approaches which had failed them in the past. Either way it appears as if online homework offers the potential for helping this important population of students.

If an instructor chooses to implement online homework, it is important to consider how this implementation affects the other aspects of the course. In this study, the implementation consisted of strictly substituting online homework for textbook homework while trying to keep everything else the same. While this approach was necessary for the experimental design, it does not necessarily reflect good educational practice. Some of the students in this study felt that if online homework was going to be used then other aspects of the course, particularly tests, should be adjusted. These students indicated that instructors should take special care to make sure the homework problems and test problems were conceptually consistent. This is a common concern expressed by many math students in both types of classrooms but it may be of particular importance when students see the online homework system as being a completely separate component of the course design. Instructors should work to integrate the online homework system into class by referring to it during lecture, by displaying and working problems directly from the online homework in class, and by showing students how the online homework problems match the textbook problems. Doing this reassures students that the tests they are taking are meant to assess the knowledge they are learning from the online homework.

Another concern expressed by students was that if homework was completed online then tests should be online. Some students thought that it was a difficult transition to make between online homework and paper-and-pencil tests. This is a valid concern that instructors should find ways of overcoming. Part of the solution may lie in integrating the online homework into the regular class discussions as mentioned before in

order to demonstrate that the homework problems are similar to what they would be if they came from the textbook. Another part of the solution may be for instructors to teach students that it is appropriate to copy a homework problem from the screen to paper and solve it like it was a paper-and-pencil problem. Part of the students' concern rested in the fact that paper-and-pencil problems have the advantage of being partially correct and receiving partial credit while online homework problems are often all or nothing. Teachers will need to find ways to help their students see that there are certain advantages of online homework, such as multiple attempts at each problem, which can be considered equally, if not more, valuable to the student than the opportunity to receive partial credit.

Overall, the result that may have more implications for teachers than all of the other results is the fact that over 70% of the students who used online homework said they would be willing to use it again, either in its current format or with some changes. For instructors, this means that students felt that the use of online homework was valuable despite the inevitable technological and pedagogical challenges. It may be that this high approval rating is the result of the "internet age" in which we live and is a reflection that the students are comfortable with and enjoy using computers to learn. Or it may be that students felt that online homework was significantly more enjoyable, valuable, or effective than the traditional textbook homework that they were already quite familiar with. Whatever the explanation, the high percentage of students who would be willing to use online homework again should cause instructors to take note.

No data was collected in this study which would provide insight into teacher's issues and concerns with using online homework. It is likely that teachers would have concerns similar to those expressed by the students in this study. In particular, teachers would have to find ways to work with the rigid automated grading system, with the preprogrammed selection of homework problems, and with issues of internet access. Teachers would also need to consider the pedagogical structure of their classes and how to most effectively integrate online homework into their classroom approaches. These challenges, alone, may be sufficient enough to discourage the adoption of online homework.

Beyond the issues related to the functionality and the implementation of online homework, teachers must also determine if they believe that online homework can effectively help students learn all of the mathematical skills which they need to be successful. Online homework may be effective in helping students develop procedural knowledge, but may be limited in its capacity to help students develop conceptual knowledge or critical thinking skills. If instructors believe this to be the case then it may be necessary for them to supplement online homework with additional problems which help students develop other important skills.

Finally, instructors need to determine their comfort level with using online homework and consider how their comfort level may influence the effectiveness of the system. If instructors are not comfortable with the system and convey this doubt to their students, it is possible that the students' learning may be affected. All of the instructors in this study who used online homework did so because they were already familiar with its

advantages and disadvantages and comfortable with its use. This confidence in and familiarity with the online homework system was the result of several semesters of hands-on experience. Instructors wishing to increase their comfort and confidence levels with online homework will also likely need to actually implement it into their classrooms and experience it firsthand.

Implications for Online Homework System Developers

Several factors currently exist in collegiate mathematics education which have important implications for the developers of online homework systems. If studies similar to this one continue to find that not only is online homework effective, but it may be more effective than textbook homework for certain critical subpopulations, then the demand for and use of quality online homework systems will continue to rise. Development of systems which continue to meet the needs of students and teachers will be critical.

As long as online homework is found to be effective, demand will likely continue to increase as individual instructors and whole institutions try to take advantage of the educational benefits of the internet. When homework is placed online and is accompanied with all of the features that are available in hyperlinked cyberspace, the homework assignments move well beyond what traditional textbook homework assignments used to be. These new, super-powered homework assignments can then be used in face-to-face, hybrid, or online classes.

The results of this study also indicate several areas that developers should work on to improve in their online homework systems. Students, who spent a semester using online homework, were primarily concerned about two things: (a) the artificial intelligence of the system and (b) access to the system. The most common complaints voiced in this study related to how well the system was able to accurately assess student answers. Most students felt that the system required too much precision and was not able to give credit for answers that were correct but in a different mathematical form or a different form of typesetting. Students also suggested that the system should be better able to issue partial credit for when a student demonstrated some understanding or got the answer mostly correct. The final suggestion related to the artificial intelligence of the system was the feeling among the students that the system could have provided more informative and appropriate feedback.

The issue of access also arose from the students. Developers may need to think of ways to allow the students to take advantage of the many features of an advanced online homework system while the students are working offline. The option to download homework assignments, along with some of the key assessment and tutorial features, to removable storage devices might be one consideration. The researcher felt that the students were concerned about access primarily because they wanted to use the online homework system and not because they did not want to have to use the internet to complete assignments. All of these student suggestions should give system developers something to consider as they plan future upgrades to their systems.

Recommendations for Researchers

The findings of this study and the subsequent observations suggest several directions for future research.

The effectiveness of online homework as compared to textbook homework needs further exploration. This study should be replicated using a larger sample size of students and a smaller collection of participating instructors. Fewer instructors would help reduce instructor-related effects that might arise.

The effect of online homework on students with low incoming skill levels should be examined further. This study found that these students might significantly benefit from the use of online homework. Therefore, future studies should attempt to determine if this result is generalizable. In addition, research should be performed which tries to determine not only if online homework is better for low skilled students, but also why homework is better for these students. Examination of the motivational and pedagogical features of online systems should be performed in order to determine the most effective components of such systems.

Researchers should also attempt to develop a student profile which more clearly describes the specific characteristics of the low skilled students who might benefit more from using online homework that from using textbook homework. This profile could include such general information as GPA, scores on standardized tests, or final grades in prerequisite math classes or the profile could look at knowledge of specific math skills such as the ability to factor algebraic expressions, solve certain equations, or interpret certain graphical information. The profile could also take into account learner

characteristics such as self-efficacy, motivation, or mathematical interest. Such a profile would aid educators in determining which type of homework to most effectively assign to each student.

Future research should also be completed which attempts to determine if online homework is more effective for other subpopulations of students. Groups to consider could be repeating students, adult students, ESL students, distance students, or strictly online students.

Other research may need to consider student attitudes toward online homework. In particular, researchers should work to determine if first-time and repeating students or low-skilled and high-skilled students view online homework differently and if these beliefs affect their selection and usage of such systems.

Even if online homework is only comparable to textbook homework, in terms of affecting mathematical achievement, other educational benefits might result from its use. This study attempted to determine if improved mathematics self-efficacy was one of these additional benefits. Further research, perhaps using different instrumentation, should be conducted which reexamines the effect of online homework on mathematics self-efficacy. In addition, other benefits such as increased motivation, increased self-regulation of learning, or improved attitude toward mathematics in general could be considered.

Current systems may be effective in helping students learn mathematical procedures through drill and practice but may be ineffective in helping students develop deeper understanding of the mathematical principles being taught. Researchers should

attempt to determine if online homework has the capacity to help students develop critical thinking skills and conceptual knowledge in addition to procedural knowledge.

Qualitative research should also be performed which attempts to determine student attitudes toward and uses of online homework. Researchers should investigate if students are more engaged when they use online homework. Additionally, researchers should examine which online features are most used and most beneficial to the students. The results of this type of research would be of value to both educators and system developers.

Nothing in this study examined the effects of instructor attitudes toward online homework. Research should be conducted which examines how an instructor's attitudes toward online homework are displayed in class and how those attitudes affect students' beliefs and actions. Instructors who prefer online homework and instructors who are reluctant to use online homework should be studied in order to understand the basis for their preferences. This information could lead to more effective and more accepted systems.

Finally, researchers should examine how students who take a class which uses online homework perform in subsequent math classes. If online homework is to be considered effective it must make it possible for students to succeed not only in their current math class, but in their future math class as well.

REFERENCES

Allain, R., & Williams, T. (2006). The effectiveness of online homework in an introductory science class. *Journal of College Science Teaching, 35*(6), 28-30.

American Mathematical Association of Two-Year Colleges. (2006). *Beyond crossroads: Implementing mathematics standards in the first two years of college*. Memphis, TN: American Mathematical Association of Two-Year Colleges.

Arriola, L. K. (1993). *Teaching college adults remedial mathematics: Is there a best way?* Unpublished doctoral dissertation, University of Massachusetts at Amherst.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191-215.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W.H. Freeman.

Baxter Hastings, N., Gordon, F. S., Gordon, S. P., Narayan, J., & Mathematical Association of America. (2006). *A fresh start for collegiate mathematics: Rethinking the courses below calculus*. Washington, DC: Mathematical Association of America.

Becker, J. P., & Shimada, S. (1997). *The open-ended approach: A new proposal for teaching mathematics*. Reston, VA: National Council of Teachers of Mathematics.

Benford, R., & Gess-Newsome, J. (2006). *Factors affecting student academic success in gateway courses at Northern Arizona University*: (ERIC Document Reproduction Service No. ED495693)

Betz, N. E., & Hackett, G. (1983a). *Mathematics self-efficacy scale, forms A and B (MSES)*. Palo Alto, CA: Mind Garden.

Betz, N. E., & Hackett, G. (1983b). The relationship of mathematics self-efficacy expectations to the selection of science-based college majors. *Journal of Vocational Behavior, 23*(3), 329.

Betz, N. E., & Hackett, G. (1993). *Mathematics self-efficacy scale sampler set: Manual, test booklet and scoring guide*. Palo Alto, CA: Mind Garden.

Bonham, S., Beichner, R., & Deardorff, D. (2001). Online homework: Does it make a difference? *Physics Teacher, 39*(5), 293.

Bridge, P., & Appleyard, R. (2008). A comparison of electronic and paper-based assignment submission and feedback. *British Journal of Educational Technology, 39*(4), 644-650.

Brilleslyper, M. A. (2002). Preparing new instructors to teach college mathematics courses: An objective-based teaching laboratory. *Primus, 12*(2), 181-191.

Campbell, N. K., & Hackett, G. (1986). The effects of mathematics task performance on math self-efficacy and task interest. *Journal of Vocational Behavior, 28*(2), 149.

Carter, M. B. (2004). *An analysis and comparison of the effects of computer-assisted instruction versus traditional lecture instruction on student attitudes and achievement in a college remedial mathematics course.* Unpublished doctoral dissertation, Temple University.

Chen, X., & Zimbler, L. J. (2002). Teaching undergraduates in U.S. postsecondary institutions. *U.S. Department of Education report number NCES-209.* Retrieved

November 20, 2008, from

http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2002209

Cobb, P. (1988). The tension between theories of learning and instruction in mathematics education. *Educational Psychologist, 23*(2), 87-103.

Cohen, B. H. (2001). *Explaining psychological statistics* (2nd ed.). New York: Wiley.

Cooper, H., Robinson, J. C., & Patall, E. A. (2006). Does homework improve academic achievement? A synthesis of research, 1987-2003. *Review of Educational Research, 76*(1), 1-62.

Creswell, J. W. (2002). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (1st ed.). Upper Saddle River, NJ: Merrill Prentice Hall.

Davidson, A. (2004). *An examination of the effects and costs of instruction that relies on computer-assisted instruction for delivering and managing homework assignments in college calculus courses.* Unpublished doctoral dissertation, University of Rochester.

Davis, R. B., Maher, C. A., & Noddings, N. (1990). *Constructivist views on the teaching and learning of mathematics*. Reston, VA: National Council of Teachers of Mathematics.

Gaines, C. L., & Johnson, W. (1996). Achieving technological equity and equal access to the learning tools of the 21st century. *T H E Journal, 23*(11), 74.

Granger, D., & Bowman, M. (2003). Constructing knowledge at a distance: The learner in context. In M. G. Moore & W. G. Anderson (Eds.), *Handbook of distance education* (pp. 169-180). Mahwah, NJ: Erlbaum.

Grubb, W. N. (1999). *Honored but invisible: An inside look at teaching in community colleges*. New York: Routledge.

Hackett, G. (1981). Mathematics self-efficacy and the consideration of math-related majors: A preliminary path model.   Retrieved September 12, 2007, from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=ED207847&site=ehost-live

Hackett, G. (1985). Role of mathematics self-efficacy in the choice of math-related majors of college women and men: A path analysis. *Journal of Counseling Psychology, 32*(1), 47.

Hackett, G., & Betz, N. E. (1982). *Mathematics self-efficacy expectations, math performance, and the consideration of math-related majors*: (ERIC Document Reproduction Service No. ED218089)

Hackett, G., & Betz, N. E. (1989). An exploration of the mathematics self-efficacy/mathematics performance correspondence. *Journal for Research in Mathematics Education, 20*(3), 261.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics. *American Journal of Physics, 66*(1), 64.

Hall, J. M. (2002). *A comparative analysis of mathematics self-efficacy of developmental and non-developmental college freshman mathematics students.* Unpublished doctoral dissertation, University of Mississippi.

Hall, J. M., & Ponton, M. K. (2005). Mathematics self-efficacy of college freshman. *Journal of Developmental Education, 28*(3), 26-33.

Hauk, S., & Segalla, A. (2005). Student perceptions of the web-based homework program WeBWorK in moderate enrollment college algebra classes. *Journal of Computers in Mathematics and Science Teaching, 24*(3), 229.

Herriott, S. R. (2006). Changes in college algebra. In N. Baxter Hastings, F. S. Gordon, S. P. Gordon, J. Narayan, & Mathematical Association of America (Eds.), *A fresh start for collegiate mathematics: Rethinking the courses below calculus* (pp. 90-100). Washington, DC: The Mathematical Association of America.

Hidi, S., & Harackiewicz, J. M. (2000). Motivating the academically unmotivated: A critical issue for the 21st century. *Review of Educational Research, 70*(2), 151.

Hirsch, L., & Weibel, C. (2003). Statistical evidence that web-based homework helps. *FOCUS, 23*(2), 14.

Hodge, J. E. (2002). *The effect of math anxiety, math self-efficacy, and computer-assisted instruction on the ability of undergraduate nursing students to calculate drug dosages.* Unpublished doctoral dissertation, West Virginia University.

Hodges, D. Z., & Kennedy, N. H. (2004). Editor's choice: Post-testing in developmental education, a success story. *Community College Review, 32*(3), 35-42.

Hoyt, J. E., & Sorensen, C. T. (2001). High school preparation, placement testing, and college remediation. *Journal of Developmental Education, 25*(2), 26-34.

Huba, M. E., & Freed, J. E. (2000). *Learner-centered assessment on college campuses: Shifting the focus from teaching to learning*. Boston: Allyn and Bacon.

Hurn, J. L. (2006). *An analysis of the effects of online practice quizzes on the achievement, self-efficacy, and academic motivation of college algebra students at a community college.* Unpublished doctoral dissertation, Kansas State University.

Jackson, J. W. (2002). Enhancing self-efficacy and learning performance. *Journal of Experimental Education, 70*(3), 243.

Jacobson, E. (2006). Computer homework effectiveness in developmental mathematics. *Journal of Developmental Education, 29*(3), 2-8.

Johnston, T. (2004). Online homework assessments: Benefits and drawbacks for students. *Academy of Educational Leadership Journal, 8*(3), 29-41.

Kinney, D. P. (2001). A comparison of computer-mediated and lecture classes in developmental mathematics. *Research and Teaching in Developmental Education, 18*(1), 32.

Kodippili, A., & Senaratne, D. (2008). Is computer-generated interactive mathematics homework more effective than traditional instructor-graded homework? *British Journal of Educational Technology, 39*(5), 928-932.

Lefcort, H., & Eiger, S. M. (2003). Preparatory versus practice homework. *Journal of College Science Teaching, 33*(1), 16-18.

Lent, R. W., & Lopez, F. G. (1991). Mathematics self-efficacy: Sources and relation to science-based career choice. *Journal of Counseling Psychology, 38*(4), 424.

Ley, K., & Young, D. B. (1998). Self-regulation behaviors in underprepared (developmental) and regular admission college students. *Contemporary Educational Psychology, 23*(1), 42.

Linnenbrink, E. A., & Pintrich, P. R. (2002). Motivation as an enabler for academic success. *School Psychology Review, 31*(3), 313.

Mavrikis, M., & Maciocia, M. (2003). Incorporating assessment into an interactive learning environment for mathematics [Electronic Version]. *Maths CAA Series*. Retrieved September 6, 2007, from http://ltsn.mathstore.ac.uk/articles/maths-caa-series/june2003/index.shtml#intro.

McGowen, M. A. (2006). Who are the students who take precalculus? In N. Baxter Hastings, F. S. Gordon, S. P. Gordon, J. Narayan, & Mathematical Association of America (Eds.), *A fresh start for collegiate mathematics: Rethinking the courses below calculus* (pp. 15-27). Washington, DC: The Mathematical Association of America.

Mendoza-Spencer, B., & Hauk, S. (2008). Novice college mathematics instructors' knowledge for teaching.   Retrieved December 4, 2008, from http://www.rume.org/crume2008/Mendoza-Spencer_SHORT.pdf

Middleton, J. A., & Spanias, P. A. (1999). Motivation for achievement in mathematics: Findings, generalizations, and criticisms of the research. *Journal for Research in Mathematics Education, 30*(1), 65.

Miller, W. L. (1974). The contract method vs the traditional method of teaching developmental mathematics to underachievers: A comparative analysis. *Two-Year College Mathematics Journal, 5*(2), 45-49.

Multon, K. D., & Brown, S. D. (1991). Relation of self-efficacy beliefs to academic outcomes: A meta-analytic investigation. *Journal of Counseling Psychology, 38*(1), 30.

National Center for Academic Transformation. (2008). NCAT Homepage. Retrieved December 5, 2008, from www.center.rpi.edu

National Center for Educational Statistics. (2004). Student effort and educational progress: Remediation and degree completion (Indicator 18). Retrieved December 4, 2008, from

http://nces.ed.gov/programs/coe/2004/section3/indicator18.asp

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: National Council of Teachers of Mathematics.

Packard, A. L., & Holmes, G. A. (2006). Prototype features of a statistics homework web-site to advise instructors about student progress. *International Journal of Instructional Media, 33*(4), 389-396.

Pajares, F., & Miller, M. D. (1995). Mathematics self-efficacy and mathematics performances: The need for specificity of assessment. *Journal of Counseling Psychology, 42*(2), 190.

Pintrich, P. R., & DeGroot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology, 82*(1), 33.

Pitcher, N. (2002). Assessment with Mathwise: Lessons, limitations, and learning curves [Electronic Version]. *Maths CAA Series*. Retrieved April 23, 2008, from http://ltsn.mathstore.ac.uk/articles/maths-caa-series/sep2002/index.shtml#intro.

Ponton, M. K. (2002). Motivating students by building self-efficacy. *Journal of Professional Issues in Engineering Education & Practice, 128*(2), 54.

Roth-McDuffie, A. (1996). *Modeling reform-style teaching in a college mathematics class from the perspectives of professor and students.* Paper presented at the annual meeting of the American Educational Research Association, New York, NY.

Saracoglu, B., Minden, H., & Wilchesky, M. (1989). The adjustment of students with learning disabilities to university and its relationship to self-esteem and self-efficacy. *Journal of Learning Disabilities, 22*(9), 590-592.

Schunk, D. H., Pintrich, P. R., & Meece, J. L. (2008). *Motivation in education: Theory, research, and applications* (3rd ed.). Upper Saddle River, NJ: Pearson/Merrill Prentice Hall.

Siegel, R. G. (1985). A comparison of two models for predicting mathematics performance: Social learning versus math aptitude-anxiety. *Journal of Counseling Psychology, 32*(4), 531.

SLCC Institutional Research. (2006). Fast facts.   Retrieved April 23, 2008, from

http://www.slcc.edu/ir/fastfacts.asp

Slemon, J. C., & Shafrir, U. (1997). *Academic self-efficacy of post-secondary students with and without learning disabilities*. Paper presented at the annual meeting of the American Psychological Association. Retrieved August 15, 2007, from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=ED413335&site=ehost-live

Snider, V. (2006). *Myths and misconceptions about teaching: What really happens in the classroom*. Lanham, MD: Rowman & Littlefield Education.

Speckler, M. D. (2007, October 2, 2007). Making the grade: A report of the success of MyMathLab in higher education math instruction.   Retrieved October 2, 2007, from http://www.mymathlab.com/success_report.html

Speckler, M. D. (2008, November 14, 2008). Making the grade: A compendium of data-driven case studies on the effectiveness of MyMathLab and MathXL.   Retrieved November 14, 2008, from http://www.mymathlab.com/makingthegrade_v3.pdf

Stake, R. E. (2006). Case studies in science education classroom observation checklist. Retrieved November 18, 2007, from http://www.ed.uiuc.edu/CIRCE/EDPSY490E/B38a.pdf

Steffe, L. P. (1996). *Theories of mathematical learning*. Mahwah, NJ: Erlbaum.

Testone, S. (2005). Using publisher resources to assist developmental mathematics students. *Research and Teaching in Developmental Education, 21*(2).

Trautwein, U., & Koller, O. (2003). The relationship between homework and achievement: Still much of a mystery. *Educational Psychology Review, 15*(2), 115.

Tuckman, B. W. (2007). The effect of motivational scaffolding on procrastinators' distance learning outcomes. *Computers & Education, 49*(2), 414-422.

Tuckman, B. W., & Sexton, T. L. (1990). The relation between self-beliefs and self-regulated performance. *Journal of Social Behavior & Personality, 5*(5), 465-472.

Tuckman, B. W., & Sexton, T. L. (1992). The effects of informational feedback and self-beliefs on the motivation to perform a self-regulated task. *Journal of Research in Personality, 26*(2), 121-127.

Williams, G. D. (1996). *An examination of computer-aided instruction, the self-concept and achievement levels of developmental mathematics community college students.* Unpublished doctoral dissertation, Baylor University.

Young, D. B., & Ley, K. (2000). Developmental students don't know that they don't know: Part I Self-regulation. *Journal of College Reading and Learning, 31*(1), 54.

Young, D. B., & Ley, K. (2001). Developmental students don't know that they don't know: Part II Bridging the gap. *Journal of College Reading and Learning, 31*(2), 171.

Young, D. B., & Ley, K. (2002). Self-efficacy of developmental college students. *Journal of College Reading and Learning, 33*(1), 21.

Zemke, R., & Zemke, S. (1995). Adult learning: What do we know for sure? *Training, 32*(6), 31-34, 36, 38, 40.

Zerr, R. (2007). A quantitative and qualitative analysis of the effectiveness of online

    homework in first-semester calculus. *Journal of Computers in Mathematics and*

    Science Teaching, 26(1), 55.

Zimmerman, B. J. (1990). Self-regulated learning and academic achievement: An

    overview. *Educational Psychologist, 25*(1), 3.

APPENDICES

Appendix A

Screenshots of the Online Homework System

Screenshot of Typical Online Homework Problem

Screenshot of First Step of "Help Me Solve This"

Screenshot of Diagnostic Assistance After an Incorrect Answer

Screenshot of "View an Example"

Screenshot of Partial Student Grade Report

Results   Legend 🖶 ⑦

[📊 Show Overall Score]

[▦ Past 2 weeks] [▦ Past month] [▦ Entire course to date]   [All Assignments ▼]

Results from entire course to date

Results from entire course to date		Correct/ Total	Score	Time Spent	Date Worked
Ⓗ 4.2 HW L	Review	0.7/5	13.3%	12m	10/22/07 11:19am
Ⓗ 3.3 HW L	Review	2/5	40%	9m	10/08/07 11:19am
Ⓗ 1.6 HW L	Review	1/5	20%	1h 7m	09/12/07 11:23am
Ⓗ R.6 HW	Review	1/31	3.2%	8m	09/05/07 11:13am
Ⓗ R.2 HW	Review	1/22	4.5%	17m	08/24/07 12:05pm
Ⓗ 2.3 HW L	Review	0/5	0%	24m	08/22/07 11:32am
◆ Chapter 1-B (Sample Test)	Review	4/22	18.2%	3m	08/25/06 12:56pm
◆ Chapter 1-B (Sample Test)	Review	0/22	0%	<1m	08/25/06 12:52pm
◆ Chapter 0-A (Sample Test)			incomplete		08/23/06 1:30pm
◆ Chapter 0-B (Sample Test)			incomplete		08/14/06 2:50pm

Appendix B

College Algebra Course Syllabus

MATH 1050

COLLEGE ALGEBRA
SPRING SEMESTER 2008

INSTRUCTOR:
OFFICE:
E-MAIL:
VOICE MAIL:
INSTRUCTOR'S WEB PAGE:
CONSULTATION:
DEPARTMENT WEB SITE: http://active.slcc.edu/math/

TEXT: College Algebra 8th Ed.
         By Michael Sullivan
         Prentice Hall, publisher

SLCC is committed to fostering and assessing the following student learning outcomes in its programs and courses:
         Acquiring substantive knowledge in the field of their choice
         Developing quantitative literacies
         Developing the knowledge and skills to be civically engaged
         Thinking critically
         Communicating effectively

GENERAL EDUCATION STATEMENT

This course fulfills the **Quantitative Literacy (QL)** requirement for the General Education Program at Salt Lake Community College. It is designed not only to teach the information and skills required by the discipline, but also to develop vital workplace skills and to teach strategies and skills that can be used for life-long learning. General Education courses teach basic skills as well as broaden a student's knowledge of a wide range of subjects. Education is much more than the acquisition of facts; it is being able to use information in meaningful ways in order to enrich one's life. While the subject of each course is important and useful, we become truly educated through making connections of such varied information with the different methods of organizing human experience that are practiced by different disciplines. Therefore, this course, when combined with other General Education courses, will enable you to develop broader perspectives and deeper understandings of your community and the world, as well as challenge previously held assumptions about the world and its inhabitants.

INTRODUCTION: Welcome to College Algebra! Please read this syllabus carefully. We feel that it will answer most of the questions you may have about

how Math 1050 fits in with your goals as a student at Salt Lake Community College. **Copies of a generic syllabus, homework exercises, course calendar, and lab assignments can be accessed at the Math Department home page.** This course, along with Math 1060, is intended to prepare students for a comprehensive course in Calculus and is required for a major in math, physics, chemistry, engineering, and computer science, as well as many of the life sciences. Math 1050 satisfies the graduation requirement in mathematics at SLCC. Math 1030 Quantitative Reasoning, Math 1040 Statistics, and Math 1090 College Algebra for Business Majors also satisfy graduation requirements. If you are not sure of the proper course for you, contact a representative in your major department at SLCC or your transfer institution. If you have not chosen a major, contact your academic advisor.

MATERIALS: Use of graphing technology is required in this course. You will be assigned homework problems and project based labs, which require the use of a graphing calculator.

CALCULATORS: Graphing calculators are used to demonstrate concepts and facilitate problem solving. They are not a substitute for learning the concepts. Basic facts, such as finding exact values, are as important for you to know without the aid of a calculator. While some homework assignments, projects, and take-home exams will require the use of a graphing calculator, questions on in-class exams will test basic facts that must be memorized. At the discretion of your instructor, graphing, programmable, and scientific calculators may not be allowed for in-class exams.

Help in learning to use a graphing calculator (and some math software) is available in the math labs, which are located in SI 092 at Redwood, and W285 and N308 at South City Campus. There is also "TI Graphing Calculator Help " linked to the department's web page; click on "Resources for Student Success". In addition, your textbook has a graphing utilities appendix.

PREREQUISITES: This course is for students who have successfully completed an intermediate algebra course, such as Math 1010, with a grade of C or better, or who otherwise qualify by virtue of acceptable CPT or ACT scores achieved within the past year. Substitutions for the intermediate algebra course include an ACT score of 23 or better, or a CPT score of at least 43 on the college algebra section. If you do not have documentation for one of these prerequisites, you are advised to enroll in a math class more appropriate for your background.

COURSE DESCRIPTION: This course continues to explore, in greater depth, standard algebra topics many of which were addressed in Math 1010. Topics will include the following: 1) functions, including polynomial, rational, exponential, and logarithmic; 2) systems of equations; matrices and determinants; partial

fraction decomposition; 3) conics; and 4) sequences and series.

COURSE OBJECTIVES: The primary objective of College Algebra is for students to gain a theoretical and operational understanding of the college algebra topics listed above. Graphing technology, computers, and / or graphing calculators will be utilized to assist students in grasping these concepts. **However, your performance will be measured primarily on your understanding of the concepts and your facility in doing symbolic operations rather than your ability to use technology to get answers.** Upon completion of this course, students should be able to:

- Demonstrate a theoretical understanding and manipulative facility of functions including polynomial, rational, exponential, and logarithmic.
- Apply algebraic skills to the formulation and solution of "real-world" application problems.
- Represent equations and systems of equations graphically through the use of graphing technology, and to integrate the algebraic and graphic interpretation of these concepts.
- Advance readily to higher-level math classes, Trigonometry and Calculus.

HOMEWORK: A list of exercises for home study is available at the department website under "Standardized Course Materials". These exercises are considered the minimum required for a sufficient understanding of the material. Students are encouraged to work more exercises than those assigned. **Homework will be collected** and will constitute a portion of your final grade. Homework problems are similar to the problems which will appear on course examinations and the final exam. **Regular practice is essential for success in mathematics. You should be prepared to spend at least two hours studying outside of class for each hour of class time.**

PROJECT-BASED LABS: The project-based labs are found by going to the mathematics department website under "Standardized Course Materials". These projects are designed to allow the student to examine "real-world" applications using technology as a tool. Your instructor will assign specific projects for you to do.

EXAMS:
CHAPTER EXAMS: There will be four chapter exams during the fall semester. All exams after the first one will be on a cumulative basis. All examinations will be closed book and will be taken during a scheduled class period. **Full credit will be awarded on test problems only if your work can be readily followed and solutions are precise and clearly indicated.** **No exam score will be dropped.**

FINAL EXAM: The final exam for daytime classes is scheduled for Tuesday April 29, 2008, from 3:00 – 5:00 p.m. Your instructor will announce the exact location. **Students should make arrangements with employers now to be free at the appointed time.** Please consult the final exam schedule in the Spring 2008 class schedule for the appropriate day and time for evening classes. The final will be a standardized department examination emphasizing topics listed under the course objectives. It is an SLCC Math Department policy that students attaining a score of less than 50% on the final shall receive a grade no higher than "D" for the course.

ADDITIONAL ASSIGNMENTS: Your instructor throughout the course may assign brief written assignments, group exercises, or computer projects.

GRADING: Grading will be as follows:

A	93% and above
A-	90% - 92%
B+	87% - 89%
B	83% - 86%
B-	80% - 82%
C+	77% - 79%
C	73% - 76%
C-	70% - 72%
D+	67% - 69%
D	63% - 66%
D-	60% - 62%
E	59% and below

POSTING OF GRADES: Grades will **not** be posted except through the Internet. Students who want early notification of their final grades should provide a stamped, self-addressed envelope or postcard at the end of the course.

CLASS SCHEDULE: Attached is a schedule for this semester. This schedule will be followed as closely as possible. However, **some modifications may be necessary during the semester**. Your instructor will announce all modifications in class.

ATTENDANCE: Class attendance is expected. Regular attendance is essential to achieve satisfactory results. It is the student's responsibility to be aware of all material covered, tests dates, and assignment due dates. Your instructor will outline specific attendance policies.

CLASSROOM DEPORTMENT: Each student is responsible for his/her own behavior. Any student who shows a pattern of disrespect for others, or who at

any time displays egregious disrespect for others, will be subject to penalties as per the student code of conduct.

PERMANENT FOLDER: To minimize the possibility of computer or human error all graded homework, bonus quizzes, and exams should be kept in a folder until you have received your final grade for the course.

CHEATING POLICY: *Students found cheating will receive an E for the entire course.* **There will be no tolerance for cheating.**

WITHDRAWAL POLICY: Students may withdraw from the course through March 11, 2008. NO withdrawals will be approved after that date.

ACCOMMODATIONS: Students with disabilities needing accommodations such as: accommodated testing, interpreting, note-taking, taped textbooks, assistive technology, equipment, accessibility arrangements, etc., must contact the Disability Resource Center (Redwood College Center - Room 244 or South City Campus Room W138), 957-4659 (voice), 957-4646 (TTY), 957-4947 (FAX).

EXTRA HELP: College Algebra is a challenging course, but the methods for success are simple: read the text, participate in class, and keep up on assignments. Many students find that forming study groups with other students is a very effective way for them to master mathematics. If you need extra help, free tutoring is available in the Learning Centers (phone 957-4172) at Redwood TB-213, South N308, Sandy Bldg. B, and Jordan Rm. 102. A list of private tutors who may be hired is available in the Learning Centers. It is also recommended that students peruse the "Resources for Student Success" link from the math department web page.

RESOURCES FOR STUDENT SUCCESS: Please visit the math department web site at: http://active.slcc.edu/math/ . On the left of the screen, click on Resources for Student Success. This page contains a wealth of valuable information! Learn about workshops, tutoring, software, videos, and web sites that are all designed to HELP YOU SUCCEED in Math 1050.

Finally, read and be aware of the regulations set forth in the Spring Schedule 2008 and the SLCC college catalog. Please see your instructor ASAP about any problems that are affecting your work in this class.

Math 1050 Tentative Schedule SPRING SEMESTER 2008

Monday	Tuesday	Wednesday	Thursday	Friday

1/7 Intro, 1.4	1/8 3.1	1/9 2.2	1/10 3.2	1/11
1/14 3.3	1/15 3.4	1/16 3.5 (calculators)	1/17 3.5, 3.6	1/18
1/21 Holiday	1/22 3.6	1/23 Review	1/24 Test 1	1/25
1/28 4.3, 4.4	1/29 4.4, 4.5	1/30 5.1	1/31 5.1, 5.2	2/1
2/4 5.2	2/5 5.3	2/6 5.4	2/7 R6, 5.5	2/8
2/11 5.5	2/12 5.6	2/13 5.6	2/14 Review	2/15
2/18 Holiday	2/19 Test 2	2/20 6.1	2/21 6.2	2/22
2/25 6.2	2/26 6.3	2/27 6.4	2/28 6.4, 6.5	2/29
3/3 6.5	3/4 6.6	3/5 6.6	3/6 6.7	3/7
3/10 6.7, 6.8	3/11 6.8 Last Day to Withdraw	3/12 Review	3/13 Test 3	3/14
3/17 -----------------------	3/18 ------ SPRING------	3/19 ------BREAK-------	3/20 ------------------------	3/21 ---------------------
3/24 8.2	3/25 8.2	3/26 8.3	3/27 8.3	3/28
3/31 8.4	4/1 8.4, 8.5	4/2 8.5	4/3 9.1	4/4
4/7 9.2	4/8 9.3	4/9 Review	4/10 Test 4	4/11
4/14 2.4	4/15 7.2	4/16 7.2, 7.3	4/17 7.3	4/18
4/21 7.4	4/22 7.4	4/23 Review	4/24 Review	4/25 Reading Day
4/28 Final Exams	4/29 **Math 1050 Final Exam 3:00 pm**	4/30 Final Exams	5/1 Final Exams	5/2

Math 1050 College Algebra

Homework Assignments
Fall Semester 2008

Text: College Algebra 8th Edition By Michael Sullivan
*The review problems should be done a few days after the section is covered in class but prior to the exam
** Read the section prior to coming to class and again prior to doing your homework.

Section	Assigned Problems	*Review Problems	**Assigned Reading
1.4	43, 45, 51, 55, 57, 59, 65, 69, 71, 89	60	1.4 &3.1
3.1	5, 6, 7, 10, 12, 13, 15, 17, 19, 23, 29, 31, 33, 35, 39, 41, 47, 49, 51, 53, 55, 57, 63, 67, 69, 73, 77, 80, 101	59, 75	2.2
2.2	4, 5, 6, 7, 11, 13, 19, 23, 27, 29, 31, 33, 35, 37, 39, 40, 41, 43, 44, 45, 51, 53, 55, 57, 59, 61, 67, 81,85	68	3.2
3.2	3, 4, 5, 6, 7, 9, 10, 11, 13, 15, 16, 17, 18, 19, 23, 25, 29, 35	14, 27	3.3
3.3	7, 8, 9, 10, 11-20, 21, 23, 25, 27, 29, 31, 33, 35, 37, 39, 43, 63, 83, 85	22, 32, 42	3.4 & Appendix A1 1-5
3.4	5, 6, 8, 9 – 16, 25, 27, 29, 33, 35, 37, 41, 42, 47, 59	26, 38	3.5
3.5	1 – 25, 27, 29, 31, 33, 35, 37, 39, 51, 53, 57, 65, 69, 87	66	3.6
3.6	1, 3, 5, 7, 9, 11, 19, 22, 23	4, 8	

Exam 1

Section	Assigned Problems	*Review Problems	Assigned Reading
4.3	5–18, 25, 27, 31, 37, 41, 45, 47, 49, 51, 59, 61, 65, 75, 86, 89	52, 63	4.3 & 4.4
4.4	3, 5, 7, 9, 11, 13, 15, 19, 31	4, 10	4.5
4.5	3-7, 11, 13, 17, 19, 23, 25, 33, 35, 41	15	5.1
5.1	6, 7, 8, 11, 13, 15, 21, 23, 25, 29, 31, 33, 39, 43, 45, 47, 49, 55, 57, 59, 63, 67, 75, 83, 87, 102, 107	77	5.2
5.2	5, 6, 10, 11, 13, 15, 17, 19, 21, 23, 25, 27, 31, 37, 41, 43, 45, 47, 49, 51, 54, 57, 59	16, 44	5.3
5.3	4-7, 9, 11, 13, 15, 17, 23, 25, 27, 33, 45, 47, 49, 55, 57	18	5.4
5.4	3, 7, 9, 11, 13, 15, 17, 19, 21, 23, 29, 31, 33, 43, 45, 57	10, 22	R6

R6	4, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25	22	5.5
5.5	5-9, 13, 15, 17, 19, 33, 37, 39, 43, 45, 49, 51, 53, 59, 61, 67, 69, 73, 78, 89, 91, 103, 105	52, 90	5.6
5.6	3-7, 9, 11, 13, 15, 17, 19, 21, 25, 27, 31, 33, 35, 41, 43	23, 32	

Exam 2

Section	Assigned Problems	*Review Problems	**Assigned Reading
6.1	4, 5, 6, 8, 10, 13,15,18,19, 21, 24, 25, 30, 33, 35, 40, 43, 47, 49, 54, 56, 60, 61, 73	38	6.1&6.2
6.2	10-30 even; 31, 35, 37, 39, 40, 42, 43, 45, 49, 51, 53, 55, 59, 63, 66, 68, 72, 75, 79, 84, 87, 98	67	6.3
6.3	17, 19, 21, 23, 25, 26, 29-36, 37,39, 42, 43, 46, 57, 59, 61, 65, 69, 73, 76, 79, 85, 90, 91,105, 108	44	6.4
6.4	4-8, 9, 11, 14,16, 17, 19, 22, 24, 25, 29, 33, 35, 37, 41, 45, 48, 55, 59, 61, 71, 74, 77, 79, 85, 89, 93, 95, 97, 101, 105, 109, 113, 117, 120, 131	60, 72	6.5
6.5	1, 2, 3, 7, 9, 12, 14, 17, 21, 24, 25, 31, 32, 33, 41, 42, 43, 45, 47, 52, 53, 56, 57, 64, 65, 66, 71, 80, 83, 85	48, 63	6.6
6.6	1, 2, 5, 9, 11, 16, 17, 21, 24, 25, 33, 36, 37, 43, 50, 75, 77, 81, 89, 91,100	22, 42	6.7
6.7	1, 2, 3, 5, 7, 12, 13, 15, 20, 25, 27,31, 34, 39, 44, 46, 49, 55, 57	40	6.8
6.8	1, 3, 5, 7, 8, 10, 12, 17, 19, 23, 26, 27	11	

Exam 3

Section	Assigned Problems	*Review Problems	**Assigned Reading
8.2	1, 2, 4, 7, 9, 11, 14, 15, 17, 19, 21, 25-36 all, 37, 39, 41, 43, 47, 51, 69, 87	29, 44	8.2, 8.3
8.3	1, 2, 5, 7, 10, 11, 14, 15, 17, 20, 23, 25, 28, 34, 35, 37, 39, 41, 45	33	8.4
8.4	1, 2, 3, 7, 9, 11, 13, 15, 17, 23, 26, 29, 31, 35, 39, 41, 43, 45, 51, 61, 62	18, 40	8.5
8.5	2, 3, 5, 12, 13, 15, 17, 19, 21, 23, 31, 33, 46	16	9.1
9.1	1, 3, 4, 5, 11, 15, 17, 18, 20, 21, 25, 27, 28, 34, 35, 39, 40, 45, 49, 51, 57, 59, 60, 61, 63, 65, 69, 70, 71, 77	16, 42	9.2
9.2	1, 3, 4, 6, 7, 9, 11, 13, 15, 20, 21, 23, 26, 27, 31, 34, 35, 39, 42, 47, 55, 61	16, 41	9.3
9.3	1, 2, 3, 4, 5, 9, 11, 13, 14, 16, 17, 19, 21, 23, 24, 26, 30, 33,	49, 75	

35, 37, 39, 41, 43, 44, 46, 47, 50, 57, 67, 69, 70, 76, 88, 90		

Exam 4

Section	Assigned Problems	*Review Problems	**Assigned Reading
2.4	1,2 , 4, 7, 10, 15, 15, 20, 21, 25, 29, 35, 40, 53	28	2.4&7.2
7.2	1, 2, 3,4 ,5, 6, 7, 11, 13, 16, 21, 23, 26, 28, 31, 35, 37, 43, 49, 55, 61, 71, 75	29, 41	7.3
7.3	1, 2, 3, 4, 5, 6, 7, 8, 9, 13, 15, 16, 19, 21, 24, 25, 27, 30, 31, 33, 36, 39, 45 ,51, 53, 57, 61, 63, 75	46, 55	7.4
7.4	1, 2, 3, 5, 6, 7, 8, 9, 13, 15, 18, 19, 21, 24, 25, 29, 31, 33, 34, 35, 37, 39,40, 43, 47, 51, 55, 65, 67	20, 48	

Appendix C

Classroom Observation Checklist

Classroom Observation Checklist

This checklist has been adapted from the CSSE Classroom Observation Checklist available at http://www.ed.uiuc.edu/CIRCE/EDPSY490E/B38a.pdf. Accessed 11/16/07.

Rate each observation area using the following 4-point response scale: (1) None; (2) A small amount; (3) A moderate amount; (4) A large amount.

Guiding and descriptive questions are provided in order to provide definitional direction.

PEDAGOGY	
Observation Area and Score	**Guiding and Descriptive Questions**
Text Orientation:	Is there evidence of considerable use of a textbook in teaching? Is the text sequence followed?
Test Orientation:	Is there evidence of considerable awareness of test? Is there emphasis on forthcoming tests?
Experience Based:	Are students' personal experiences a basis for approaching new understandings? Do teachers "honor" events of their own experience?
Objectives Based:	Are learning activities oriented around instructional objectives? Are students expected to master well-specified tasks?
Problem Oriented:	Are concepts draw from practical applications? Is the teaching inductive, proceeding from problems to solutions to generalizations?
Operations, Drill:	Is there considerable emphasis on drill, memorizing definitions? Do students repeat basic operations time and time again?
Rules, Examples:	Are rules studied first then examples to illustrate and emphasize the principles? Is the teaching deductive?
Integrated Subject Matter:	Are concepts networked across disciplines? Are students encourages to apply learning to different situation. Is deliberate effort made to teach more than one subject matter at the same time?
Diversions:	Are the unexpected and unplanned allowed to take over? Do discussions meander? Is there spontaneity here?

TEACHER AIM

Observation Area and Score	Guiding and Descriptive Questions
Didactic:	Is the teaching mode one of conveying information? Imparting knowledge? Building skills? Is the aim for the students "to remember"?
Heuristic:	Is the teaching mode one of serving to guide, to discover, to reveal? To solve problems? Is the aim for students "to know how to learn"?
Philetic:	Does the teaching mode evidence a concern for student's development, both intellectually and as a person? Is the aim for students "to know themselves"?

KNOWLEDGE USE

Observation Area and Score	Guiding and Descriptive Questions
Replicative:	Is there an emphasis on recall, recognition of facts? Are students expected to duplicate, repeat learning?
Associative:	Is there an emphasis on a readiness to respond to cue or stimulus by bringing to consciousness ideas, images, analogues, contracts, and elaborations?
Applicative:	Is content in one area used to solve problems in another area? Are techniques viewed as a way to "use" a theory?
Interpretive:	Is there an emphasis on understanding? Ability to explain? Are students encouraged to restate essential ideas in their own ways?

TIME ALLOCATION

Observation Area and Score	Guiding and Descriptive Questions
Lesson:	Percent of total class time allotted to the current instructional topic, broadly considered, including study time?
Other Education:	Percent of total class time allotted to learning of an educational nature but not related to current topics?
Admin and Other Non-Education:	Percent of total class time spent taking roll, collecting assignments, handing out exams, discussing "rules", disciplining students, announcing course-related activities, shooting the bull.

Appendix D

SLCC Math Department Letter of Information

Letter of Information: The Effects of Online Homework on Achievement and
Self-Efficacy of College Algebra Students

Introduction/Purpose Professor Kurt Becker in the Department of Engineering and
Technology Education at Utah State University and Shane Brewer, a Doctoral Student in
Curriculum and Instruction in the College of Education and Human Services, are
conducting research to investigate the effect of online homework assignments as
compared with traditional textbook homework assignments on the mathematical
achievement and self-efficacy of students enrolled in college algebra. Your department
has been asked to participate because you are currently using an advanced online
homework system and because of the Department's interest in an objective study of
online homework systems.

The field of collegiate mathematics education is currently being challenged by the large
number of students who enroll in college algebra and subsequently fail. Online learning
systems may offer solutions to this problem. This study will examine the effectiveness of
using online homework systems to address these issues.

Procedures If the Math Department agrees to participate in this study they will be
expected to make the following arrangements and grant the following permissions: (a)
identify and grant permission to college algebra instructors to participate; (b) allow the
researcher (via the section instructors) to administer a short survey (10-15 minutes)
during weeks one and fourteen of the semester <u>and</u> a math skills pretest during week two
of the semester; (c) allow the researcher to make two classroom observation visits during
the semester; and (d) allow the researcher to use final exam grades for statistical analysis.

The online homework system used in this study was created entirely by the textbook
publisher. The online homework problems have been chosen to match the textbook
homework problems as much as possible.

This study will last the entire Fall 2008 semester. Every effort has been made in the
design of this study to minimize its impact on instructor workload and time. For the most
part, instructors teaching both the online homework and textbook homework sections of
college algebra should see little, to no, change in their day-to-day, in-class and out-of-
class, teaching activities.

Risks/Benefits There is minimal risk in participating in this study. This research may
benefit college mathematics educators and Salt Lake Community College's Mathematics
Department by providing insights into the effectiveness of online learning systems for
students of varying skill levels and circumstances.

Explanations and offer to answer questions Shane Brewer has explained this research
study to you and answered your questions. If you have further questions or research-

related problems, you many reach Professor Kurt Becker at (435) 797-2758 or Shane Brewer at (435) 678-2201 ext. 8185.

<u>Confidentiality</u> Research records will be kept confidential, consistent with federal and state regulations. Only Dr. Becker and Shane Brewer will have access to the data which will be kept in a locked file cabinet in a locked room. Names, or any other identifying characteristics, will not be used in any data summaries or publications. All information gathered will be destroyed after analysis has been completed.

<u>USU and SLCC IRB Approval Statement</u> (PENDING) The Institutional Review Board for the protection of human participants has approved this research study. If you have any questions or concerns about your rights, your may contact the IRB at (435) 797-1821.

_____   _____
Kurt Becker, Ph.D., Principal Investigator   Shane Brewer, Doctoral Candidate
(435) 797-2758   (435) 678-2201 ext. 185

Appendix E

Participating Instructor Letter of Information

Letter of Information for Participating Instructors: The Effects of Online Homework on Achievement and Self-Efficacy of College Algebra Students

<u>**Introduction/Purpose**</u> Professor Kurt Becker in the Department of Engineering and Technology Education at Utah State University and Shane Brewer, a Doctoral Student in the Department of Education and Human Services, are conducting research to investigate the effect of online homework assignments as compared with traditional textbook homework assignments on college algebra students. You have been asked to participate because you will be teaching college algebra during the Fall 2008 semester.

The field of collegiate mathematics education is currently being challenged by the large number of, often unprepared, students who enroll in college algebra and subsequently fail. Online learning systems may offer solutions to this problem. This study will examine the effectiveness of using online homework systems to address these issues.

<u>**Procedures**</u> If you agree to participate in this research study you will be expected to: (a) fill out, prior to the beginning of the study, a short informational sheet describing you, your class, and how you implement homework; (b) administer a short survey (10-15 minutes) during weeks one and fourteen of the semester and a math skills pretest during week two of the semester; (c) provide the researcher with the individual scores from the final exam; and (d) allow the researcher to make two classroom visits during the semester to informally observe general classroom activities. The data collected from these classroom visits will only be seen by the researcher and Dr. Becker and will not be shared with the math department or others.

In order to answer the research questions, students will first be grouped together based on their math skills pretest scores. Scores from the short surveys and the final exam will then be analyzed to identify any possible group differences.

Every effort has been made in the design of this study to minimize its impact on instructors' workload and time. <u>For the most part, the instructors teaching both the online homework and textbook homework sections of college algebra should see little, to no, change in their day-to-day, in-class and out-of-class, teaching activities.</u> You will not be expected to grade the surveys or the math skills pretest.

This study will last the entire Fall 2008 semester.

<u>**Risks/Benefits**</u> There is minimal risk in participating in this study. This research may benefit college mathematics educators and Salt Lake Community College's Mathematics Department by providing insights into the effectiveness of online learning systems for students of varying skill levels and circumstances. In addition, this research may benefit you as an instructor by giving you additional experience with and insight into online learning systems.

<u>Explanations and offer to answer questions</u> Shane Brewer has explained this research study to you and answered your questions. If you have further questions or research-related problems, you many reach Professor Kurt Becker at (435) 797-2758 or Shane Brewer at (435) 678-2201 ext. 185.

<u>Confidentiality</u> Research records will be kept confidential, consistent with federal and state regulations. Only Dr. Becker and Shane Brewer will have access to the data which will be kept in a locked file cabinet in a locked room. Names, or any other identifying characteristics, will not be used in any data summaries or publications. All information gathered will be destroyed after analysis has been completed.

<u>USU and SLCC IRB Approval Statement</u> (PENDING) The Institutional Review Board for the protection of human participants has approved this research study. If you have any questions or concerns about your rights, your may contact the IRB at (435) 797-1821.

_____   _____
Kurt Becker, Ph.D., Principal Investigator   Shane Brewer, Doctoral Candidate
(435) 797-2758   (435) 678-8185

Appendix F

Student Letter of Information and Informed Consent

INFORMED CONSENT

The Effects of Online Homework on Achievement and Self-Efficacy of College Algebra Students

Introduction/Purpose Professor Kurt Becker in the Department of Engineering and Technology Education at Utah State University and Shane Brewer, a Doctoral Student in Curriculum and Instruction in the College of Education and Human Services, are conducting research to investigate the effect of online homework assignments as compared with traditional textbook homework assignments on college algebra students. You have been asked to participate because you are currently taking college algebra.

The purpose of this study is to determine if using an online homework system is more effective than using traditional textbook homework to learn college algebra. This study will try to determine which method of homework (if either) is more effective in improving learning and confidence.

The online homework problems and the textbook homework problems cover the same college algebra material. The online homework problems have been chosen to match the textbook homework problems as much as possible, although they differ in numbering and quantity.

Procedures If you agree to be in this research study and you are in an online homework section you will be expected to have internet access in order to complete your homework using the online homework system designed for this study. If you are in a textbook homework section you will be expected to complete your homework from your textbook.

 All participants will also be expected to complete a pretest and two short (10-15 minute) surveys during the semester. The pretest and surveys will be given during class and will not require extra out-of-class work. With your permission (given by signing below) the researcher will then use this data, along with your final exam score, to determine whether the online homework or the textbook homework method is more effective.

The online homework system used in this study was designed so that the online homework problems are similar to the textbook homework problems. The online homework problems have been chosen to match the textbook homework problems as much as possible. The online homework system will immediately grade every homework problem and allow the student the chance to rework the problem as many times as they wish until they are happy with the results. This option is also available when completing textbook homework through the use of the solutions found in the back of the textbook or in the student solutions manual. If the student needs some help with the problem, the online homework system has several ways to help, including helping to solve the actual problem, working a similar problem, or showing a video lecture. Students completing

textbook homework can receive help by consulting the similar examples found in the textbook.

This study will last the entire Fall 2008 semester.

Risks/Benefits There is minimal risk in participating in this study. This research may help students by identifying better ways to teach college algebra.

Explanations and offer to answer questions Shane Brewer has explained this research study to you and answered your questions. If you have further questions or research-related problems, you many reach Professor Kurt Becker at (435) 797-2758 or Shane Brewer at (435) 678-2201 ext. 185.

Voluntary nature of participation and right to withdraw without consequence Participation in research is entirely voluntary. You may refuse to participate or withdraw at any time without consequence or loss of benefits. If you refuse to participate you are not required to withdraw from the course.

Confidentiality Research records will be kept confidential, consistent with federal and state regulations. Only Dr. Becker and Shane Brewer will have access to the data which will be kept in a locked file cabinet in a locked room. Names, or any other identifying characteristics, will not be used in any data summaries or publications. All information gathered will be destroyed after analysis has been completed.

USU IRB Approval Statement (PENDING) The Institutional Review Board for the protection of human participants has approved this research study. If you have any questions or concerns about your rights, your may contact the IRB at (435) 797-1821.

Copy of consent You have been given two copies of this Informed Consent. Please sign both copies and retain one copy for your files.

Investigator Statement "I certify that the research study has been explained to the individual, by me or my research staff, and that the individiaul understand the nature and purpose, the possible risks and benefits associated with taking part in this research study. Any questions that have been raised have been answered."

_____   _____
Kurt Becker, Ph.D., Principal Investigator   Shane Brewer, Doctoral Candidate
(435) 797-2758   (435) 678-2201 ext. 185

Signature of Participant By signing below, I agree to participate.

_____   _____
Participant's Signature   Date

Appendix G

College Algebra Prerequisite Skills Pretest

Intermediate Algebra Skills Pretest

<u>Please do not write on this test. Record your answers on the answer sheet that is provided.</u>

<u>When finished please return the test and the answer sheet to the instructor.</u>

1. **Solve:** $\sqrt{5x+5} + 5 = 0$

    A) 1/4   B) 4   C) 100   D) No Solution

2. **Solve the equation:** $2x^2 + 7x - 4 = 2x + 8$

    A) (-4, 3/2)   B) (-2, 3)   C) (-3/2, 4)   D) (-3, 2)

3. **Use the quadratic formula to solve the equation:** $x^2 + 16x + 41 = 0$

    A) $8 - \sqrt{41}, 8+\sqrt{41}$ B) $-16 \pm \sqrt{41}$

    C) $-8 - \sqrt{23}, -8+\sqrt{23}$ D) $8 \pm \sqrt{23}$

4. **Find the domain of the function:** $f(x) = \sqrt{4-x}$

    A) $\{x|x \neq 4\}$ B) $\{x|x \geq -4\}$ C) $\{x|x \geq 4\}$ D)

$\{x|x \leq 4\}$

5. **Factor the polynomial completely:** $9 - 49x^2$

    A) $(3 + 7x)(3 - 7x)$ B) $(3 - 7x)^2$

    C) $(3 + 7x)^2$ D) prime polynomial

6. **Write in terms of i:** $\sqrt{-169}$

A) -13i   B) $-i\sqrt{13}$ C) 13i   D) ± 13

7. Use the properties of exponents to simplify: $\left(b^{2/3}\right)\left(b^{1/2}\right)$

A) $b^{1/3}$ B) $b^{5/3}$ C) $b^{7/6}$ D) $b^{2/5}$

8. Find the maximum or minimum value of the function: $f(x) = 2x^2 - 4x + 7$

A) 5   B) -2   C) 7   D) 23

9. Find $f(-4)$ when $f(x) = 3x^2 - 2x - 2$

A) 48   B) 54   C) 38   D) 58

10. Find the distance between the points (6, -1) and (4, -5)

A) $12\sqrt{3}$ units   B) 2 units   C) $2\sqrt{5}$ units   D) 12 units

11. Solve the equation: $6x + 8 + 3x - 5 = 3(x + 3) - 3$

A) 2   B) -1/2   C) -2   D) ½

12. Factor the polynomial completely: $3x^2 + 11x - 4$

A) $(3x + 4)(x - 1)$ B) $(3x + 1)(x - 4)$

C) $(3x - 1)(x + 4)$ D) $(3x - 4)(x + 1)$

13. Write the equation of the line with slope = 3 and that passes through the point (-4, -3)

A) y − 3 = 3x − 4   B) y + 3 = x + 4   C) y = 3x + 9

D) y = 3x − 9

14. Solve the absolute value equation: $|6x + 3| = 6$

A) $\dfrac{1}{2}, -\dfrac{3}{2}$ B) $-\dfrac{1}{2}, \dfrac{3}{2}$ C) 1, -3   D) $\dfrac{1}{2}$

15. Solve the system of equations for y: $\begin{cases} 5x - 3y = 12 \\ x + 2y = 5 \end{cases}$

A) y = 1   B) y = -3   C) y = 6   D) y = 3

16. Divide and simplify: $\dfrac{x^2 - 4x + 4}{3x - 6} \div \dfrac{8x - 16}{24}$

A) $\dfrac{(x-2)^2}{9}$ B) 1   C) $\dfrac{x^2 - 4x + 4}{(x-2)^2}$ D) 24

17. Find the equation of the line that passes through (3, -5) and is parallel to 2x – 3y = 9

A) 3x – 2y = 19   B) 2x + 3y = -1   C) 2x – 3y = 21

D) 2x – 3y = -21

18. Divide: $\left(5x^2 - 6x - 27\right) \div (x - 3)$

A) x – 6   B) 5x + 9   C) 5x – 9   D) $5x^2 + 6$

19. Simplify and write with positive exponents: $\dfrac{\left(4xy^{-2}\right)^{-2}}{2xy^3}$

A) $-\dfrac{4}{x^3 y^7}$ B) $\dfrac{y}{32}$ C) $-\dfrac{8y}{x^3}$ D) $\dfrac{y}{32x^3}$

20. Factor the polynomial completely: $x^3 + 16x^2 + 64x$

A) $x(x + 8)^2$

B) $x(x + 8)(x - 8)$

C) $x(x - 8)^2$

D) prime polynomial

Appendix H

Mathematics Self-Efficacy Scale and Demographic Survey

MATHEMATICS SELF-EFFICACY SCALE AND DEMOGRAPHIC SURVEY

All of the information in this survey will be kept strictly confidential in accordance with federal and state regulations. Only the researchers will have access to the data which will be kept in a locked file cabinet in a locked room. Students will remain anonymous.

Full Name (Please Print) _____   Date _____

Instructor's Name _____   Section Number _____

Gender (Circle One): Male   Female

Year in SLCC (Circle One): First Year   Second Year   Other (specify)

1. Place an "X" next to the class(es) you have taken before:

_____   High School Algebra I

_____   High School Algebra II

_____   Fundamentals of Math (usually called Math 0970 in college)

_____   Beginning or Elementary Algebra (usually called Math 0990 in college)

_____   Intermediate Algebra (usually called Math 1010 in college)

_____   College Algebra (either in high school or college)

2. Have you ever taken a math class before where you did all (or much) of your homework using a computer homework system? Circle one.   Yes   No

3. Do you feel comfortable using computers to learn? Circle one.   Yes   No

---

Place an "X" next the option that best applies to you (choose only one):

_____ This is the first time I have taken a college algebra class.
_____ I am retaking college algebra because I am unhappy with my previous grade or was unable to complete the course due to academic reasons.
_____ I am retaking college algebra for other reasons not related to academics.

Copyright prevents the inclusion of the entire Mathematics Self-Efficacy Survey but allows for the inclusion of five sample questions. Four questions are given from Part I of the survey and one question is given from Part II of the survey. Students are asked to assess their level of confidence to complete the following tasks or math-related courses. Students select answers to each question based on a 10-point scale (0-9) with "0" representing "No Confidence at All" and "9" representing "Complete Confidence".

Part I Sample Questions

1. Determine how much interest you will end up paying on a $675 loan over 2 years at 14 ¾% interest.

2. Figure out how long it will take to travel from Columbus to Chicago driving at 55 mph.

3. Understand a graph accompanying an article on business profits.

4. Figure out how much lumber you need to buy in order to build a set of bookshelves.

Part II Sample Question

5. Complete a Trigonometry course with a final grade of "A" of "B".

Note: This portion will only be included in the posttest and will be placed near the top, in place of the existing demographic survey.

Please <u>estimate</u> the average number of hours **<u>PER WEEK</u>** that you spent working on college algebra homework. (Circle one.)

0-2 hours per week   3-5 hours per week   6-8 hours per week   9-11 hours per week

12-14 hours per week   15 or more hours per week

mind garden

www.mindgarden.com

To whom it may concern,

This letter is to grant permission for the above named person to use the following copyright material;

Instrument: *Mathematics Self-Efficacy Scale*

Authors: *Nancy E. Betz & Gail Hackett*

Copyright: *1993 by Nancy E. Betz and Gail Hackett*

for his/her thesis research.

Five sample items from this instrument may be reproduced for inclusion in a proposal, thesis, or dissertation.

The entire instrument may not be included or reproduced at any time in any other published material.

Sincerely,

Vicki Jaimez
Mind Garden, Inc.
www.mindgarden.com

Appendix I

College Algebra Departmental Final Exam

Math 1050 Final Exam Form E

Name_____   Instructor_____

Student ID_____   ID Verification_____

Section Number_____

****

This exam has three parts: Part I – Ten Multiple Choice Questions
                               Part II – Ten Open-Ended Questions – You **MUST** show all your work
                               Part III – Choose FIVE out of ten open-ended questions – you **MUST** show your work and indicate which five problems are to be graded

Students are **NOT** allowed to use books or notes.
****

PART I: Question 1-10, Multiple Choice
Answer all TEN questions and circle the correct answer.

****
Find the domain of the function.

1) $h(x) = \dfrac{x-4}{x^3 - 49x}$

A) $\{x \mid x \neq -7, 0, 7\}$ B) $\{x \mid x \neq 4\}$

C) $\{x \mid x \neq 0\}$ D) all real numbers

Solve the equation.

2) Find all the real solutions of the following equation: $\log_3 x + \log_3 (x-8) = 2$

A) 9   B) 3   C) -1, 9   D) 1,-9

Find the function that is a result of using the following transformations which are applied to the graph of $y = \sqrt{x}$.

3)   i) Shift up 3 units
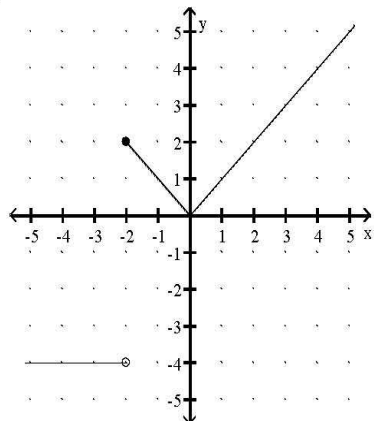   ii) Reflect about the y-axis
       iii) Shift left 5 units

A) $y = -\sqrt{x+5} + 3$ B) $y = \sqrt{-x-5} - 3$

C) $y = \sqrt{-x-5} + 3$ D) $y = \sqrt{-x+5} - 3$

Graph the function.

4)

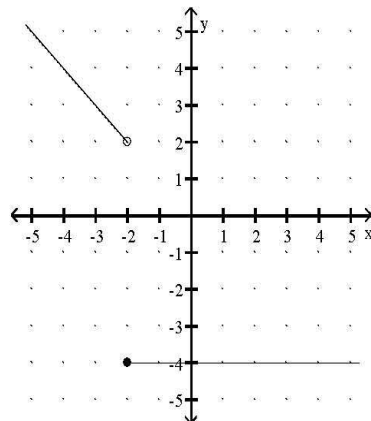$$f(x) = \begin{cases} |x| & \text{if } x < 2 \\ -4 & \text{if } x \geq 2 \end{cases}$$
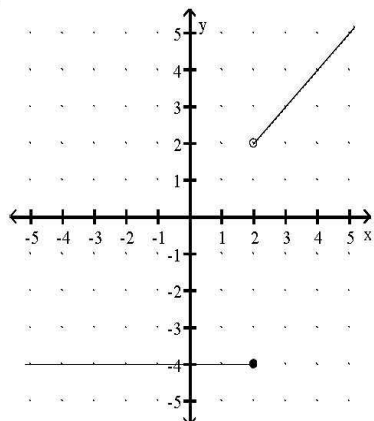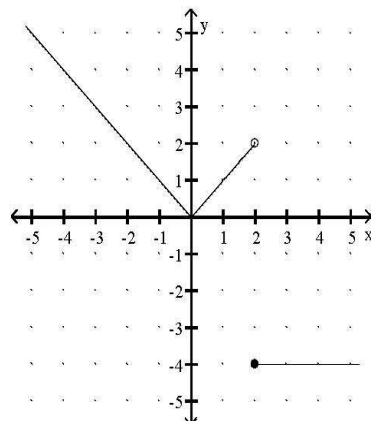
A)

B)

C)

D)

Solve the system of equations for x.

5)

$$\begin{cases} 3x + 2y + z = 14 \\ 2x - 2y - z = -9 \\ 4x + y + 5z = 23 \end{cases}$$

A) x = 1   B) x = 3   C) x = 4   D) inconsistent

Find the first term, the common difference for the arithmetic sequence.

6) 7th term is 59; 15th term is 43

A) $a_1 = 71, d = 2$ B) $a_1 = 71, d = -2$

C) $a_1 = 73, d = 2$ D) $a_1 = 73, d = -2$

List the potential rational zeros of the polynomial function. Do not find the zeros.

7) $f(x) = 5x^3 - x^2 + 3$

A) $\pm\dfrac{1}{3}, \pm\dfrac{5}{3}, \pm1, \pm5$ B) $\pm\dfrac{1}{5}, \pm\dfrac{3}{5}, \pm1, \pm3$

C) $\pm\dfrac{1}{5}, \pm\dfrac{3}{5}, \pm1, \pm3, \pm5$ D) $\pm\dfrac{1}{5}, \pm\dfrac{1}{3}, \pm1, \pm3, \pm5$

Determine whether the function is even, odd, or neither.

8) $f(x) = \dfrac{x}{x^2 - 3}$

A) even   B) odd   C) neither

Solve the problem.

9) The size P of a small herbivore population at time t (in years) obeys the function $P(t) = 1000e^{0.2t}$ (if they have enough food and the predator population stays constant). After how many years will the population reach 3000?

A) 10.49 yrs   B) 14.98 yrs   C) 5.49 yrs   D) 38 yrs

Compute the product.

10) $\begin{bmatrix} 0 & -3 & 1 \\ 5 & -1 & 0 \end{bmatrix} \begin{bmatrix} 1 & 2 \\ 0 & 1 \\ 1 & -1 \end{bmatrix}$

A) $\begin{bmatrix} 1 & 5 \\ -4 & 9 \end{bmatrix}$ B) $\begin{bmatrix} 1 & -4 \\ 5 & 5 \end{bmatrix}$ C) $\begin{bmatrix} 1 & 5 \\ 9 & -4 \end{bmatrix}$ D) $\begin{bmatrix} 1 & -4 \\ 5 & 9 \end{bmatrix}$

Answer Key
Testname: MATH 1050 FINAL EXAM FORM E PART 1

1) A
2) A
3) C
4) D
5) A
6) B
7) B
8) B
9) C
10) D

****

PART II: Question 11-20, Open Ended
Answer all TEN questions. You must show all your work in a clear and logical progression and clearly indicate your answer to receive full credit.

****

State the domain and range of f(x). Find $f^{-1}(x)$.

11) $f(x) = \dfrac{3x-2}{x+5}$

Domain of f(x):_____   Range of f(x):_____

$$f^{-1}(x) = \text{_____}$$

Solve the inequality.

12) $x(x+3)(5-x) \geq 0$

Use the graph of the function f(x) to answer the following questions.

13) f(x)
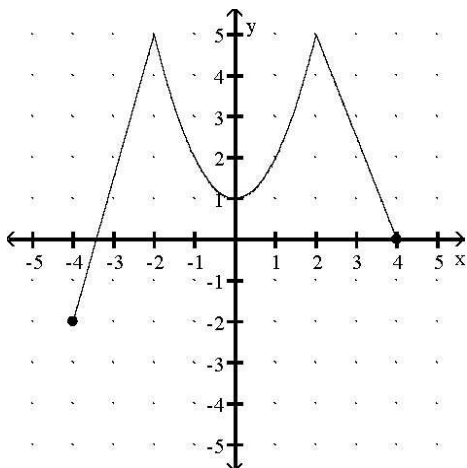
a) Find f(-2)

b) For what value(s) of x is f(x) = -2 ?

c) What is the domain of f(x)?

d) On what interval(s) is f(x) increasing?

Write as the sum and/or difference of logs. Express powers as factors.

14) $\ln\left(\dfrac{(x)\sqrt[7]{1+5x}}{(x-7)^5}\right), x > 7$

Graph the function. Include any asymptotes and intercepts if applicable.

15) $f(x) = \dfrac{x}{x^2-9}$

Solve the problem.

16)   A wire of length 5x is bent into the shape of a square. Express the area A of the square as a function of x.

Write an equation for the ellipse satisfying the given conditions. Graph the ellipse.

17) Vertices at (5, -4) and (5, 8); length of the minor axis is 6

Form a polynomial f(x) with real coefficients having the given degree and zeros.

18) Degree: 3; zeros: 1 and 3 + i

Solve the problem.

19) Given the polynomial function $f(x) = (x-2)^3(x-3)^2(x-4)$

The power function is: _____

The y-intercept is: _____

In the table below, list each zero and its multiplicity.

Zero: Multiplicity: Touch/Cross:

Use this information to sketch a graph of the function.

Solve by hand.

20) $\begin{vmatrix} 5 & -4 & -1 \\ -2 & 2 & 0 \\ -1 & -2 & 8 \end{vmatrix}$

****
PART III: Question 21-30, Self Select
Choose **FIVE** out of the next TEN questions to complete. **You must show all your work and clearly indicate your answer for full credit.** CROSS OUT the problems that you do not want graded. The first five problems that are not crossed out will be graded.

****

Find the inverse of the matrix without using your calculator.

21) $\begin{bmatrix} -2 & 2 \\ -6 & 1 \end{bmatrix}$

Write the partial fraction decomposition of the rational expression.

22) $\dfrac{x}{(x-6)(x-7)}$

Use synthetic division and the Factor Theorem to determine whether x − c is a factor of f(x).

23) $f(x) = x^3 + 4x^2 - 10x + 12; \quad x + 6$

Find the center (h, k) and radius r of the circle. Graph the circle.

24) $x^2 + y^2 - 2x - 12y + 21 = 0$

Solve the problem.

25) Find the amount earned at the end of 4 years if $6000 is invested at a rate of 8.5% compounded monthly.

The sequence is defined recursively. Write the first four terms.

26) $a_1 = 3$ and $a_n = 4a_{n-1} - 2$ for $n \geq 2$

Find the sum of the infinite geometric series.

27) $\sum\limits_{k=1}^{\infty} 2\left(\dfrac{1}{3}\right)^{k-1}$

Solve the equation. Give BOTH the <u>exact solution</u> and the <u>approximate solution</u> to the nearest hundredth.

28) $2^{(2x)} = 3^{(x+1)}$

Find the real solutions of the equation.

29) $x - 9x^{1/2} + 20 = 0$

Graph BOTH functions below. For each function <u>list at least three ordered pairs</u> that lie on the graph.

30) $f(x) = \log_3 x$ $g(x) = 3^x$

Appendix J

Institutional Review Board Permissions

UtahState
UNIVERSITY

INSTITUTIONAL REVIEW BOARD OFFICE
9530 Old Main Hill, Suite 214a
Logan, UT 84322-9530
Telephone: (435) 797-1821
FAX: (435) 797-3769

USU Assurance: FWA#00003308
Protocol # 2107

SPO #:
AES #: UTA00

6/26/2008

MEMORANDUM

TO: Kurt Becker
        David Shane Brewer

FROM: Gretchen G. Peacock, IRB Chair
        True M. Fox, IRB Administrator

SUBJECT: The Effects of Online Homework on Achievement and Self-Efficacy of College Algebra Students

Your proposal has been reviewed by the Institutional Review Board and is approved under exemptions #1 and #2.

X   There is no more than minimal risk to the subjects.
    There is greater than minimal risk to the subjects.

This approval applies only to the proposal currently on file. **Any change in the methods/objectives of the research affecting human subjects must be approved by the IRB prior to implementation.** Injuries or any unanticipated problems involving risk to subjects or to others must be reported immediately to the IRB Office (797-1821).

The research activities listed below are exempt based on the Department of Health and Human Services (DHHS) regulations for the protection of human research subjects, 45 CFR Part 46, as amended to include provisions of the Federal Policy for the Protection of Human Subjects, June 18, 1991.

1. Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

2. Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (a) information obtained is recorded in such a manner that human subjects can be identified, directly or through the identifiers linked to the subjects: and (b) any disclosure of human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

July 9, 2008

Shane Brewer

Your study, *The Effects of Online Homework on Achievement and Self-efficacy of College Algebra Students*, involving volunteer student participants from Salt Lake Community College has been reviewed and approved. We remind you of the need to protect students and student information. It is critical that you follow the planned study process. We ask that you inform us if there are any changes to the study procedures through the duration of the study. We also ask that your findings be shared with interested parties at Salt Lake Community College so we may use this information in ways that could improve our commitment to our students.

Thank you for your interest in working with Salt Lake Community College.

Ray Emett

Director of Institutional Research

Salt Lake Community College

Redwood Campus

Institutional Research
4600 South Redwood Road · Salt Lake City, Utah 84123
Phone: (801) 957.4198 · Fax: (801) 957.4444 · www.slcc.edu

CURRICULUM VITAE

DAVID SHANE BREWER

College of Eastern Utah
San Juan Campus
639 West 100 South
Blanding, Utah 84511

(435) 678-8185
shanebrewer@sjc.ceu.edu

EDUCATION

Doctor of Education *(2009)*

Utah State University, Logan, Utah
Curriculum and Instruction

Master of Science *(1995)*

Brigham Young University, Provo, Utah
Mathematics

Bachelor of Science *(1993)*

Brigham Young University, Provo, Utah
Mathematics

PROFESSIONAL EXPERIENCE

College of Eastern Utah - San Juan Campus - *Blanding, Utah*   *8/97-Present*
    Tenured Faculty - Mathematics

Utah Valley State College - *Orem, Utah*   *8/95-7/97*
    Adjunct Faculty - Mathematics
    Math Lab Manager

Brigham Young University - *Provo, Utah*   *9/90-7/95*
    Adjunct Faculty/Teaching Assistant - Mathematics   *9/93-4/95*
    Math Lab Administrator   *6/95-7/95*
    Intermediate Algebra Coordinator   *6/95-7/95*
    Math Lab Administrative Assistant   *5/93-5/95*
    Math Lab Teaching Assistant   *9/90-5/93*

TEACHING

Live Classes, Distance Classes, and Online Classes
> Mathematics Learning Community Lab
> Basic Math/Pre-Algebra/Arithmetic
> Elementary/Intermediate Algebra
> Quantitative Reasoning
> College Algebra
> Trigonometry
> Applied/Business Calculus
> Calculus I and II
> Statistics
> Beginning Chess
> Intermediate Chess

CURRICULUM DEVELOPMENT

Quantitative Reasoning
> Materials developed for this course included supplementary study aids using Scientific Notebook. For use in the Native American Studies program.

College Algebra
> Materials developed for this course include Tips sheets designed to help students understand key topics, computer explorations designed to make use of graphing utilities and computer algebra systems, practice exams to allowed for test preparation, web pages to distribute and manage this information, and LiveMath notebooks that allowed for interactive mathematics over the web. For use in the Native American Studies program.

Beginning Chess
> A course designed to teach the rules of the game as well as some basic opening, middle game, and endgame theory. Additionally, students are introduced to the vast internet resources available to a chess player. As far as I know, no other institution offers a recreational course in chess.

Intermediate Chess
> A course designed for players that are already familiar with the basics of chess. This class introduces students to more advanced theory in the opening, middle game, and endgame. Additionally, students start to explore strategy and tactics.

PRESENTATIONS

CEU–SJC Noon Forum Series *"Understanding and Overcoming Math Anxiety"*
Blanding, Utah – Annual Presentation

The presentation covers the myths of mathematics, dealing with math anxiety, mathematics study skills, and choosing a math class.

CEU-SJC 25th Anniversary Celebration *"An Introduction to Ethnomathematics"*
Blanding, Utah - *1999*

Number origins and numbers words were considered and explored.

Innovation in the Rockies Conference *"Typesetting Mathematics"*
Rock Springs, Wyoming – *2000*

How to type mathematics and how to present mathematics on a website were covered. MathType 5.0 and Scientific Notebook were used.

Early Reading First National Conference *"The Big Picture on the Box: Finding the Missing Pieces of the Puzzle in Educating Our Native American Children"*
Seattle, Washington – *2009*

A report on RUCD's ERF project which included a description of the project, outcome data, and teacher and parent testimonials.

Teaching with Technology Idea Exchange *"Using Online Homework in Traditional College Math Classes or How to Grade 45,000 Homework Problems and Still Keep Smiling"*
Orem, Utah – *2009*

Presentation of dissertation research results and a discussion of practical applications of online homework in college mathematics classes.

PROFESSIONAL MEMBERSHIPS

National Council of Teachers of Mathematics
Mathematical Association of America
American Mathematical Association of Two Year Colleges
United Stated Chess Federation

CONFERENCE ATTENDANCE

National Council of Teachers of Mathematics
>Washington, District of Columbia - *1998*
>Chicago, Illinois – *2000*
>Las Vegas, Nevada – *2002*
>Salt Lake City, Utah – *2008*

American Mathematical Association of Two-Year Colleges
>Salt Lake City, Utah – *2003*
>San Diego, California – *2005*
>Washington, District of Columbia – *2008*

National Tutoring Association
>Baltimore, Maryland – *1996*

Community College Tutoring and Learning Association
>San Diego, California – *1997*

Innovation in the Rockies
>Rock Springs, Wyoming - *2002*

Retaining and Graduating Indigenous Students
>Albuquerque, New Mexico – *2003*

Calculus Educators
>Grand Junction, Colorado – *2003*

Service Learning Workshop
>Moab, Utah – *2006*

Recruiting and Retention Retreat
>Orem, Utah - *2006*

SERVICE AND LEADERSHIP

Ad-Hoc Committee Participation
>Hiring Committee for SBDC Assistant – *1997*
>Student Judiciary Committee – *1998, 2001*
>Strategic Planning Committee – *1998*
>Associate Degree Task Force – *1998*
>Nursing Program Selection Committee – *1998*
>Student Orientation Committee – *1998*

Grievance Panel – *1999*
Sterling Scholar Judge for Mathematics – *2000, 2003, 2007*
Service Unit Outcomes Report Committee – *2001*
General Education Computer Literacy Task Force – *2001*
Alex Review Study – *2002*
Mountain Plains Distance Learning Project Training – *2002*
Professional Development Panel – *2002*
San Juan Campus Dean Search Committee – *2002*
Native American Studies Curriculum Development Committee – *2002*
Christmas Party Committee – *2002*
Class Matrix Committee – *2003*
Mandatory Placement Committee – *2003, 2004*
Developmental Education Committee – *2005*

Standing Committee Participation

College Senate – *1998, 1999*
Faculty Senate – *1998, 1999, 200, 2004, 2005, 2007*
Budget Committee – 2002, 2009
Commencement Committee – *1999*
Library Committee – *1999, 2000, 2002, 2003, 2007, 2008*
Retention and Recruitment Committee - *2002, 2003, 2007*
AA/EEO Committee – *1999*
Technology Oversight Committee – *2000, 2001, 2002*
Cal Black Memorial Scholarship Committee – *2003-2008*
San Juan Campus Cabinet – *2008, 2009*

Service

Founder and Sponsor of San Juan Campus Chess Club – *2000-Present*
Founder and Sponsor of San Juan Campus Golf Club – *2000*
Director of San Juan Campus Summer Experience Program – *2003-Present*
Regional Director for the Utah State Math Contest – *2006-Present*
External Evaluator for RUED ERF Grant – *2007 – Present*

AWARDS

USHE Exemplary Use of Technology Award - *2006*
CEU-SJC 10 Year Service Award - *2008*