

A COMPARISON OF TWO COMPUTER-AIDED INSTRUCTION METHODS
WITH TRADITIONAL INSTRUCTION IN FRESHMEN
COLLEGE MATHEMATICS CLASSES

by

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A DISSERTATION

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ABSTRACT

Computer Aided Instruction (CAI) has vast possibilities that are just beginning to emerge as the medium is being utilized by more and more institutions nationwide. The new educational software industries have the potential to meet the educational needs of a large and increasingly diverse student population.

The purpose of the present study is to compare achievement among remedial college algebra students in classes where predominantly computer-aided instruction was used to that of students in classes using traditional lecture instruction. The researcher aimed to identify key aspects that may translate into student success and achievement in remedial college algebra classes.

Theoretically, CAI should enhance learning according to well-known principles of behaviorism and constructivism. In reality, studies of learning outcomes using CAI report mixed results about whether the use of CAI actually provides educational benefit beyond that of traditional instruction.

This study was a comparative study using an *ex-post-facto* design. Class sections were randomly assigned to instructional methods. Students, although not randomly assigned to sections, were blind to instructional methods when registering for classes. The study evaluated student performance using scores on individual semester tests, a comprehensive final exam, and overall course grade.

Regardless of whether achievement is measured in terms of single semester test, comprehensive final exam, course average, or test performance across the semester the

results presented here indicate that students perform better in traditional classes than in CAI classes regardless of the CAI curriculum used. Moreover, despite instructional method, students perform better on tests at earlier and later points in the semester than in the middle. Comparison of the two CAI curricula used in this study indicated that student test performance is better for students using Thinkwell CAI than those receiving the MyMathLab CAI curriculum. These results have implications for math educators considering how best to use CAI to teach remedial college algebra.

DEDICATION

To my parents, Seyed Ali Mousavi and Seyade Sharbanu Mousavi

LIST OF ABBREVIATIONS

ACE	American Council on Education
AERA	American Education Research Association
ALEKS	Assessment and Learning in Knowledge Spaces
CAI	Computer-aided instruction
CBI	Computer-based instruction
CERL	Computer-based Education Research Laboratory
COMPASS	Computerized-Adaptive Placement Assessment and Support System
ENIAC	Electronic Numerical Integrator and Computer
ES	Effect Size
F	Frequency
ILS	Integrated learning system
NADE	National Association for Developmental Education
NBER	National Bureau of Economic Research
NCDE	National Center for Developmental Education
NCR	National Council on Research
PLATO	Programmed Logic for Automatic Teaching Operations
SD	Standard Deviation
USDE	United States Department of Education

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CHAPTER 1

INTRODUCTION

In the past, students learned by traditional teaching methods infused with the current technology and the new teaching methods of the time. As innovations in teaching have been developed, teachers have integrated these innovations into their classrooms. Whereas calculators or graphing software have been used in higher-level math classes for decades, computerized teaching tools are relatively new in remedial math classes. It has been noted that “[e]vidence is mounting to support technology advocates’ claim that 21st century information and communication tools, as well as more traditional computer-assisted instruction applications, can positively influence student learning processes and outcome” (Cradler, McNabb, Freeman, & Burchett, 2002, p. 47).

Computers began appearing in schools as early as the 1960s. In 1966, Patrick Suppes predicted that computers would change the face of education at a rapid pace. During the early stages of the introduction of computers in education, users were mainly restricted to small groups of dedicated teachers and selected students. Software-based educational programs of that era were developed by educators who had little or no commercial interests in mind. Originally the cost and processing power of computers posed the biggest obstacle to implementation in the educational arena. At that time, microcomputers were slow and limited in their capabilities. Many of the initial economic and technical problems that hindered computer implementation were solved with the development of progressively more powerful and less expensive machines. These technological innovations led some educators to perceive computers, and later the Internet,

as revolutionary tools that could be used to present interactive teaching material in novel ways that were previously not available through other media. Educational researchers also believed that computers offered the flexibility to adapt to different learning and teaching styles (Underwood & Underwood, 1990).

The use of computer hardware and software technology in schools is on the rise (Gasiorowski, 1998). In their book, *Technology-Based Learning*, Ross and Bailey (1996) suggested that the assumptions and practices of schooling in the United States have changed from those of the industrial era to that of an information era. The authors suggested that “this paradigm shift from an industrial to an information society” (p. 12) will require the use of emerging technologies which, in turn, will test the fundamental premises of education. This phenomenon is witnessed in today’s colleges and universities; educators are encouraged to include the use of personal computers and technology-based instruction in their teacher training programs (Bitter, 1989). Use of technology in the curriculum indisputably will vary based on educational philosophies, educational theories, teaching styles, and, perhaps most importantly, economic factors.

Personal computers clearly have great potential as instructional tools in the classroom (Moore, 1997). There is little doubt that computer technology will play a role in the classrooms of tomorrow. The trick is how to optimize usage and minimize disadvantages.

Gonzalez and Birch (2000) claimed that computer-assisted instruction has the ability to promote active learning in a wide variety of disciplines from literature to the social sciences and beyond. Educators from several countries have expressed similar excitement about the use of computers and the possibilities that this tool can provide. Svensson (2000), a Swedish educator who has conducted a great deal of research into the ability of computers to influence learning in

schools, suggested that computers can influence learning in schools and lead educational practices toward more student-active learning, thus allowing students the ability to develop strategies for learning through interaction.

It remains to be seen whether computer-based instruction will be able to fulfill the optimistic goals that some educators profess. Observers note that “[c]omputer-based technology is increasingly being used in classroom teaching at all levels” (Shuell & Farber, 2001, p. 119). Yet, the danger exists that some educators may use computer-based technologies without improving their own teaching methods. The computer is a tool that educators can use to help them reach their teaching objectives, but perhaps nearly as important as the use of computers is the manner in which these tools are used.

Unfortunately, much of the educational software purchased by schools and adopted for classroom use is subject to the same problems that have always affected textbook selections. One of the main problems of educational software is the lack of a diverse product range. This lack of diversity is because much of the educational software for mathematics on the market today is nearly identical to and modeled after popular mathematics textbooks published by just a few publishing houses. At least two meta-analyses completed to date seem to suggest that commercial software programs used in math classrooms have limitations in comparison to teacher authored software programs (Hsu, 2003; Kuchler, 1998).

Mathematics education spending in the United States currently exceeds \$25 billion per year (National Research Council, NRC, 1989). This staggering amount constitutes more than 10% of total U.S. educational expenditures. In spite of the great expense placed on new programs, “mathematics education in the United States is facing major challenges on nearly every front” (NRC, p. 5). Ironically, research also indicates that the basic format of math

instruction has changed very little over time. The current state of mathematics education is “an enterprise rooted in antiquity, with some of today’s curricula matching very closely the educational pattern of 500 years ago” (NRC, p. 1). Beginning in the 1980s, a series of comprehensive research studies were conducted to analyze almost every aspect of math education in order to help remedy the deficiencies of the present educational system (NRC, 1989). With large-scale proliferation of personal computers, some educators view computer-based teaching as the ultimate teaching tool to combat the shortcomings of the educational system throughout the country.

Colleges and universities are investing enormous sums of money to develop, maintain, and upgrade computer labs and computer-assisted instruction (CAI) mathematics software. Within academia, the push toward using computers in collegiate mathematics instruction is amplified by the demand for asynchronous learning methodologies and the presence of computer laboratories that enhance or replace traditional lecture formats. Outside of academia, the push toward CAI originates from publishing houses and educational resource companies claiming to offer innovative and comprehensive solutions to the elementary college mathematics dilemma. As a promising instructional tool for enhancing student learning (Yu, 2001), the use of CAI to teach college mathematics will continue to grow.

Decisions regarding the adoption of educational policies, methods, and the outlay of educational funds must be informed by research performed on student outcomes. These data can be produced by comparing CAI to other teaching methods. Evidence regarding the usefulness of CAI in meeting student learning objectives for an intermediate algebra curriculum within the traditional liberal arts college is, at best, sporadic and sometimes conflicting (Hedges, Konstantopoulos, & Thorsen, 2003). The potential that computers offer is largely dependent on

educators' use of them. For example, although our current society offers an array of different means of communication among people (e.g., Internet, cell phone, email, etc.), use of this novel technology alone does not guarantee that a more significant level of effective communication exists between members of our society. Likewise, the use of computers in schools similarly does not guarantee a positive shift in teaching and learning. This concern is particularly true if computers are used as surrogate teachers and not as a tool in the hands of capable instructors in order to achieve educational goals based on sound learning objectives.

Three distinct methods of CAI are currently used in classrooms and labs in academia today: (a) drill-and-practice, or tutorials; (b) learning and problem-solving tools; and (c) programming tools. Some educators perceive the use of these learning methods as the solution to the challenges of classroom teaching (Bell & Elmquist, 1992; Bruder, 1990; Cuban, 1993). Other educators perceive CAI as the implementation of an archaic teaching method of acquiring factual knowledge, accompanied by a drill-and-practice style, with little or no use of information-processing skills (Underwood & Underwood, 1990). This apparent conflict of perceptions may be the result of the underlying metrics that each particular group uses to measure the success of CAI learning. The latter group of educators is concerned about the qualitative as well as the quantitative effects of CAI in the classroom, whereas the former group more often focuses on the success of repeating drills rather than understanding the underlying mathematics.

Beyond the contention about the types of skills taught with computers, there are still other advantages of CAI. Miller's (1999) research, for instance, indicated that one of the benefits of CAI is the immediate feedback received by the student. The immediacy of feedback is becoming increasingly important in a society that demands instant gratification and often appreciates continuous assessment. For example, Iino (1998) concluded that students

demonstrated a significantly higher understanding of algebraic topics (e.g., finding the coordinates of a point and the slope of a line on a Cartesian plane) when CAI was used as compared to when traditional methods were used. The 9th and 10th graders in Iino's study evaluated the use of computers favorably. Miller's studies also emphasized the value of the computer interacting with the user as well as the advantages of learning mathematics with individualized instruction.

Given the numbers of students a mathematics teacher often faces, the advantages that the computer gives for personalized instruction are important. In an introductory college mathematics class at a public liberal arts college, the instructor may have as many as 75 to 80 students enrolled in a single lecture section. In such a setting, individual one-to-one interaction between instructor and student is limited. Frequently classroom teaching is combined with computer laboratory assignments in order to provide large numbers of students with a greater array of options for mathematics practice and drill. More studies are needed, however, to evaluate the full effects of replacing teacher guidance with computer labs. In recent years, some universities have relied on the computer lab as a main source of teaching freshman math classes. In other words, universities are using the computer as a way to have larger classes and less human-to-human contact. Much research indicates that students prefer smaller classes and, presumably, class size affects student retention rates and overall experiences. Thus, discussions about computers in the classroom need to be contextualized within broader concerns about the effects of using computers to create larger class sizes.

A number of these concerns appear in a study conducted at The University of Alabama. A CAI program for intermediate algebra was adopted at UA in the fall semester of 2000. An early evaluation of the program entitled Intermediate Algebra Math 100 Evaluation Report 2000-

2001 (McCallum, Bolland, & Stem, 2001) was undertaken as a joint effort between the Department of Mathematics and the Institute of Social Science Research. The results of the evaluation indicated wide disparities among students in acceptance of CAI. Reasons for this disparity during the initial move toward CAI included hardware and software technical difficulties, problems with implementing the program, and software inflexibility in input and output formats. Other problems, such as frequent server crashes, lack of organization, and ambiguity in the grading system, were reported. The evaluation report also reflected other difficulties, such as lack of motivation, student procrastination, lack of traditional student-teacher interaction, a feeling of detachment, and student discomfort with computers. The report further suggested that, students with weak math backgrounds or who have accepted from the outset that, as they put it, "I am bad at math," have trouble learning math from computers. Very few prior studies have examined such a large population of students. Most prior studies focused on merely one or two classes. This dissertation is confined to the examination of achievement as test performance. It does not account for motivational components of achievement but it does rectify the problem of small sample size by investigating 688 students. This large sample is unique to achievement studies and will give a clearer picture of the effects of widespread incorporation of CAI in teaching methods.

Purpose of the Study

The purpose of this study was to examine the use of CAI in remedial college algebra classrooms. Specifically, this study compared the achievement of precalculus algebra students in classes where predominantly computer-based instruction was used as opposed to the achievement of students taught through traditional lecture classes. Usage of computers or

calculators as a teaching tool is a common practice in math classrooms around the world; however, the usage of computers as a main source of instruction is a fairly recent phenomenon. Using computer-based instruction involves a range of factors, including philosophical predisposition to teaching, learning styles, and methodologies. Many educators are increasingly frustrated with the lack of tangible progress in introductory math classes in colleges and universities. Also evident is that many universities are confronted with the potential economic savings when computers are used mainly as teaching instruments. Within academia the prestige of having computer-based instruction labs sometimes unduly influences their implementation and subsequent use. This study focused exclusively upon the following factors as possible predictors of achievement: instructional method and student demographic attributes.

Significance of the Study

The computer-based learning environment has vast possibilities that are just beginning to emerge as the medium is being utilized by more and more institutions nationwide. The new educational software industries have the potential to meet the educational needs of a large and increasingly diverse student population. In order for any college educational program to succeed, it must fill a need for students. Because a computer-based learning environment is still a relatively unexplored frontier, it is important to identify key aspects that may translate into student success and achievement.

Research Questions

The following research questions delimited the scope of this study:

1. Do precalculus algebra final exam scores differ as a function of teaching method (traditional, CAI-1, and CAI-2)?
2. Do precalculus algebra final course grades differ as a function of teaching method (traditional, CAI-1, and CAI-2)?
3. Does student math achievement in precalculus algebra differ significantly across time (Test 2, Test 4, and final exam score) as a function of instructional method (traditional, CAI-1, and CAI-2)?
4. Do the three statistical methods used for comparing the instructional methods in research questions 1, 2, and 3 differ in terms of their conclusions or precision?

Definition of Terms

Computer aided instruction (CAI): Usually computers are used as a supplement to the instruction vs. CBI where the computers are main source of instruction. It is common for researchers to use these two terms (CAI, CBI) for the same purpose. The research has followed the same approach.

For the purposes of this study, two CAI methods were examined and are identified as CAI-1 and CAI-2:

CAI-1: For this paper, CAI-1 is operationally defined as the computer-aided instruction method that used the Thinkwell software by Edward Burger.

CAI-2: CAI-2 is operationally defined as the computer aided instruction method that used the MyMathLab by Lial, Hornsby, and Schneider, published by Addison Wesley. The two software packages are very similar in content and approach to teaching.

Computer-based instruction (CBI): Computer programs that allow students to progress at their own rate by completing a series of complex tasks, each of which receives immediate feedback.

Competency-based model: A teacher-training approach that requires the development of specific, measurable competencies over a specified period of time.

Content-centered teaching: A teaching style that employs lecturing and formal discussion as a means to cover content coherently and systematically and measure student learning objectively.

Essentialism: An educational theory based in the philosophical school of realism, asserting that the primary function of the school is the transmission of essential facts.

Progressivism: An educational theory, based on the philosophical school of pragmatism, believing that curriculum and teaching methodologies should relate to students' interests and needs.

Remedial math: The U.S. Department of Education (2003) defines mathematical remedial courses as “courses in mathematics for college-level students lacking those skills necessary to perform college-level work at the level required by the institution”(p. iii).

Student-centered teaching: A teaching style in which instruction is tailored to the needs of the student.

Subject-centered teaching: A teaching style similar to content-centered in that it focuses on covering the subject matter; it differs in that student learning is not central.

Traditional methods: A teaching style in which technology is used very little; blackboard, chalk (or similar instruments), and lectures are the primary teaching tools.

Organization of the Study

This research project is presented as a dissertation in five chapters. Chapter 1 introduces the research topic, the significance and purpose of the study, and the research questions that were posed. Additionally, Chapter 1 describes key assumptions and certain limitations of the research as well as definitions of the terminologies that are utilized throughout the entire report. A review of the relevant research literature is contained in chapter 2. Chapter 3 outlines the research methods utilized in the study. The results of the research are offered in chapter 4. The research problem is summarized, results are interpreted, and implications of the findings are discussed in chapter 5.

Summary

The advent and availability of personal computers, shortage of mathematic teachers, and lack of luster and progress in math education has made computer-based instruction (CBI) an attractive alternative to traditional math classrooms. The benefits of computers include permitting learning at one's own pace, being objective, and individualizing learning (Hornbeck, 1991). Educational institutions must have a clear vision with a solid understanding of educational philosophy and be able to absorb the economical ramifications of implementing costly computer labs. This paper examines an ongoing project at a university in Alabama to see whether a significant difference exists between the achievements of students using CAI and the achievement of students given traditional instructions.

CHAPTER 2

REVIEW OF THE LITERATURE

Chapter 2 begins with a brief explanation of subject matter, developmental/ remedial mathematics. Secondly, it gives an overview of theoretical basis for computer – facilitated mathematics. Thirdly, a short history of computers in education and their origin is given. Finally, a survey of the relevant literature is provided.

Developmental/Remedial Mathematics

The U.S. Department of Education (USDE, 2003) defined mathematical remedial courses as “courses in mathematics for college-level students lacking those skills necessary to perform college-level work at the level required by the institution” (p. iii). The focus of this study was students who take precalculus algebra, which is the higher end of remedial/developmental math courses. Other classes in this category include elementary mathematics, intermediate algebra, finite mathematics, precalculus trigonometry, and precalculus algebra & trigonometry. The designation for these math classes may not be the same in other institutions.

How students get placed in these courses needs some explanation. At UA, incoming students take a mathematics placement exam--a sample copy of this exam is included as Appendix A--this score will determine each student’s placement in math classes. Some other college or universities have more rigorous methods of placement. For instance, Harper College uses more than one method. In most instances, these placement methods may include the use of scores from the ACT or SAT. Sometimes COMPASS scores, from the Computerized-Adaptive

Placement Assessment and Support System developed by the American College Testing program, may be used, as well, to determine appropriate an entry-level course and to diagnose a student's strengths and weaknesses (LaForte, 2000).

Several organizations that focus exclusively or in part on developmental education are the National Center for Developmental Education (NCDE), the National Association for Developmental Education (NADE), the National Center for Educational Statistics (NCES), the American Council on Education (ACE), and the American Educational Research Association (AERA). These organizations have a broad nature, as they have collected data and conducted research related to developmental education.

According to a 1995 study completed by the NCES, over 80% of public four-year institutions offer remedial math courses. The same report indicated that in 39% of these institutions, enrollment in such programs has increased by 50% from 1990 to 1995. The figures are higher in two-year colleges than in four-year colleges. Data from the USDE indicates that 30% of college students who take remedial mathematics do not achieve passing grades. Some researchers, such as Colby and Opp (1987), Boylan and White (1987), and Brier (1984, 1985), believe this trend is the result of a decline in educational level that started in the mid-1960s with equal access to education within the U.S. Some universities, disappointed by meager achievements of the students in these classes, have favored cutting funds for such programs, recommending that funds be limited to high school or community colleges. Other universities still consider remedial classes as a means of success for motivated, underprivileged students (Bahr, 2008; USDE, 2003).

Among the ongoing debate about remediation in postsecondary education, there is little doubt that higher education continues to deal with teaching students with academic deficiencies.

If traditional methods of instruction have not resulted in significant improvements in student success, then other instructional methods should be employed to achieve better results. Computer technology, when properly used, can enhance learning and has the potential to positively influence students' success rates (Carter, 2004).

Theoretical Basis for Computer-Aided Instruction (CAI) Behaviorism

The primary focus of the behavioral perspective is the influence of the external environment on behavior. One of the processes by which behavior is shaped is called conditioning. The two main branches of behavioral systems of thought are classical conditioning and operant conditioning. Classical conditioning is based on the scientific work of Pavlov (1927) and has to do with associational learning in which conditioned responses may be achieved by pairing selected stimulus with the desired behavior. Eventually, the desired behavior can be elicited by the presentation of the conditioned stimuli. Operant conditioning, the basis of most learning theory (Hamtini, 2000), was originally developed by Skinner (1938). Operant conditioning is affected by introducing punishment or reinforcement after a behavior has been exhibited. In this way, the probability that the behavior will be repeated is diminished or increased.

In 1969, Skinner outlined four behavioral learning principles based on his research.

According to Reed and Bergemann (1992), Skinner's learning principles suggest the following:

- (1) Student will learn better if they know exactly what they are expected to learn – in other words, what learning will be reinforced.
- (2) Students must master basic simpler skills before they can master complex skills.
- (3) All students do not learn at the same rate.
- (4) Subject matter should be programmed into small bits, with immediate positive feedback. (p. 354)

Based on Skinner's principles, computer-programmed instruction was developed.

The drill and practice modus operandi of CAI are based on the principle of behaviorism (Hogan, 2004). The computer provides immediate feedback to the learner during drills and practice activities thereby reinforcing and discouraging respective responses (Cassaza & Silverman, 1996; Hamtini, 2000; Kulik & Kulik, 1991; McMillan, Parke, & Lanning 1997; Silverman & Cassaza, 2000).

According to Ertmer and Newby (1993), learning is defined as the probability of a given behavior occurring in a particular situation. The environment presents an antecedent (A) that prompts a behavior (B) that is followed by some consequence (C) and then determines whether the behavior will occur again. If the learner repeatedly behaves in the desired manner in response to the specific antecedent, then learning has occurred (Longstreet & Smith-Gratto, 1997). In order to reinforce desired behaviors and eliminate undesired behaviors, instructions must guide the student's behavior by providing clear and measurable objectives at each stage.

Constructivism

Constructivism is a recent term used to represent a collection of theories, such as generative learning (Wittrock, 1990), discovery learning (Bruner, 1961), and situated learning (Brown, Collins, & Duguid, 1989). The fundamental insight of constructivist theory is that knowledge is actively constructed and not simply acquired by the learner. The constructivist foundation is based on the principle of learning rooted in cognitive theories (Hsu, 2003). The common thread among these theories is that "learners construct knowledge themselves rather than simply receiving it from knowledgeable teachers" (Roblyer & Edwards, 2000, p. 67). The links between behaviorist learning theory and CAI, but that CAI is also linked to constructivism is not so clear (Hogan, 2005). "Interactive CAI programs have been tied to constructivism in that

students are at the center of the learning process. Rather than being passive recipients of instruction, they are actively involved in constructing knowledge” (Hogan, p.377). Piaget and Vygotsky in psychology and social science and Ernst Von Glaserfeld in mathematics and science education are well-known constructivists.

The term constructivism denotes a school of thought that proposes that an individual’s knowledge is *constructed* from the building blocks of previously acquired knowledge of a subject. Piaget, Bruner, Vygotsky, and in science education and mathematics, Ernst Von Glaserfeld, are associated with constructivism as an active process on the part of the learner. Computer-based instruction programs that are truly interactive and enable students to control the pace and sequence of their learning are tied to this approach (Driscoll, 2000; Silverman & Casazza, 2000).

In mastery learning, as proposed by Benjamin Bloom, a student is presented with specific tasks and must master them before going to the next level. In the drill and practice modality of computer-based instruction, the pace and number of trials to reach mastery varies from student to student. The curriculum for both constructivism and mastery learning types of computer-based instruction is designed by experts in a given subject area, and the traditional role of teachers is lessened to that of a monitor in a computer lab.

Brief History of Computers in Education

Although the first computers were not meant to be an educational tool, the Electronic Numerical Integrator and Computer (ENIAC), was the first large-scale, electronic, digital computer built to calculate artillery firing tables for the U.S. Army’s Ballistics Research Laboratory in 1946 (Shurkin, 1996). Educators soon recognized the computer’s academic

potential. Computers soon replaced the slide rule and other primitive devices and allowed students to calculate mathematical problems with more accuracy than before computer development (Molnar, 1997). PLATO, an acronym for Programmed Logic for Automatic Teaching Operations, was one of the first generalized computer-assisted instruction systems, originally built by the University of Illinois. Bitzer, regarded as the “father of PLATO,” succeeded largely due to his rejection of “modern” educational thinking. Returning to a basic drill-based system, his team improved on existing systems by allowing students to bypass lessons they already understood.

PLATO I, II, and III had been funded by small grants from a combined Army-Navy and Air Force funding pool. By the time PLATO III was in operation, everyone involved was convinced it was worthwhile to bolster the project. Accordingly, in 1967 the National Science Foundation granted the team steady funding, allowing Bitzer to set up the Computer-based Education Research Laboratory (CERL) at the University of Illinois. The PLATO program was designed to provide competency-based individualized instruction from remediation to enrichment (Carter, 2003).

Patric Suppes and Richard Atkinson of Stanford University composed a software program in 1963 regarding computer-assisted instruction in mathematics. CAI provided individualized instruction that allowed learners to correct their responses through rapid feedback. In the early 1970s, the National Science Foundation funded the establishment of 30 regional computing networks. These networks included more than 300 higher education institutions and some high schools, and they provided access to more than 2 million students. The later 1970s brought about the development of less expensive systems. Over the next few decades, with the

advance of technology, new methods of computer learning environments emerged that included high power calculating, graphing, artificial intelligence, and the Internet.

Advantages and Disadvantages of CAI

CAI is considered by some to be a nontraditional instructional method. CAI's revolutionary impact on education has been compared to the invention of writing and printing (Kulik & Kulik, 1987). "The most sophisticated CAI programs typically incorporate interactive multimedia software to assess a student's background knowledge and readiness, introduce new information, provide practice and feedback, and assess the student again using tests or quizzes" (Hogan, 2005. p. 34). Most CAI software also has links to an array of related sites for mathematics and science.

Computer-based instruction has advantages for institutions over the traditional classroom lecture method. Meta-analyses by Kulik and Kulik (1986, 1991) found that computer-based methods can reduce time spent by instructors by up to one-third. Institutions can save costs of replacing materials and reduce recordkeeping and the costs of test administration by implementing a computer-based system. A curriculum using computer-based instruction without assigning a specific class time can meet students' diverse schedule needs and thus expand enrollment. In addition, improved examination scores for adults have been reported, along with improved attitudes towards instruction and towards computers. Christmann and Badgett's (2000) meta-analysis showed that college students who received traditional instruction coupled with computer-based instruction had higher achievement gains than those receiving traditional instruction alone. Hsu (2003), in his meta-analysis examining the effectiveness of CAI in teaching introductory statistics classes, found a moderate positive effect in favor of the use of

CAI. Hsu considered several questions of interest including whether CAI effect sizes could be attributed to the source of the studies (dissertations, journals, etc.) or to the date of publication (early versus recent years). Also of interest were questions of whether CAI effectiveness varied by level of education (graduate versus undergraduate), technique or mode of CAI (drill and practice, tutorial, multimedia, simulations, computations, expert-systems, or web-based), and by software author type (teacher-made versus commercial). Technique and software author type were the only characteristics to demonstrate a significant influence on CAI effect size.

Effectiveness of CAI was higher for teacher-made products and for techniques other than computational or web-based modes. Hsu's findings on software authoring mirrored those of Kuchler (1998) who, in his meta-analysis on the effectiveness of using computer technology in the classroom, found that teacher-made software was more effective than commercial software.

Administrators at institutions across the U.S. at both the junior college and university level have implemented computer-based instruction in basic college mathematics courses in the last several years, sometimes for the wrong reasons. The University of Texas recently used computer-based instruction to remedy the problem of a shortage of qualified mathematics teachers. Computer-based mathematics instruction may be implemented to deal with a nationwide math crisis of low math scores on standardized tests. However, the economic reality is that mathematics textbooks contain less substance in recent years because publishers are competing with each other for a larger market share to buy their texts. This translates to software that is marketed by these same educational publishers having correspondingly watered down and less rigorous subject content. Computer-based instruction based on this software can make the nation's math problems worse. Other disadvantages for institutions implementing computer-based instruction include technological difficulties that impair student progress, and the

likelihood of grade inflation that occurs with a mastery learning module when all students who finish receive an “A.” The costs of technical support and computer lab personnel are ongoing and nontrivial (McMillan et al., 1997).

The primary advantages of computer-based instruction for a student in mathematics are flexibility and convenience with self-paced instruction that provides immediate and frequent feedback without the embarrassment that a mistake in a traditional classroom might cause. Other advantages of CAI include clarity and structure, impartiality, active learning and involvement, and variety and appeal to those students accustomed to using computers (Hogan, 2005). In addition, a student would be free to consult a teacher/lab assistant as needed for help with a challenging concept. For many students who have experienced failure with traditional mathematics instruction, CAI offers an alternative to the classroom situation that did not work for them (Seese, 1994).

Computer programs are interactive and can illustrate a concept through attractive animation, sound and demonstration. They allow students to progress at their own pace and work individually or problem solve in a group. Computers provide immediate feedback, letting students know whether their answers are correct. If the answers are not correct, the program shows students how to correctly answer the question. Computers offer a different type of activity and change of pace from teacher-led or group instruction. (American Institutes of Research, Access Center research brief. “Computer-Assisted Instruction and Mathematics,” available at: http://www.k8accesscenter.org/traning_resources/computeraided_math.asp)

CAI also has disadvantages for students. Technology may not be equally accessible to all students at all times and may fail, causing frustration. A student’s background with computers can make a difference in using computers for learning mathematics. Students who do not have initial familiarity with computers may suffer from fear of computers compounded with math phobia. The students who populate the lower-level precalculus college math courses are generally there because they are weak in mathematics. Students may also be exposed to changing

personnel in the computer lab and may not be comfortable asking a total stranger to explain a difficult concept. The self-paced component of CAI could be the downfall for some students who need the motivation or a specific class meeting time to keep a learning schedule on track.

Application of CAI to Mathematics Classrooms

In a CAI model, instructional technology can be integrated into the classroom with various levels of facilitation and can even completely replace the traditional teacher/student classroom model. Ross and Bailey (1996) based their models of levels of computer-assisted instruction on how much control the learner has in acquiring new knowledge. In the traditional classroom setting, the teacher is the central focus of learning and essentially acts as a sage dispensing knowledge. As more technology is introduced, the role of the teacher changes from sage to aide to motivator to a peripheral role as an abstract examiner of the learning process who evaluates software applications for divergent learning needs. The learner is afforded more control with increasing levels of CAI as compared to traditional teaching methods.

In the most basic model of CAI as an integrated learning system (ILS), the teacher remains very much a presence in the classroom and directs the pace and sequence of all technology, which is used as a tool. A teacher implementing this model would use multimedia presentations, videotapes, and employ training sessions with students for all computer-based segments of classroom instruction. CAI would be used for drill and practice for specific problem sets during class time. For example, a teacher could assign students to look up subjects on the Internet and report their findings back to the class thereby using computers as a tool to augment traditional instruction.

In the Ross and Bailey (1996) model, the next level of ILS has the computer predominately replace the teacher as the center of learning, allowing students to have much greater control over the pace of their learning than in traditional classrooms. At this level of the model, each student sits at his or her own computer station, usually in a centralized computer lab with a central networked computer. ILS are networked computer hardware systems that use software with programmed instructional content and include management and assessment capabilities. Suppes conceived of ILS in the 1960s as a complete system to deliver and manage standardized curriculum materials to students in a manner that affords individualized instruction. A typical software package directs the learner through a sequence of programmed modules that offer drill and practice on a set of problems. This model is the dominant mode of instruction across the U.S. for lower-level college mathematics. The focus of the present study was the implementation of a typical ILS model at a university in Alabama in the spring of 2002.

ILS systems are expensive and funds must be allotted, not only for the initial outlay of purchasing computers and software, but also for continuing maintenance and support personnel. Because ILS systems have been implemented in college mathematics courses only during recent years, a definitive cost-benefit analysis has not yet emerged from the research findings. Remedial education costs in U.S. public colleges and universities were estimated to exceed more than \$1 billion per year more than 10 years ago (Breneman, Costrell, Haarlow, Ponitz, & Sternberg, 1998) with remedial education costs for State of Alabama estimated in excess of \$540 million in 2004 alone (Hammons, 2004). Between 2000 and 2001, the total estimated cost of implementing the ILS system used to deliver CAI in remedial mathematics classrooms for the present study was in excess of \$1.65 million dollars for a mathematics lab with 240 stations.

Research in educational technology during the last two decades has focused mainly on ILS in primary and secondary school settings and has found demonstrative learning gains (Becker & Hativa, 1994). However, the reported gains have been tempered by findings that show younger students become inured with learning via CAI. After introduction, students' enthusiasm for program novelty and achievement plateau. Findings are encouraging for ILS components that are integrated into classroom activities with a teacher's guidance in contrast to students working separately in an isolated computer lab.

CAI systems represent the next generation of ILS. A CAI system can be implemented as either a complete learning environment where the computer is the central medium of instruction or in a hybrid environment where students receive instruction both from a teacher and from a computer. An ILS system may be implemented as part of a synchronous CAI where all students in a particular location are exposed to the same material at the same time. An asynchronous CAI is a sophisticated individualized adaptation of an ILS system in which each student can be exposed to different material at a different time and place.

Use of CAI in College Algebra Courses

Several researchers have sought to identify specific factors related to student achievement when a CAI system is implemented in college mathematics. Most of these investigations have examined student achievement using an outcome measure of final course grade in comparisons of traditional instruction with CAI at the same institution for the same college algebra course. A few have examined the question slightly differently using course success (completion versus dropout or failure rates) as the outcome variable.

Early studies of CAI produced mixed results. For example, Ford and Klicka (1998) studied outcomes at a community college for students in basic mathematics classes. These investigators established three conditions: self-paced CAI, CAI with lecture, and traditional instruction. In the algebra course, students taught by traditional methods had significantly higher pass rates than did the students in the self-paced computer group; however, students in the CAI section with lecture performed better than did the other two groups. However, Sadatmand (1994) compared intermediate algebra students for one semester at Grossmont College. Students who took traditional instruction fared worse than students who took the same course taught in a CAI format, but the difference was not significant. No significant differences were found between males and females in the outcome measure of final exam scores.

Williams (1996) used a pretest-posttest, nonequivalent-groups, quasi-experimental design to study math achievement and course completion as a function of instructional method in a sample of developmental mathematics students. A convenience sample of 313 participants enrolled in a Texas community college was used. The sample was predominantly female, Caucasian or Hispanic, and several years older than traditional college age students. The control group received traditional lecture instruction with no computer exposure, while the experimental group received a minimum of 15 out of 45 classroom contact hours exposed to CAI. Results of this study indicated that the final course grade distributions differed significantly as a function of instructional method. Students exposed to traditional instruction more frequently received a grade of C or less. When grade distributions were examined separately for students less than 21 years of age and students over 21 years of age, no significant effect of instruction was found for grade distribution in the younger student age group but a statistically significant effect of instruction was found on grade distribution in the older student age group, and the effect

indicated that students exposed to CAI were more likely to receive a grade of B or better than were students who received traditional lecture. Furthermore, when student data was examined for effects of instruction on course completion rates, a statistically significant difference was found, with students in the CAI group demonstrating a greater likelihood of successful course completion and those in the traditional group showing a greater likelihood of course attrition. Overall, Williams concluded that CAI was potentially associated with improved student performance and course completion in the developmental mathematics classroom. However, the author called for extensive replication of the study since several factors, including a possible selection bias among participants and some variability in CAI use within CAI classrooms, may limit the generalizability of the findings.

A number of studies from more recent years have failed to shed much light on the question of when and if CAI results in improvements in achievement beyond traditional instruction. For example, Summerlin (2003) used a pre-test/post-test, quasi-experimental design to study the effect of instructional method on final grades in intermediate algebra and grades in a subsequent college-level math course at a community college. The intermediate algebra course was taught as either traditional instruction or as CAI. A convenience sample of 2,035 students was used. Of these 2,035 students, 1,875 were enrolled in traditional lecture sections and 160 were enrolled in CAI sections. Variables included in the study were course grades, course pass rates, age, gender, ethnicity, and reading ability. Results of this study showed no significant difference in student achievement in intermediate algebra as a function of instructional method. No significant performance differences were found on any of the demographic variables for age, gender, or ethnicity. Students taught by traditional instruction were more likely to pass remedial algebra than were students taught by the CAI method. Students taught intermediate algebra by

traditional instruction were also more likely than those taught using CAI to pass their subsequent math course. Both of these findings on course success warrant attempts at replication. Summerlin went on to note that “The dropout and failure rate in the Internet course is much higher than in the traditional classroom” (p. 82). Generalizability of Summerlin’s findings to other courses, samples, and sites is somewhat limited, however, since the number of participants in the group receiving CAI was substantially smaller (8% of the total sample) than the number of students in the group receiving traditional lecture (92% of the total sample). Summerlin concluded that while CAI students dropped out of intermediate algebra at a higher rate than traditional students, those students who received CAI and remained enrolled throughout the course were able to demonstrate achievement at a level equal to or better than students in traditional lecture. Thus, decisions in favor of widespread adoption of CAI for remedial algebra remain a matter for policy and judgment.

Reagan (2004) conducted an inquiry into the use of CAI for developmental mathematics comparing math achievement in CAI or traditional classroom settings. In this study, 112 community college students taking beginning algebra or intermediate algebra participated in a quasi-experimental design to test the relative effectiveness of a CAI intervention beyond that of traditional instruction. The CAI intervention differed from the traditional instruction in that CAI classes began with brief mini-lectures by the instructor followed immediately by web-based modules for instruction, practice, and certification of learning. Demographics and attitude scores as well as pretest and posttest mathematics achievement scores were collected. An ANCOVA on posttest achievement using pretest achievement as the covariate revealed no significant differences in students’ math achievement as a function of instructional method. Students receiving CAI were about evenly split on whether they would recommend other students take a

math course utilizing CAI. Students indicated that they enjoyed self-paced learning and immediate feedback; however, they also indicated a need for more examples and better explanations from the software program. Reagan concluded that while students tended to enjoy CAI, it was not universally preferred among students who had experienced it and it conferred no greater benefit in achievement than did traditional instruction.

Carter (2004) conducted an experiment in which 55 students enrolled in remedial college algebra classes were randomly assigned to receive either traditional lecture instruction or CAI supplemented with traditional lecture over the course of a 15-week semester. The CAI group used a web-based, self-paced, mastery-oriented curriculum by McGraw-Hill publishers: the Assessment and Learning in Knowledge Spaces (ALEKS). A pretest-posttest design was used, and 36 of the original 55 study participants completed the course. Using ANCOVA with the pretest scores as a covariate, Carter examined differences in mathematics achievement as a function of instructional method for the 36 course completers. While both the CAI and traditional lecture groups exhibited a measurable increase in achievement from pretest to posttest, no significant differences in posttest mathematics achievement scores were found for instructional method. Carter concluded that both CAI and traditional lecture instruction were equally effective in producing increases in mathematical knowledge among remedial college algebra learners. In a similar study using ALEKS as the CAI intervention, Fleming (2003) found greater achievement among students taught with traditional lecture than students taught with CAI, but she also found no differences between the two groups in course success as measured by pass rates.

Using less stringent controls than Carter (2004) or Fleming (2003), but drawing on a larger sample size, Hogan (2005) reported an evaluation of traditional instruction vs.

asynchronous CAI. She analyzed data from a convenience sample that included all students who enrolled in a Survey of Algebra course at a western community college. Data were collected on 1,720 students who took Survey of Algebra from 2002 to 2004. Hogan's study had two parts: a quantitative analysis of student achievement and a qualitative analysis of student perceptions. In the quantitative analysis, she used archival student data to analyze the relationship between method of instruction and students' gender, age, and final course grade. Results showed that students who were taught by lecture instruction had significantly higher final course grades than students who were taught using CAI. Female students in Hogan's study had higher grades than did their male counterparts regardless of method of instruction. This difference was much more pronounced in CAI than traditional classes. Female students in CAI classes were twice as likely to be successful (make A or B) compared to their male counterparts. Nontraditional age students (25 years and older) achieved higher grades regardless of method of instruction than did traditional age students (24 and younger). According to Hogan, when students' grades in subsequent math classes were examined as a function of method of instruction, those students who were taught Survey of Algebra using traditional lecture method performed better in their subsequent math class while those who received CAI disproportionately underperformed in their subsequent math class.

Hogan (2005) extended her research to include follow-up qualitative interviews with 12 students evaluating their experiences using an asynchronous CAI method. She noted that while her quantitative assessment of preference revealed "no clear patterns in final grade based upon gender, age, or a combination of gender and age," student preferences for CAI (Hogan, 2005, p. 92) were influenced by compatibility between the CAI course structure and students' personal characteristics including learning styles, prior content knowledge, and math aptitude. Her

qualitative interviews identified three major themes as being crucial to students' preferences for or against CAI in their algebra course: convenience, individualization, and support. Students who liked the convenience of CAI indicated that the CAI format offered them scheduling flexibility while those who did not like it expressed a need for greater class structure. Those who preferred individualized instruction enjoyed the self-paced format, while others indicated that individualized instruction left them feeling isolated. Finally, students who preferred CAI indicated that immediate feedback was a critical factor in their learning, while others wanted to have additional resources or assistance beyond that available in the computer explanations of problems.

In the most recent, well-designed study to date, Barrow, Markman, and Rouse (2008) developed a working paper for the National Bureau of Economic Research (NBER) on the use of CAI. NBER researchers conducted a randomized control trial examining the use of traditional lecture or CAI in a sample of 1,605 secondary school students, primarily 9th graders, in urban schools who were taking prealgebra and algebra. Randomization was done at the level of the classroom with 146 classrooms from 17 schools in three school districts participating in the study. The *I Can Learn*[®] curriculum by JRL Enterprises was used in CAI classrooms. A variety of mathematics achievement measures were used including a study-designed assessment, a statewide standardized test, and the Iowa Test of Basic Skills. Pretest scores were used as a covariate in the analyses. The authors found that students assigned to CAI classrooms had higher mathematics achievement posttest scores than did students given traditional lecture instruction. Gender and race/ethnicity differences in mathematics achievement by instructional method were not found. Contrary to the findings of Hogan (2005) and Carter (2004), these authors note an effect of instruction in favor of CAI. The overall magnitude of the instructional method effect

(combined across prealgebra and algebra classes) was estimated to result in CAI students achieving a grade-level equivalent gain between 27% and 34% greater than their peers receiving traditional instruction. The effect of a CAI advantage was found to be statistically significantly larger in prealgebra classes than in algebra classes and in larger classes than in smaller ones, suggesting that CAI is more effective in some situations than in others. The authors concluded that CAI may confer benefits primarily through helping teachers achieve greater individualization of instruction.

In the current study, data were collected on gender, age, ethnicity, college classification, high school grade point average, ACT entrance exam score, college major, and math placement score. Analyses were performed in order to determine whether or not these variables were related to the final course grade. Although several other studies have compared traditional instruction with CAI in lower-level college mathematics classes, no other study used all of these variables.

Summary

Theoretically, computer technology should improve learning (Hamtni, 2000). CAI software could be engineered so as to provide the types of conditions that educational theory envisions will lead to learning (McCoy, 1996; Kahn & Friedman, 1998). However, despite these rich possibilities, CAI has not been shown to consistently generate outcomes superior to those of traditional instruction. Instead, as the literature review in this chapter indicates, results concerning the effectiveness of CAI have been mixed at best (McCoy, 1996). Although some studies (Mayes, 1995; O'Callaghan, 1998; Palmiter 1991) indicated the type of enriched learning that constructivist theory would predict, other studies (e.g., Hollar & Norwood, 1999) found few significant differences between CAI and traditional instruction. Some studies (e.g., Ford &

Klicka, 1998) revealed significant benefits of traditional instruction over CAI. Evidence regarding the moderating effects of students' demographic characteristics on their performance in CAI mathematics courses remains equivocal. The complex relationship between CAI and final grades will be resolved by further research.

CHAPTER 3

METHOD

The purpose of this study was to compare the mathematics achievement of college students who were taught by CAI to their peers who were taught by traditional lecture instructional method without the use of CAI. This researcher sought to determine the relative effectiveness of a computer-based interactive system of mathematics instruction using either *Precalculus with MyMathLab* by Lial/ Hornsby/Schneider and published by Addison Wesley or *Precalculus* by Edward Burger published by Thinkwell Company.

Design

This study is comparative in nature and uses an *ex-post-facto* design. Although students were not randomly assigned to precalculus algebra sections, they were blind to instructional method when they registered for classes. Class sections were randomly assigned to instructional methods. This study allows a comparison of the two CAI programs. First, the relationship between traditional lecture instruction versus CAI classes and mathematics achievement is examined; second, the two CAI software programs are compared based on mathematics achievement.

The grading policy in use at the time of the study allowed for final course grades of “A,” “B,” “C,” or “NC.” The grades of “A,” “B,” and “C” reflected traditional grading cut-offs of 90-100%, 80-89%, and 70-79%. Students who made less than 70% were assigned “NC,” or No

Credit, instead of a “D” or an “F.” Spring 2002 was the first term that No Credit grading policy was implemented.

Variables

The main independent variable in this study was the method of instruction. There were two levels of the independent variable: traditional lecture instruction or CAI instruction. Within CAI instruction, two different software programs were used. The other independent variables, gender and age, were both attribute variables.

Three dependent variables were identified for assessing mathematics achievement: final course grade in precalculus algebra and test scores on two semester tests. Among the four semester tests that were administered, only semester tests two and four were common across all precalculus algebra students. Final course grade was selected as an indicator of the effectiveness of the instructional method for control group (taught using traditional methods) and treatment groups (taught using CAI software) during the spring 2002 semester.

Subjects

The students participating in this study were taking precalculus algebra at a public university in Alabama. The majority of the students were Alabama residents, in their freshman year. Prerequisite for the class was a grade of “C” or better in introductory algebra or a minimum of 31 on the mathematics placement test given by the university to all freshmen students.

All freshmen students, except those transferring approved math credit or those with high school calculus credit and a score above 29 on the ACT math subtest, take the University’s Mathematics Placement Exam (MPE) prior to enrolling in math classes. The score on the MPE is

used to guide enrollment determinations about an appropriate starting level of math class for each student. Students with MPE scores between 31.0 and 43.9 are eligible for enrollment in precalculus algebra.

A total of 934 students were enrolled in precalculus algebra in the spring of 2002. Data was unavailable for 246 students due to factors including course withdrawals, incomplete grades, and administrative issues. Thus, these students were deleted from the analyses presented here. Of the total precalculus algebra enrollment in Spring 2002, course performance data was available for analysis on a subset of 688 of the 934 students (378 males and 310 females) who began the term. Test score data used in the analyses presented here was de-identified such that specific scores could not be associated back to identify individual students by name.

Math Class Placement

Students who enter a university in Alabama from high school take a math placement test to determine the suitable mathematical class they should take first. An example of a typical math placement test is provided in (Appendix A) to provide some perspective for researchers who are not familiar with the basics of the placement tests that are common in this state. Scores on the MPE can range from 0-55. In this particular setting, students who score from 0-18 are placed in Elementary Mathematics. Those scoring from 19-30 are placed in Intermediate Algebra. Students who score 31-43 take precalculus algebra. Students who score between 44-55 are eligible to choose either Calculus I or Calculus and its Application. Calculus and its Application is the same as Calculus I except that it is designed for students who are entering business school.

Course Description and Objectives

Math 112 is a precalculus algebra course designed for freshman college students.

Precalculus courses include precalculus algebra and precalculus trigonometry. Topics included in a typical precalculus algebra course are linear, quadratic, and rational equations and inequalities. The algebra of functions (i.e., polynomial, rational, exponential, and logarithmic functions and their graphs), systems of equations in two or three variables, basics of matrix algebra, and the binomial theorem are also covered topics.

Upon completion of the precalculus algebra course, the student should be able to perform operations with and solve equations and inequalities involving polynomial, rational, exponential, and logarithmic functions. The student should also be able to graph such functions; solve linear, quadratic, exponential, and absolute value equations; solve systems of equations; and expand binomials using the binomial theorem. Evaluation was based on quizzes, tests, and attendance. A copy of the class syllabus is also included (Appendix B) at the end of this chapter.

Procedures

Students taking Math 112, precalculus algebra, were taught using one of three instructional methods. Teachers were masters-prepared instructors accustomed to teaching a variety of undergraduate level courses offered in a university mathematics department. Students received instruction via either traditional lecture or by one of two CAI teaching formats.

Traditional classes were held in regular classroom environments. The students attended classes on Mondays, Wednesdays, and Fridays for 50 minutes or Tuesdays and Thursdays for 75 minutes. The instructional method used was largely lecture style instruction. The students were allowed non-graphing scientific calculators. Unlike students taught using CAI, students under

traditional method did not receive points for attendance. Instructors followed a rigid syllabus and all tests were prepared by the math department as departmental exams.

CAI classes were held in the computer math lab. The precalculus algebra CAI software was installed in the computer lab. The students were also able to install the software on their personal computers. Internet access was required for students to reach the website and to have access to notes, homework, and exercises. Students were required to spend a minimum of 4 hours in the computer lab per week (for each week they received 4 points, for a total of 56 points). Students were also required to attend weekly class sessions in the computer lab, for which they received 3 points for a total of 39 points, therefore, a student taught using a CAI method could have earned equivalent to a letter grade just for showing up for their lab's required attendance hours. Students in CAI classes took two departmental exams, Semester Test 2 and Semester Test 4, in common with students in traditional classes.

CAI Curricula

The CAI classes used two software programs: (1) *Thinkwell* software by Edward Burger, available from www.Thinkwell.com, and (2) *MyMathLab* by Lial, Hornsby, and Schneider, published by Addison Wesley. The two software packages were very similar in content and approach to teaching. Both software packages employed sophisticated video clips in their instruction as well as extensive teacher-friendly management sub-programs. The biggest difference between the two CAI methods was the fact that *MyMathLab* was more web-based. Students could do their homework on the web. In *Thinkwell*, classes, students had to come to the university lab to do their homework. According to the lab coordinator, *Thinkwell* worked as a supplement to the lecture class, while *MyMathLab* was more independent. Promotional materials

from the software publishers indicate that *Thinkwell* is designed to appeal to students with a preference for visual learning styles, while *MyMathLab* is designed to provide students with a self-paced interactive experience.

Null Hypotheses

1. There are no differences between teaching methods (traditional, CAI-1, and CAI-2) as measured by the final exam scores.

2. There are no differences between teaching methods (traditional, CAI-1, and CAI-2) as measured by the final grade in the course.

3. Student math achievement demonstrates no significant differences across time as measured by Test 2, Test 4, and the final exam score as a function of instructional method (traditional, CAI-1, and CAI-2).

4. The three statistical methods used for comparing the instructional methods in Null Hypotheses 1, 2, 3, and 4 will not differ in terms of their conclusions or precision.

Data Analysis

At the time of the experiment, the researcher was working as a math instructor in the math lab where the study was conducted. Data for this study were obtained from the individual grade sheets of instructors involved in conducting precalculus algebra classes. Additional data were obtained from the University Records Office. These records, unfortunately, did not reflect the numerical final grade but did include final categorical grades, as well as gender, race, major, ACT math grades, and residency of students for spring 2002.

SPSS was used to analyze data collected from Students Records Office and individual math instructors. An ANOVA procedure was conducted to examine the difference between the three teaching methods (Traditional, CAI-1, CAI-2) on the final score. An ANOVA was conducted to examine the effect of the three teaching methods on the overall course grade. To test the fourth null hypothesis, a multivariate repeated measures procedure was conducted to test the effect of independent variable, instructional methods, on grades across Test 2 and Test 4. A summary of the data management plan is given on the next page.

	Hypothesis	Measures	Dependent Variable(s)	Independent Variable(s)	Analysis
1	$H_0 : \mu_{Trad} = \mu_{CAI-1} = \mu_{CAI-2}$	Scores on t2, t4, and final exam grade.	Final Exam Score	Methods of instruction	One-way ANOVA $\eta^2 = .035$
2	$H_0 : \mu_{Trad} = \mu_{CAI-1} = \mu_{CAI-2}$	Scores on t2, t4, average and final grade.	Overall Course Grade	Methods of instruction	One-way ANOVA $\eta^2 = .078$
3	$H_0 : \mu_{t2} = \mu_{t4} = \mu_{finalexame}$ $H_0 : \mu_{Trad} = \mu_{CAI-1} = \mu_{CAI-2}$ $H_0 : \mu_{T2Trad} = \mu_{T2CAI-1} = \mu_{T2CAI-2} = \mu_{T4Trad}$ $= \mu_{T4CAI-1} = \mu_{T4CAI-2} = \mu_{FETrad} = \mu_{FECAI-1} = \mu_{FECAI-2}$	Progress from test 2 to test 4 to final	Departmental exams: t2, t4 and final	Semester test over time Methods of instruction	Multivariate Repeated measures $\eta^2 = .067$
4	The three tests (Null Hypotheses 1, 2, and 3) for comparing the instructional methods above will not differ in terms of their precision or conclusions.	η^2, p			Multivariate comparison, p -values, effect sizes

Figure 1. Data management plan.

CHAPTER 4

RESULTS

Descriptive statistics on participant characteristics are presented first. Results of inferential tests pertaining to each of the five research questions are presented next and are addressed in the following order:

1. There are no differences between teaching methods (traditional, CAI-1, and CAI-2) as measured by the final exam scores.

2. There are no differences between teaching methods (traditional, CAI-1, and CAI-2) as measured by the final grade in the course.

3. Student math achievement demonstrates no significant differences across time as measured by Test 2, Test 4, and the final exam score as a function of instructional method (traditional, CAI-1, and CAI-2).

4. The three statistical methods used for comparing the instructional methods in Null Hypotheses 1, 2, and 3 will not differ in terms of their conclusions or precision.

Descriptive Demographic Analyses

Demographic characteristics on enrolled students by course instructional method are presented in Tables 1 and 2. Approximately 54.9% of the sample was male and 45.1% was female. Participants were predominantly Caucasian (78.8%), African American (17.6%), or other ethnicities (3.6%). Students' ages ranged from 18 to 62. Course enrollment was based on math placement test scores with most precalculus algebra students scoring within the range of 31-43

on the math placement exam. The distribution of categorical grades for the 688 students enrolled in precalculus algebra was 9.2% (A), 25.4% (B), 30.1% (C), and 30.5% (NC), respectively.

Students receiving a grade of W comprised 4.8% of the sample.

Table 1

Demographic Characteristics of Students by Instructional Method

	Instructional Method			Sig.
	Traditional N=233	CAI-1 N=214	CAI-2 N=241	
Gender				ns
Female (N=310): 45%	47.2%	44.4%	43.6%	
Male (N=378): 55%	52.8%	55.6%	56.4%	
Race/Ethnicity				ns
African-American (N=121): 17.6%	17.2%	17.3%	18.3%	
Caucasian (N=542): 78.8%	78.1%	79.0%	79.3%	
Other (N=25): 3.6%	4.7%	3.7%	2.4%	
Mean Age	20.61	20.49	20.52	ns
Mean Math Placement Score	26.32	25.11	25.94	ns
Mean GPA*	2.62	2.68	2.49	.011
Mean Cumulative College Hours	33.26	33.46	28.74	ns
Mean Lab Attendance Hours*	---	66.58	59.56	.018
Final Grade Distribution				.003
A	10.7%	11.7%	5.4%	
B	26.6%	23.8%	25.7%	
C	32.6%	29.4%	28.2%	
NC	22.7%	29.9%	38.6%	
W	7.3%	5.1%	2.1%	

Note: * Bolded values are significantly different, $p < .05$.

Table 2

Student Participation by Instructional Method

Instructional Method	# Sections	# Students	% Students	Cumulative %
Traditional	7	233	33.9	33.9
CAI-1 (Thinkwell)	6	214	31.1	65.0
CAI-2 (MyMathLab)	7	241	35.0	100.0
Total	20	688		

Tests of Null Hypotheses

Hypothesis 1. An analysis of variance (ANOVA) was computed on the dependent variable of final exam as a function of the independent variable of teaching method (traditional, CAI-1, and CAI-2). A significant effect of teaching method was revealed, $F(2, 623) = 11.286, p < .001$. Post-hoc contrasts indicated a significant difference exists in student final exam scores between students in classes that use traditional teaching methods compared to those in classes using CAI, $t(1, 613) = -6.097, p < .001$. No significant difference was found for student final exam scores when comparing the two CAI curricula: CAI-1 and CAI-2, $t(1, 433) = -.163, p = .871$. Participants who were taught with traditional methods had a mean final exam score of 73.34 ($SD = 15.916$). Participants exposed to the CAI-1 teaching method earned a mean final exam score of 61.27 ($SD = 30.748$) while participants exposed to the CAI-2 teaching method earned a mean final exam score of 61.78 ($SD = 34.237$). Therefore, these results suggest that traditional instruction was a significantly better teaching method than either of the CAI teaching methods. Final exam means and standard deviations are presented in Table 3.

Table 3

Final Exam Score Means and Standard Deviations by Instructional Method

Instructional Method	Mean Final Exam Scores	<i>SD</i>	<i>N</i>
Traditional	73.34	15.92	189
CAI-1 (Thinkwell)	61.27	30.75	214
CAI-2 (AW)	61.78	34.24	223

Note: $\eta^2 = .035$

Hypothesis 2. An analysis of variance (ANOVA) was computed on the dependent variable of final grade in the course as a function of the independent variable of teaching method

(traditional, CAI-1, and CAI-2). A significant effect of teaching method was revealed for final grade in the course, $F(2, 633) = 26.829, p < .001$. Post-hoc contrasts revealed that final course grades for students receiving traditional instructional methods differed significantly from those receiving CAI instructional methods, $t(1, 625) = -9.212, p < .001$. Contrasts between the two CAI methods indicated a trend in favor of CAI-1, but no significant difference in final grades, $t(1, 449) = 1.913, p = .056$.

Participants who were taught with traditional methods had a mean final grade in the course of 77.62 ($SD = 12.007$). Participants exposed to the CAI-1 teaching method earned a mean final grade in the course of 66.04 ($SD = 24.553$), while participants exposed to the CAI-2 teaching method earned a mean final grade in the course of 61.34 ($SD = 27.626$). Thus, these results suggest that traditional instruction was a significantly better teaching method than either of the CAI teaching methods. However, of the two CAI methods, students receiving CAI-1 performed better than those in CAI-2. Final course means and standard deviations by instructional method are presented in Table 4.

Table 4

Final Course Grade Means and Standard Deviations by Instructional Method

Instructional Method	Mean Final Course Grade	SD	N
Traditional	77.62	12.01	185
CAI-1 (Thinkwell)	66.04	27.63	214
CAI-2 (AW)	61.34	24.55	237

Note: $\eta^2 = .078$

Hypothesis 3. A 3 x 3 MANOVA was computed on the dependent variable of math achievement as measured by Test 2, Test 4, and final exam as a function of teaching method

(traditional, CAI-1, and CAI-2). A MANOVA summary table is provided in Table 5. A statistically significant main effect was found for the within-subject variable of semester test, $\lambda=.871$, $F(2, 1218) = 27.576$, $p < .001$. Estimated marginal means showed a V pattern in which students test scores fell and then improved over the course of the semester, ($\bar{X}_{Test2} = 65.73$, $\bar{X}_{Test4} = 61.23$, $\bar{X}_{TestFinal} = 66.89$). A statistically significant main effect was also found for the between-subjects variable of instructional method, $F(2, 609) = 20.640$, $p < .001$. Estimated marginal means for the instructional method variable indicated that students receiving traditional lecture outperformed students receiving CAI instruction ($\bar{X}_{Traditional} = 72.19$, $\bar{X}_{CAI-1} = 63.67$, $\bar{X}_{CAI-2} = 57.99$). The effect size for instructional method was found to be $\eta^2 = .067$, which represents a moderate effect size for instructional method.

Of greatest interest was the interaction between semester test and method of instruction. A statistically significant interaction was identified between semester test and instructional method, $\lambda=.973$, $F(4, 1216) = 2.562$, $p = .037$. Estimated marginal means for semester test scores by instructional method are provided in Table 6. Decomposition of the interaction into simple effects was performed using Fisher's LSD tests. LSD tests were conducted on the differences between pairs of means for the instructional methods within each level of semester test. Mean differences and significance test values for each combination of means are provided in Table 7.

Table 5

MANOVA Summary Table

Effect	Sums of Squares	Mean Squares	F	<i>p</i>
Between Subjects				
Instruction	20708.165	10354.083	20.640	<i>p</i> < .001
Error	305509.504	501.658		
Within-Subjects				
Semester Test	10910.679	5455.339	27.576	<i>p</i> < .001
Instruction x Semester Test	2027.150	506.787	2.562	<i>p</i> < .05
Error	240955.701	197.829		

Note: $\eta^2 = .067$

Table 6

Estimated Marginal Means for Semester Test x Instructional Method

	Semester Test 2	Semester Test 4	Final Exam Score
Traditional	73.39	69.83	73.34
CAI-1	64.30	61.17	65.56
CAI-2	59.51	52.69	61.78

Note: $\eta^2 = .067$.

The pattern of semester test scores achieved by students in each instructional method is shown below in Figure 2.

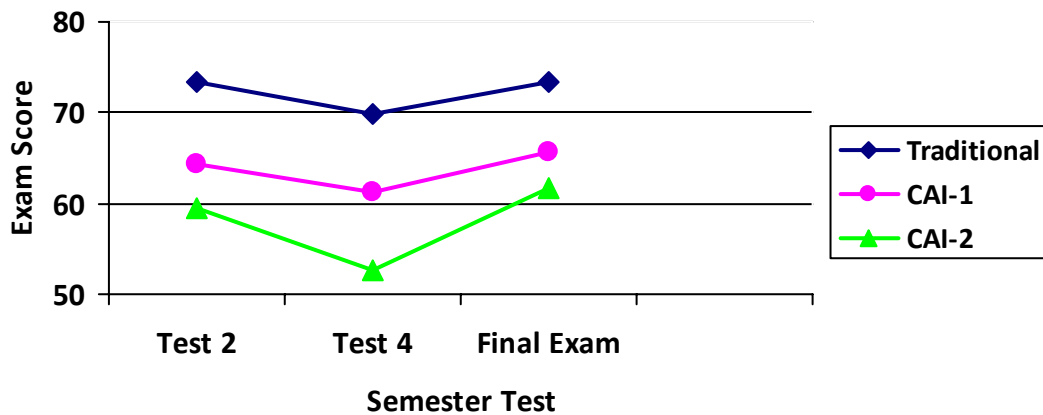


Figure 2. Estimated marginal mean exam scores by teaching method.

Table 7

Pairwise Mean Differences for Simple Effects of Method of Instruction within Semester Test

Semester Test	Method of Instruction	Mean Difference	q _r	t-test	p-value
Test 2	Trad-CAI1	9.09	9.10	6.43	<.001*
	Trad-CAI2	13.88	14.26	10.08	<.001*
	CAI1-CAI2	4.79	5.05	3.57	.051
Test 4	Trad-CAI1	8.67	8.63	6.10	<.005*
	Trad-CAI2	17.15	17.56	12.41	<.001*
	CAI1-CAI2	8.48	8.94	6.32	<.005*
Final Exam	Trad-CAI1	7.79	7.82	5.53	.015
	Trad-CAI2	11.57	11.90	8.41	<.001*
	CAI1-CAI2	3.78	4.00	2.82	.465

Hypothesis 4. Results of the analysis of variance tests computed for Hypotheses 1, 2 and 3 do not differ in terms of their conclusions. Null Hypotheses 1, 2 and 3 were each rejected with the conclusion that traditional instruction resulted in superior performance in terms of final exam scores and final course averages when compared to either of the CAI methods. Post-hoc comparisons for Hypothesis 2 indicate that students using the *Thinkwell* curriculum (CAI-1)

perform marginally better in terms of final course average than those using the *MyMathLab* curriculum (CAI-2), although neither CAI group performs as well as students who received traditional instruction. This is a similar result to that found for Hypothesis 3 in which significant main effects and an interaction were found. Main effects for both instructional method (between-subject variable) and test scores over the semester (within-subjects variable) showed students receiving traditional instruction outperformed those receiving CAI and students performed better by final exam than at earlier semester tests. Decomposition of the interaction effect, instructional method x test scores, indicated that students in the CAI classes had lower scores at all test points and that those in CAI-2 (using the *MyMathLab* curriculum) not only had the lowest test scores but also exhibited the most precipitous decline in scores from Test 2 to Test 4 and the steepest improvement in scores from Test 4 to Final Exam.

The analysis also revealed that Hypotheses 1, 2 and 3 do not differ in terms of their precision. Comparison of the effect sizes for each of the hypotheses testing the effect of instructional method on grades suggests that instructional method produces a small to moderate effect. The ANOVA computed to test Hypothesis 1, the effect of instructional method on final exam scores, resulted in an effect size of $\eta^2 = .035$. The ANOVA computed to test Hypothesis 2, the effect of instructional method on final course average, resulted in a slightly larger effect size of $\eta^2 = .078$. The MANOVA testing the between-subject effect for Hypothesis 3, the effect of instructional method on semester test scores, resulted in an effect size of $\eta^2 = .067$, similar in size to that noted for Hypothesis 2.

CHAPTER 5

DISCUSSION

The overall purpose of this study was to compare the achievement of precalculus college algebra students in classes where CAI was used with the achievement of students in traditional classes. This study served as an evaluation of three instructional methods for teaching remedial college algebra: traditional lecture instruction compared with two different computer-aided instructional curricula, *Thinkwell* and *MyMathLab*. The study was conducted at an urban southern university during the Spring semester of 2002. Data on 688 students who enrolled in precalculus college algebra was analyzed.

First, the author investigated the relationship between instructional method and math achievement as measured by final exam scores. Next, the relationship between instructional method and math achievement as measured by overall course grade was examined. Finally, the relationship between instructional method and math achievement over time as measured by repeated semester testing was investigated.

Assumptions, Delimitations, and Limitations of the Study

Several assumptions were made in developing this study. Specifically, students enrolled in this study and assigned to a CAI section were assumed to have the minimum necessary computer skills to use CAI effectively. Study participants were also assumed to be representative of both the student population found in CAI math classes at postsecondary institutions in general and the college student population in the state of Alabama in particular. Furthermore, instructors

participating in the study were assumed to have generally adhered to the departmental syllabus for precalculus algebra. Finally, because placement testing has been in use by the math department for many years, the math placement exam used to place students in precalculus algebra was assumed to be a valid and reliable method of determining students' remedial math needs.

The scope of this study is relatively narrow and focuses on achievement in quantitative terms (i.e., test scores and final grades). This study is delimited to examining the effect of three instructional methods used in a remedial college precalculus course on math achievement measured with departmental exams. It is further delimited to traditional age college students enrolled in a public, state university and who have tested as in need of remediation based on a standardized math placement exam. Several issues that may be of interest in future research on the use of CAI in remedial college algebra classrooms were considered beyond the scope of the present study. Most notably, variables considered beyond the scope of this study included instructor training, instructor experience with CAI, student use of tutors, amount of time students studied, class participation, students' math anxiety, and student success in subsequent math courses.

This research has a number of limitations linked to it. One limitation is that the participants were students enrolled at a single university in Alabama, limiting generalizability to universities in other geographic regions and to non-university postsecondary settings. The second limitation of this study is the range of instructional methods examined; that is, the study was restricted to a comparison of the three specific instructional methods described herein and did not examine other instructional alternatives such as Internet or distance learning. A third limitation concerns course formats. Although the topics taught in each section were the same, the final test

as well as first and third test's layouts varied in format; only the second and fourth semester tests were identical across math sections. Furthermore, whereas students in all three instructional groups responded to similar items testing the same concepts on the final, the CAI students took their tests in multiple-choice format on computer while traditional students took their tests in traditional paper-pencil format. An identical computer-generated multiple-choice test in traditional paper-pencil format was used for both CAI and traditional classes for the second and fourth tests. A fourth limitation is that the variable of course instructor was not controlled. Any variability due to instructor is reflected in error. Finally, the lack of a randomized assignment of students and teachers to instructional methods precludes definitive conclusions about the extent to which instructional method may be causally linked to changes in math achievement. Indeed, the fact that the study design relies upon the use of a convenience sample in which all students enrolled in precalculus algebra were accepted into the study and assigned to a course section (and therefore an instructional method) in a nonrandom manner places limits on the generalizability of results from this study. It is well known that the use of nonrandom samples may result in biased estimates in which the magnitude of bias is unknown. Thus, caution should be used in drawing firm conclusions about student groups beyond the scope of this study. Results are limited to providing insight about the use of CAI in remedial precalculus algebra classes with traditional college aged students. Furthermore, many studies of CAI in college classrooms fail to disclose the particular CAI curriculum in use. Therefore, it is not known to what extent the results reported here will hold true for all CAI curricula.

Additional potential limitations were knowledge of students' skills in using computers was not established; therefore, factors such as "fear of computers" were not examined. The students who took CAI were able to take a given test twice (two different adaptations of the same

test); therefore, the better grade was registered as their exam grade. This factor alone could have been a major source of grade inflation for students who took the class under CAI methods. An examination of the grading structure for the traditional and CAI sections shows that 10% of the final course grade for CAI students was based solely on attendance points, not test performance. Moreover, an examination of the raw data suggests that instructors may have awarded additional extra credit points to CAI students for lab attendance and that extra credit attendance points were not also awarded to traditional students. If, in fact, this occurred, then CAI students received an opportunity to improve their grades through attendance rather than just test performance. Traditional students were not afforded this opportunity; thus, the true difference in group means, and the corollary effect sizes reported here, may be underestimated in this sample.

Conclusions

Students enrolled in classes using traditional instruction methods performed better than those enrolled in classes using CAI methods, regardless of whether performance was measured by final exam scores, semester test scores, or final course averages.

Comparisons of the two CAI methods indicated that students exposed to the *Thinkwell* curriculum (CAI-1) performed slightly better than those receiving the *MyMathLab* curriculum (CAI-2) when performance was measured in terms of semester tests or final course average. In terms of test performance across the semester, students receiving either traditional instruction or the *Thinkwell* CAI curriculum demonstrated a smaller drop in achievement at the time of semester test 4 than did students who were exposed to the *MyMathLab* curriculum.

Small effect sizes ranging from $\eta^2 = .035$ for the effect of instructional method on final exam scores to $\eta^2 = .078$ for the effect of instructional method on final course average were

found in favor of traditional instruction. The effect sizes reported in this study are small; however, differences in the formulas used for grading in traditional versus CAI classrooms may have obscured some of the effect of instructional method. In particular, students in CAI were credited with up to 10 points on their final course average based on their class attendance, while students in traditional instruction classes were not awarded any points for class attendance. Thus, attendance points may have artificially increased final course grades in the CAI group compared to the traditional group. If this is the case, then the effect sizes reported here may be considered underestimates of the true effect of instruction.

Students in CAI classes could earn at least 100 attendance points, counting for 10% of the final course grade. Attendance points included at least 56 points for accumulating 4 hours weekly in the computer lab. To examine the possibility that students in the CAI groups could have gained or lost points on the basis of attendance that would have unduly influenced their final course grade, frequency and descriptive data on attendance and final course grade was examined. At each letter grade, mean attendance grades and final course averages were highly similar, indicating that students' attendance points did not have undue influence on course averages. That is, students did not gain or lose substantial points based on attendance that would have changed their final course averages. Only one student (2.6%) making a grade of "A" failed to accumulate the full number of attendance points given for computer lab. Seven students (6%) making a grade of "B" failed to accumulate the full number of computer lab attendance points. Thirty-seven (28%) students making a grade of "C" failed to accumulate the full number of attendance points for computer lab. Almost three-quarters of students making a grade of "NC" failed to accumulate the full number of attendance points for computer lab. Among students who failed the course with a grade of "NC," the mean final course average suggests that these

students would have scored well below the passing score cutoff of 70% based on test grade average alone, even if they had received every possible attendance point that could have been awarded. Tables 8 and 9 provide summary information on the number and percentage of CAI students who acquired less than the full possible number of points for attendance at computer labs and on the attendance and course averages for CAI students at each letter grade level.

Table 8

Number and Percentage of Students Achieving Less Than Full Points for Computer Lab Attendance

Letter Grade	N of students	N with less than full points	Percent with less than full points
A	38	1	2.6%
B	113	7	6.0%
C	128	37	28.0%
NC	153	114	74.5%

Table 9

Attendance and Course Averages among Students in CAI Classes

Letter Grade	Attendance Grade		Final Course Average
	Mean	SD	
A	92.70	12.27	92.90
B	83.92	14.89	83.02
C	72.60	22.14	74.23
NC	36.47	27.24	37.84

Taken together, the findings presented in this study suggest that precalculus algebra students may derive greater benefit from a traditional lecture classroom with instruction from an individual teacher rather than receiving instruction in a computer lab setting with guidance from a preset sequence of modules as is used in the two CAI curricula examined in this study. CAI has long been claimed to be an active learning strategy (Bonwell & Eison, 1991); however,

according to Mayer (2004), active learning strategies that promote concept mastery must require learners to be cognitively active not simply behaviorally active. CAI designed for drill and practice may not meet Mayer's definition of active learning.

Comparison of Study Results with Existing Literature

Results reported to date in the literature are mixed regarding the use of CAI to promote learning at the college level in the developmental algebra classroom. Traditional instruction has been shown by some researchers to result in greater math achievement (Fleming, 2003), higher pass rates for precalculus algebra (Ford & Klicka, 1998), and greater likelihood of passing in subsequent math courses (Summerlin, 2003). In addition, students in CAI classrooms have been noted to show higher course dropout and failure rates (Hogan, 2005; Summerlin, 2003). Others find that while CAI offers no additional benefit beyond that of traditional instruction, students receiving CAI perform as well as do those in traditional instruction classrooms (Carter, 2004; Reagan, 2004).

However, this is in contrast to results reported elsewhere that students receiving CAI performed better, albeit not significantly better, than those receiving traditional instruction (Sadatmand, 1994) or that students receiving CAI were more likely than those receiving traditional instruction to obtain a course grade of B or better (Williams, 1996). The strongest study results in favor of CAI note that while CAI generally outperforms traditional instruction, CAI is not better in every setting (Barrow et al., 2008). To the extent that CAI works better in some settings than others, it may also be true based on Hsu's (2003) findings that some CAI curricula are qualitatively better than others, particularly those that are teacher-made or that utilize tutorials, simulations, expert-systems, and drill and practice. Like Fleming (2003), the

findings from the present study suggest that traditional instruction, at least in comparison to some CAI, results in better math achievement. Furthermore, like Hsu, the results of the present study suggest that math achievement is not necessarily equivalent across various CAI curricula.

Interestingly, the review of studies on the use of CAI in college math courses shows a trend toward earlier years of research findings that tend to favor the use of CAI and later years of research findings that tend to favor the use of traditional instruction. The results of this study are consistent with those reported in other studies of recent years that find in favor of traditional instruction. While it is beyond the scope of this study to determine the extent to which the noted trend is real, the potential for such a trend raises questions about how the use of CAI has changed over the years, how teacher preparation has changed, and how methodology for studying student outcomes as a function of different instructional methods may have changed.

For example, it is possible that CAI software programs have undergone changes as a result of commercialization that have rendered the programs less effective than non-commercial programs or traditional instruction. It is also possible that teacher education programs have improved in their ability to prepare teachers of mathematics. Finally, it is possible that changes in evaluative research designs used in studies of CAI have changed over time, resulting in superior studies or better measurement of outcomes or other improvements in design and measurement that could influence study findings and conclusions.

Recommendations

Certain visual tools have held a well-established place in teaching basic algebra concepts long before the adoption of CAI. Tools, such as graphing calculators or manipulatives such as origami, have long been used to assist students in constructing internal visual representations of

mathematical concepts and ideas. CAI methods that incorporate and expand visual learning tools to promote higher level cognitive activities may result in greater student performance. However, CAI is simply a technological tool that can serve to amplify concepts. It should not be seen as a substitute for the human interaction and motivational advantages that a trained teacher can bring to the classroom. In short, as with any other teaching tool, CAI must be scrutinized for the ability of a CAI curriculum to assist in students' achievement of course learning objectives. Cautions for math educators wishing to adopt CAI methods include the following:

- Instructors who want to use CAI should be trained and have experience with computers and programming.
- CAI programs should be chosen based on pedagogical and philosophical underpinnings as well as for usefulness in achieving desired levels of Bloom's Taxonomy of Learning.
- CAI may be best used to supplement traditional instruction. Traditional instruction contains a human element of student-teacher interaction not easily replicated in CAI. The teacher is able to impart enthusiasm, motivation, recognize student struggles, and intervene appropriately.
- Teachers should not equate the use of CAI as a new technological tool with increases in math literacy.
- CAI curricula should be carefully chosen to match students' needs and abilities with course objectives. What may be suitable for advanced students may not meet the needs of novice or remedial students.

Implications

This study allowed comparison of two CAI curricula for use in the precalculus algebra classroom. Based on differences in performance between the CAI-1 and CAI-2 groups, it appears that CAI programs differ in usefulness for promoting student achievement. In this comparison, *MyMathLab* students performed worse than *Thinkwell* students on semester tests, final exams, and course grades.

The study found a significant difference in drop-out rate between traditional teaching method and CAI. Many more students dropped out of CAI classes than traditional classes. One possible explanation for the difference in attrition rates across instructional method groups is that some students perform better when taught in a situation that offers greater structure and guidance; another potential explanation is that students taking CAI math courses may experience anxiety about the use of computers as well as anxiety over math, thereby compounding their anxiety level in the course. Ultimately, more mixed (quantitative and qualitative) research is needed on CAI programs in order to identify weaknesses of available CAI instructional methods and software programs. Educators and administrators considering investing in CAI for use with remedial math students may want to carefully examine the usefulness of particular CAI curricula for meeting educational objectives of the population for whom this program is designed. Classroom teachers may need to integrate CAI technology into traditional classrooms to enhance existing teaching formats and promote learning but they may wish to do so by creating a tradition of choosing and using CAI as instructional supplements. This study also suggested that CAI is not a panacea, a teaching method that can single-handedly meet and remedy the challenges of remedial math.

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APPENDIX A
SAMPLE MATH PLACEMENT TEST

Math Placement Practice Exam

This is a **PRACTICE** exam only.

It is *similar*, but **NOT IDENTICAL** to the math placement exam.

NO CALCULATORS allowed

50 minute time limit

55 questions

Time remaining posted in upper left corner

Exam is on one page -- Scroll down for problems

Do NOT hit backspace

If you finish early, check to see that you have answered all questions *before* you click submit.

Once you have clicked submit, you may *not* go back to the test questions.

If you run out of time, the exam will automatically submit for you.

You will see your score when you have finished, and you can find out your *potential* math course placement.

Good luck!

1 of 55

Find the exact value of

$\tan 300^\circ$

- $-\frac{\sqrt{3}}{3}$
- $\sqrt{3}$
- $-\sqrt{3}$
- $\frac{\sqrt{3}}{3}$

2 of 55

$$\frac{\csc \theta \cot \theta}{\sec \theta}$$

Use trigonometric identities to simplify the expression:



$\csc^2 \theta$



$\cot^2 \theta$



$\sec^2 \theta$



1

3 of 55

$$\frac{(x-8)^2}{12} \div \frac{12x-96}{144}$$

Divide and simplify:



$x - 8$

$\frac{12(x-8)^2}{12x-96}$



$12x - 96$

$\frac{1}{x-8}$



$x - 8$

$\frac{(x-8)^3}{144}$



144

4 of 55

Write the expression as a sum, difference, or product of logarithms:

$$\log_4 \left(\frac{x^3 y^9}{16} \right)$$



$2 \log_4 x + 9 \log_4 y + 2$



$(\log_4 x)^2 + (\log_4 y)^9 - 2$



$$2\log_4 X + 9\log_4 Y - 2$$



$$2\log_4 X + 9\log_4 Y \div \log_4 16$$

5 of 55

Five times the sum of some number plus 2 is equal to 7 times the number minus 2. Find the number.



6



-12



-6



12

6 of 55

Evaluate:

$$\log_5\left(\frac{1}{25}\right)$$



-2



5



-5



2

7 of 55

Find the domain of the function $\sqrt{2-x}$



$$(-\infty, 2) \cup (2, \infty)$$



$$(-\infty, \infty)$$



$$[\sqrt{2}, \infty)$$



$$(-\infty, 2]$$

8 of 55

If $f(x) = 3x + 6$ is a one-to-one function, find an equation for its inverse.



$$f^{-1}(x) = \frac{x}{3} - 6$$



$$f^{-1}(x) = \frac{x-6}{3}$$



$$f^{-1}(x) = \frac{x+6}{3}$$



Not a one-to-one function

9 of 55

Convert the rectangular coordinates (9, -9) to polar coordinates.

$\left(-9\sqrt{2}, \frac{7\pi}{4}\right)$

$\left(9\sqrt{2}, \frac{7\pi}{4}\right)$

$\left(9\sqrt{2}, \frac{5\pi}{4}\right)$

$\left(9\sqrt{2}, \frac{3\pi}{4}\right)$

10 of 55

Write an equation in slope-intercept form for the line with slope 2 that passes through the point (-2, 6).

$y - 6 = x + 2$

$y = 2x + 10$

$y = 2x - 10$

$y - 6 = 2x + 2$

11 of 55

Factor the polynomial function

$$f(x) = 2x^3 - 3x^2 - 5x + 6$$

into linear factors given that $x = 1$ is a zero of the function.

- $f(x) = (x - 1)(x + 2)(2x - 3)$
- $f(x) = (x + 1)(x + 2)(2x - 3)$
- $f(x) = (x - 1)(x + 1)(2x - 6)$
- $f(x) = (x - 1)(x - 2)(2x + 3)$

12 of 55

Add and simplify: $\frac{5x}{x+6} + \frac{3}{x-6}$

$\frac{5x+3}{x^2-36}$

$\frac{5x^2-27x+18}{x^2+12x+36}$

$\frac{5x^2-27x+18}{x^2-12x+36}$

$\frac{5x^2-27x+18}{x^2-36}$

13 of 55

Use the vectors $\mathbf{v} = 8\mathbf{i} + 4\mathbf{j}$ and $\mathbf{w} = 9\mathbf{i} - 4\mathbf{j}$ to find the dot product

$\mathbf{v} \cdot \mathbf{w}$

- 16
- 56
- 72
- 88

14 of 55

Find the product: $(2x + 5)(3x - 11)$



$$6x^2 - 7x - 7$$



$$6x^2 - 7x - 55$$



$$5x^2 - 7x - 55$$



$$5x^2 - 7x - 7$$

15 of 55

Factor the trinomial:

$$9x^2 + 18x + 8$$



$$(9x + 2)(x + 4)$$



$$(3x - 2)(3x - 4)$$



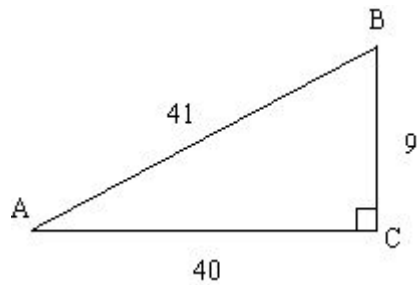
$$(3x + 2)(3x + 4)$$



Prime

16 of 55

Find the value of $\cos B$ in the triangle.



$$\frac{41}{40}$$



$$\frac{9}{41}$$



$$\frac{40}{41}$$

$\frac{9}{40}$

17 of 55

For the function $\frac{x^2 + 5}{x^3 - 8x}$, evaluate $f(-1)$.

$-\frac{2}{3}$

$-\frac{4}{9}$

$\frac{6}{7}$

$-\frac{6}{7}$

18 of 55

Solve the equation

$$2 \sin^2 x = \sin x$$

$\frac{\pi}{2}, \frac{3\pi}{2}, \frac{\pi}{3}, \frac{2\pi}{3}$

$\frac{\pi}{3}, \frac{2\pi}{3}$

$0, \pi, \frac{\pi}{6}, \frac{5\pi}{6}$

$\frac{\pi}{6}, \frac{5\pi}{6}$

19 of 55

Simplify the radical expression $\sqrt{48k^7q^8}$

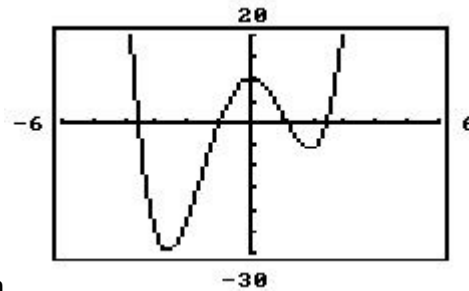
$4k^3q^4\sqrt{3}$

$4k^7q^8\sqrt{3k}$

$$4k^3q^4\sqrt{3k}$$

$$4q^4\sqrt{3k^7}$$

20 of 55



Find the equation that is represented by the graph

$$p(x) = x^4 + x^3 - 10x^2 + 10$$

$$p(x) = -x^5 - 10x^2 - 10$$

$$p(x) = x^5 - 4x^3 + 12x^2 + 10$$

$$p(x) = -x^4 + x^3 - 12x^2 + 10$$

21 of 55

Solve the compound inequality and express in interval notation.

$$-17 \leq 4m - 5 < 11$$

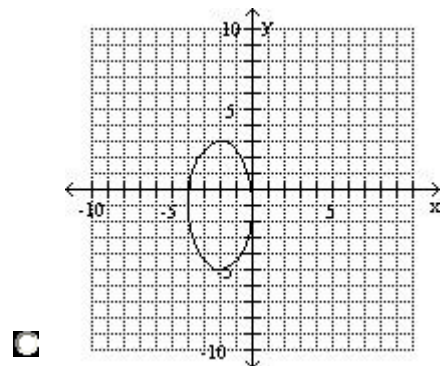
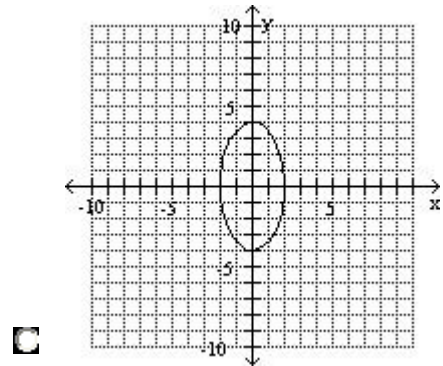
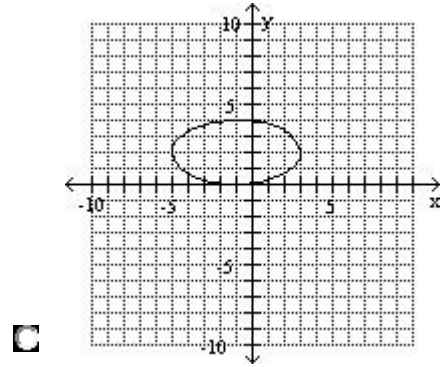
$$(-3, 4]$$

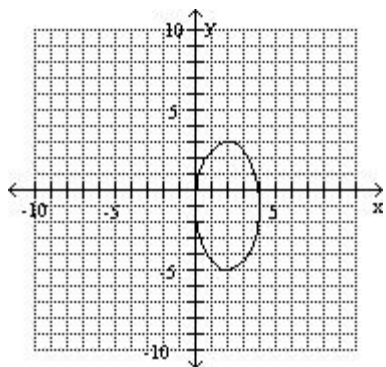
$$[-11/2, 3/2)$$

$$[-3, 4)$$

$$[-4, 3)$$

Graph the ellipse: $\frac{(x-2)^2}{4} + \frac{(y+1)^2}{16} = 1$





23 of 55

Solve the equation for c: $\frac{1}{a} + \frac{1}{b} = \frac{1}{c}$

$c = a + b$

$c = ab(a + b)$

$c = \frac{ab}{a + b}$

$c = \frac{a + b}{ab}$

24 of 55

Solve the quadratic inequality:

$$x^2 + 3x - 10 > 0$$

Express the solution set in interval notation.

$(-5, 2)$

$(-\infty, -5) \cup (2, \infty)$

$(-5, \infty)$

$(2, \infty)$

25 of 55

Simplify the expression

$$(3x^6y^7)^2(x^8y)^{-3}$$

$\frac{9y^{11}}{x^{12}}$

$\frac{9}{x^{12}y^{11}}$

$\frac{y^{11}}{9x^{12}}$

$9x^{12}y^{11}$

26 of 55

Factor:

$$49x^2 - 36$$

$(7x - 6)(7x - 6)$

$(7x + 6)(7x + 6)$

$(7x + 6)(7x - 6)$

Prime

27 of 55

Find the product of the complex numbers:

$$(4 - 2i)(5 + 4i)$$

$28 - 6i$

$28 + 6i$

$12 - 26i$

$12 + 6i$

28 of 55

Evaluate the algebraic expression $\frac{y - 6x}{3x + xy}$ for $x = -4$ and $y = 5$.

- $-\frac{29}{32}$
 - $-\frac{25}{32}$
 - $\frac{19}{32}$
 - $-\frac{19}{8}$
-

29 of 55

Find the degree measure of

$$\theta = \cos^{-1}\left(-\frac{\sqrt{2}}{2}\right)$$

- 135°
 - 90°
 - 45°
 - -45°
-

30 of 55

Find the horizontal asymptote of the function $\frac{3x^2 - 2x - 7}{5x^2 - 9x + 2}$

- $y = 0$
- $y = \frac{3}{5}$
- $y = -\frac{7}{2}$

None

31 of 55

Rationalize the denominator and simplify as much as possible: $\frac{42}{\sqrt{7x}}$

$\frac{6\sqrt{7x}}{x}$

$\frac{6\sqrt{7x}}{7x}$

$\frac{42\sqrt{7x}}{7x}$

$\frac{42\sqrt{x}}{x}$

32 of 55

A vector \mathbf{v} has initial point $(-1, -2)$ and terminal point $(-5, 3)$. Write \mathbf{v} in component form.

$\langle -4, 5 \rangle$

$\langle 5, -4 \rangle$

$\langle 4, -3 \rangle$

$\langle -3, 4 \rangle$

33 of 55

For the functions $f(x) = 4x^2 + 6x + 4$ and $g(x) = 3x - 5$, find the composition $(g \circ f)(x)$

$$36x^2 - 102x + 74$$



$$12x^2 + 6x - 1$$



$$12x^2 + 18x + 7$$



$$12x^3 - 20x^2 + 18x - 20$$

34 of 55

Find the slope of the line that goes through the points (6, -7) and (-3, 5).

$\frac{4}{3}$

$-\frac{4}{3}$

$-\frac{3}{4}$

$\frac{3}{4}$

35 of 55

Solve the absolute value equation:

$$|3x - 5| + 3 = 10$$

$\left\{-\frac{2}{3}, 4\right\}$

$\left\{-4, \frac{2}{3}\right\}$



4

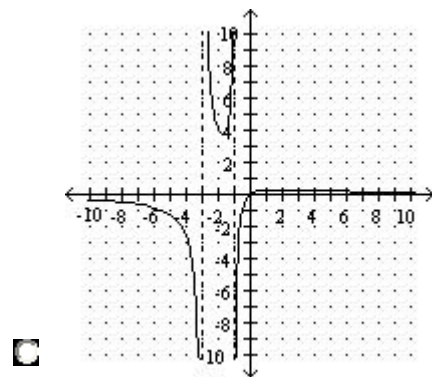
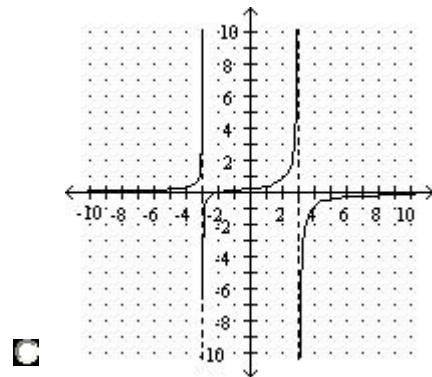
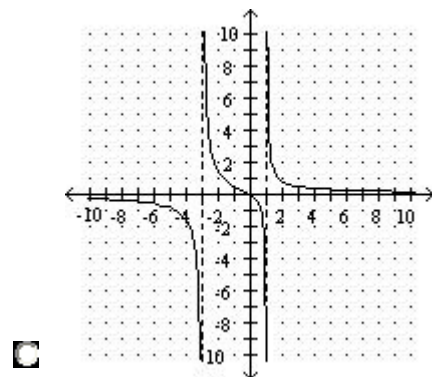
36 of 55

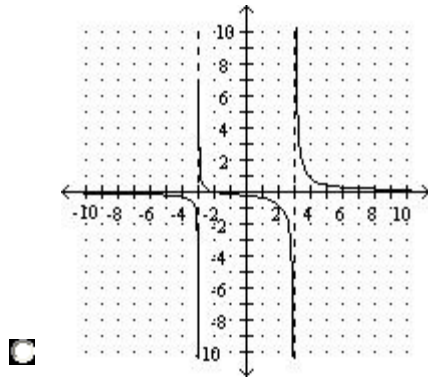
Evaluate the sum: $\sum_{k=2}^5 \frac{(k^2 - 5)}{2}$

- 34
- 10
- 17
- 20

37 of 55

Sketch the graph of the rational function $\frac{x+2}{x^2-9}$





38 of 55

Use the complex numbers

$$z_1 = 5(\cos 20^\circ + i \sin 20^\circ) \text{ and } z_2 = 4(\cos 10^\circ + i \sin 10^\circ)$$

to find the product

$$z_1 z_2.$$

Leave your answer in polar form.

$$20(\cos 30^\circ + i \sin 30^\circ)$$

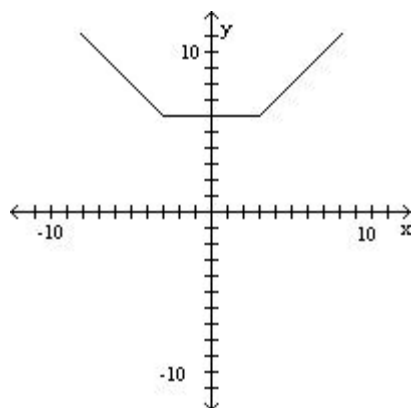
$$9(\cos 30^\circ + i \sin 30^\circ)$$

$$20(\cos 200^\circ + i \sin 200^\circ)$$

$$-9(-\cos 200^\circ - i \sin 200^\circ)$$

39 of 55

Determine the intervals over which the function represented by the given graph is increasing, decreasing, and constant.



Increasing $(3, \infty)$; Decreasing $(-\infty, -3)$; Constant $(-3, 3)$



Increasing $(-\infty, 3)$; Decreasing $(-\infty, -3)$; Constant $(-3, 3)$



Increasing $(6, \infty)$; Decreasing $(-\infty, 6)$; Constant $(-3, 3)$



Increasing $(6, \infty)$; Decreasing $(-\infty, 6)$; Constant 6

40 of 55

Find the sum of the solutions of the equation:

$$x^2 - x = 6$$



1



13



5



-1

41 of 55

Find and simplify the difference quotient $\frac{f(x+h) - f(x)}{h}$ for the function $x^2 + 7x + 5$



1



$2x + h + 5$

- $2x + h + 7$
 $\frac{h^2 + 2h + 14x + 10}{h}$
-

42 of 55

Find the supplement of an angle whose measure is

63°

- 153°
 27°
 243°
 117°
-

43 of 55

Find the 6th term of the geometric sequence: 4, -12, 36, ...

- 972
 -8748
 -243
 2916
-

44 of 55

Solve the equation: $3(5x + 4) - 6 = 11x - 2$

- 32
 -2
 -8
 2
-

45 of 55

Find the distance between the points (5, -3) and (-1, 5).

- 100
- 11
- 10
- 14

46 of 55

Solve the equation:

$$2^{5+3x} = \frac{1}{16}$$

- $\frac{1}{8}$
- 3
- 4
- 3

47 of 55

Simplify the rational expression: $\frac{x^2 + 6x + 9}{x^2 + 10x + 21}$

- $\frac{x+3}{x+7}$
- $\frac{3x+3}{5x+7}$
- $\frac{3x+3}{5x+7}$
- $\frac{15}{31}$

48 of 55

$$\frac{18x^4 - 21x^3 + 18x^2}{3x^3}$$

Divide:



$$6x - 7 + \frac{6}{x}$$



$$6x - 7$$



$$6x - 7x^3 + \frac{6}{x}$$



$$6x + 18x^2$$

49 of 55

Subtract: $\frac{4}{5} - \left(-\frac{1}{9}\right)$

$\frac{41}{45}$

$-\frac{1}{10}$

$-\frac{41}{45}$

$\frac{31}{45}$

50 of 55

Simplify the expression:

$$25 - [8 - (6 - 10)] + (1 - 3)^3$$

-21

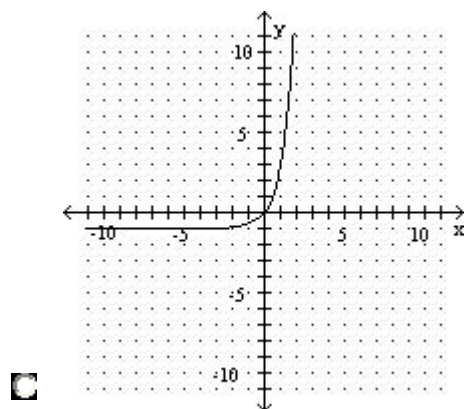
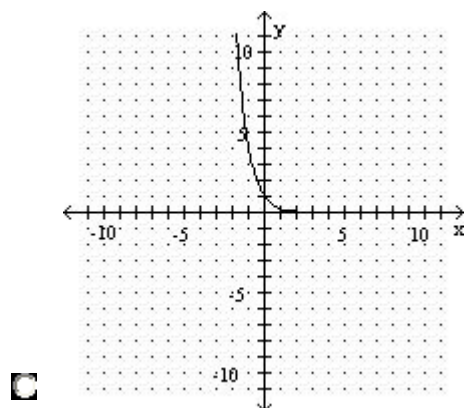
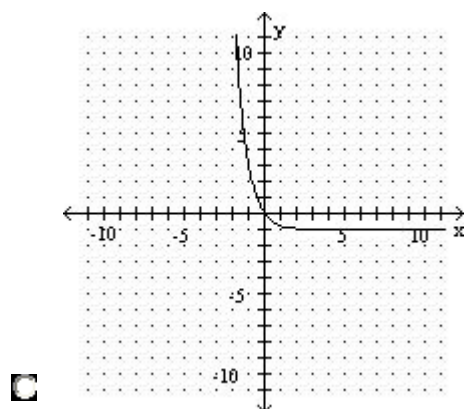
29

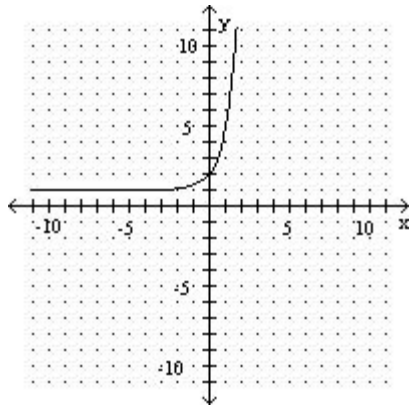
21

5

51 of 55

Graph the exponential function
 $f(x) = 4^x - 1$





52 of 55

$$3x + 3y = -3$$

Solve the system of equations: $5x - 7y = 19$

- (-2, 1)
- (1, -2)
- (6, -7)
- (5, -6)

53 of 55

Factor out the greatest common factor:

$$14x^3 - 4x^2 + 10x$$

$$2x(7x^2 - 2x + 5)$$

$$2x(7x^3 - 2x^2 + 5x)$$

$$x(14x^2 - 4x + 10)$$

$$2(7x^3 - 2x^2 + 5x)$$

54 of 55

Multiply:

$$(5x - 1)^2$$



$$5x^2 - 10x + 1$$



$$25x^2 + 1$$



$$5x^2 + 1$$

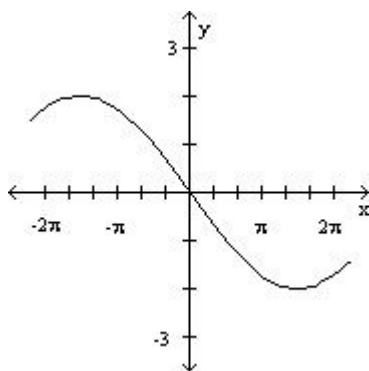
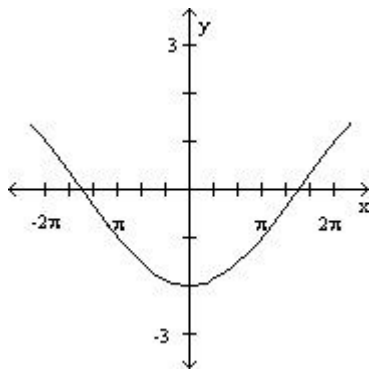


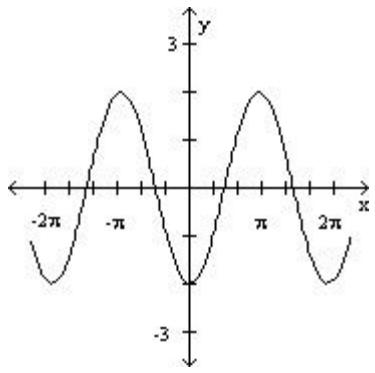
$$25x^2 - 10x + 1$$

55 of 55

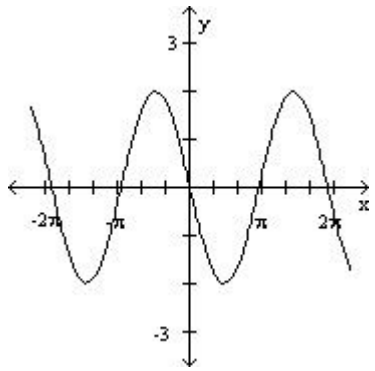
Graph the function

$$y = -2 \cos\left(\frac{x}{3}\right)$$





C



C

APPENDIX B

SAMPLE PRECALCULUS ALGEBRA SYLLABUS

Math 112 Syllabus

Welcome to Math 112

MyMathLab PreCalculus
By:Lial/Hornsby/Schneider

Course Requirements

- Every student must have an active EMAIL account to register for this course.
- Every student must have a NEW access/registration code.

Prerequisites

- Grade of C- or better in Math 100
- Minimum of 31 on the math placement test

Test Dates & Times

- The four regular tests will be held on Tuesday nights
- The final exam is Thursday May 9th.
- Your class section determines your test time.

Format of tests

Test 1 ---multiple choice

Test 2 ---traditional-instructor graded

Test 3 ---multiple choice

Test 4 ---traditional-instructor graded

Final exam---multiple choice

Make-up policy

- To be allowed a makeup, you must present to your instructor a verifiable excuse within 2 days of missing a test.
- You will receive a zero for any work that is not made up.

Course Grades

4 tests & Quiz average	60%
Attendance	10%
Final Exam	30%

Quizzes

- There will be a minimum of 15 quizzes given this semester. Additional work may be given during weekly meetings.
- Check your email and/or announcements for dates of quizzes.

Course Grades

Grades of A,B,C, or NC will be given in this course.

Note: A grade of NC means you will receive no credit for this course. You must retake this course again. However, an NC does not affect your GPA.

Attendance

- Attendance is mandatory for the weeks of orientation (Wed. 1/9 – Fri. 1/18). Attend your regularly scheduled class time.
- Attendance counts for 10% of your final course grade.
- Attendance points:

Orientation	5 points
Lab hours	56 points
Weekly class meetings	39 points

Lab Hours

- You MUST work a minimum of 4 hours each week in the MTLC.
- You will earn 4 points for each week you work 4 or more hours.
- 4 points * 14 weeks = 56 total points
- Lab hours start the week of 1/20/2002.
- A week is from Sunday – Friday.

MTLC Hours Attendance Bonus

- If you earn attendance credit for 12 of the 14 weeks, you will have the option of having your final exam replace your lowest test grade.
- A zero grade due to an unexcused absence or academic misconduct cannot be replaced.

MTLC Closings

- Closes on 1/20 and 1/21 for MLK holiday.
- Closes on 3/22 at 5pm and reopens on Monday 4/1 at 9:00am for spring break.
- No work will be permitted after 5:30pm on Tuesdays during test week.
- Wednesdays and Fridays during test weeks will have a limited number of computers available due to testing.

Weekly Class Meetings

- You are required to attend a weekly class meeting at your designated class time.
- Your instructor will inform you of your correct day to attend.
- You will earn 3 points for each week you attend the class meetings.
- 3 points * 13 weeks = 39 points

Weekly Class Meetings

- Class meetings will be held in the MTLC club room.
- Weekly class meetings start the week of 1/20/2002.

Class Rules & Test Rules

- Turn to the last page of your syllabus.

- A signed acknowledgement form must be turned in to your instructor before you will be allowed to take any tests.
- Final thoughts
- We are looking forward to you being successful in this course.
- Work hard
- Get help
- Have fun