DISSERTATION

TRADITIONAL AND ASYNCHRONOUS COMPUTER-ASSISTED INSTRUCTION IN A COMMUNITY COLLEGE REMEDIAL MATHEMATICS COURSE: A MIXED METHODS STUDY OF STUDENT SUCCESS AND PERCEPTIONS

Submitted by

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In partial fulfillment of the requirements

For the Degree of Doctor of Philosophy

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY STACEY HOGAN ENTITLED TRADITIONAL AND ASYNCHRONOUS COMPUTER-ASSISTED INSTRUCTION IN A COMMUNITY COLLEGE REMEDIAL MATHEMATICS COURSE: A MIXED METHODS STUDY OF STUDENT SUCCESS AND PERCEPTIONS BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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ABSTRACT OF DISSERTATION

TRADITIONAL AND ASYNCHRONOUS COMPUTER-ASSISTED INSTRUCTION IN A COMMUNITY COLLEGE REMEDIAL MATHEMATICS COURSE: A MIXED METHODS STUDY OF STUDENT SUCCESS AND PERCEPTIONS

The purpose of this study was to increase understanding about the impact of instructional delivery method on students' final grades in a community college remedial mathematics course. The study specifically addressed the effectiveness of using *Interactive Mathematics* software developed by Academic Systems Corporation. The study included two parts, which were conducted simultaneously. The first part was quantitative and the second part was qualitative.

In the first part of the study, the investigator used archived student data to analyze the relationship between instructional delivery method (traditional instruction vs. asynchronous computer-assisted instruction [CAI]), students' gender, students' age, and students' final course grades in Survey of Algebra and in a subsequent, college-level mathematics course (College Algebra). Data were analyzed from 1,720 students who enrolled in Survey of Algebra from 2002 to 2004. Results indicated that students who used traditional instruction had higher grades than students who used CAI; females had higher grades than males, regardless of type of instruction; and non-traditional age students had higher grades than traditional age students, regardless of type of instruction. In most cases, the differences were statistically significant when analyzed using *t* tests. Effect sizes ranged from small to medium-large. Results of an ANOVA indicated that

although the main effects were significant and large, there were no significant interactions between the independent variables.

The second part of the study was a qualitative exploration of students' experiences and perceptions using asynchronous CAI. The investigator conducted 12 one-on-one interviews with students and used a systematic, multi-level coding process for analyzing and interpreting data from the interviews. Students' experiences in and perceptions about taking Survey of Algebra using computerized instruction seemed to be based on the degree to which external variables (i.e., the structure and format of the course) were or were not compatible with students' personal characteristics, learning preferences, prior knowledge of the content, and aptitude for mathematics. Three major themes related to CAI were salient across all interviews – convenience, individualization, and support – although some students commented favorably and others commented unfavorably about those aspects of using CAI.

Results of this study suggest that method of instruction can be a factor in student success in remedial mathematics courses. Traditional instruction was found through quantitative analysis to be the more effective method of instruction. However, qualitative analysis showed that some students had a strong preference for CAI and were successful in Survey of Algebra using CAI. There appear to be advantages to both methods of instruction.

The overall implication stemming from this study is that traditional instruction should not be eliminated and nor should CAI. Instead, the participating institution should continue to offer remedial mathematics courses in a variety of instructional formats, perhaps guiding each student toward a particular method of instruction based upon his/her unique mix of personal and motivational qualities. Because this was a study of a single institution, similar studies should be conducted before results can be generalized to a larger population of developmental mathematics students.

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DEDICATION

For Brian, ever patient.

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CHAPTER 1 – INTRODUCTION

The use of computers in education is ubiquitous, from the early childhood level through graduate study, and in virtually every content area. Computers are used as a tool to help students who are behind to catch up, and they are utilized in assignments designed to challenge gifted students. Over the past few decades, computers have become increasingly prevalent as a means to either replace or enhance traditional, lecture-based instruction. That is the case in community college developmental mathematics as much as in any other subject. Unfortunately, the published literature suggests that too little is known about the true impact of computers on student achievement and success in developmental mathematics.

Problem Statement

Many students entering higher education lack the skills and knowledge to succeed in college-level mathematics. In fall 2000, 22 percent of entering college freshmen enrolled in remedial mathematics courses, and 35 percent of freshmen at public community colleges enrolled in remedial mathematics, up from 32 percent in 1995 (U. S. Department of Education [USDE], 2003).

Virtually all associate and baccalaureate degree programs require students to complete at least one college-level mathematics course, and many certificate programs also include mathematics courses. Often, remedial mathematics courses are considered “gate-keeper” courses. Students who are successful are able to move on to upper-level, more career- or discipline-specific coursework and eventually earn their degree or certificate. Unsuccessful students, at best, must repeat courses, resulting in more time spent in college. At worst, non-success discourages students, leading many to drop out of college altogether, which can have unfortunate consequences for individuals' personal and professional lives (Institute for Higher Education Policy [IHEP], 1998; McCabe & Day, Jr., 1998; Roueche & Roueche, 1993, 1999; USDE, 2002, 2004).

Findings about the effectiveness of developmental mathematics are not consistent. Most studies have focused on course pass rates at only one or a few institutions and results as low as 26 percent have been cited (McDonald, 1988). It is imperative, therefore, for educators to find ways to ensure greater student success in developmental mathematics. One way to do that is to introduce new instructional delivery methods that are aligned with increased understanding of student development and learning theory.

Recent research on developmental mathematics has focused on the effectiveness of integrating technology in the classroom. In fall 2000, public community colleges were more likely than other types of postsecondary institutions to use advanced technology in developmental education, with 84 percent reportedly using computers as a hands-on instructional tool *occasionally* or *frequently* in remedial mathematics (USDE, 2003). Recently, some states have mandated that remedial coursework be offered only at community colleges. In keeping with their open-door policies and ideals of accessibility, community colleges must respond by becoming more innovative in how they deliver developmental education to students.

However, many community college instructors and administrators are still unclear about the most effective methods of utilizing computers in the classroom. The number and variety of available computer applications can be overwhelming, and technology is often integrated into the curriculum before there is sufficient evidence of its impact – positive or negative – on student learning.

With respect to computer-assisted instruction (CAI) for developmental mathematics in particular, questions that must continue to be explored include: Does CAI positively impact student learning? Can computers be used to replace instructors entirely, or should they be used in combination with human instruction? What combination works best? Can CAI be used successfully with all types of students, or only with certain groups? What is it, specifically, about the use of CAI that leads to student success or non success? and how do students describe their experiences utilizing CAI in developmental mathematics education? In conducting research to answer these questions, educators will gain greater understanding of some factors that lead to success in developmental mathematics. Then, by designing programs that reflect the factors identified through research, practitioners may see increased rates of academic achievement, retention, and graduation, as well as success in the workplace.

Purpose Statement

The overall purpose of this study was to increase understanding about the impact of instructional delivery method on student success in community college remedial mathematics. More data on the effectiveness of using CAI compared to traditional instruction for students in remedial mathematics courses may help educators and students make better decisions about whether and how to use CAI programs in the future. Results of this study may also provide richer, more meaningful insight into specific factors that may impact student success using CAI programs for remedial mathematics instruction.

This study had two parts. First, the investigator analyzed the relationship between instructional delivery method (traditional versus asynchronous computer-assisted), students' gender, students' age, and students' final course grades in a remedial mathematics course (Survey of Algebra) and in a subsequent, college-level mathematics course (College Algebra). Second, the investigator focused specifically on asynchronous CAI, conducting interviews with students to explore in greater detail their experiences and perceptions using asynchronous CAI in Survey of Algebra.

Research Questions

In Part I of this study, the investigator used archived student data to address the following research questions:

1. Is there a difference between instructional delivery method (traditional versus asynchronous computer-assisted) in a remedial mathematics course (Survey of Algebra) in regard to students' final course grades?
2. Is there a difference between instructional delivery method (traditional versus asynchronous computer- assisted) in a remedial mathematics course (Survey of Algebra) in regard to students' final course grades in a subsequent college-level mathematics course (College Algebra)?
3. Is there a difference between male and female students in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) using traditional instruction?

4. Is there a difference between male and female students in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) using asynchronous CAI?
5. Is there a difference in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) between males who completed the course using traditional versus asynchronous computer-assisted instruction?
6. Is there a difference in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) between females who completed the course using traditional versus asynchronous computer-assisted instruction?
7. Is there a difference between traditional-age students (up to 24 years old) and non traditional-age students (25 years and older) in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) using traditional instruction?
8. Is there a difference between traditional-age students (up to 24 years old) and non traditional-age students (25 years and older) in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) using asynchronous CAI?
9. Is there a difference in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) between traditional-age students (up to 24 years old) who completed the course using traditional versus asynchronous computer-assisted instruction?
10. Is there a difference in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) between non traditional-age students (25

years and older) who completed the course using traditional versus asynchronous computer-assisted instruction?

11. Is there an interaction between instructional delivery method (traditional versus asynchronous computer-assisted), students' gender, and students' age (up to 24 years, 25 years and older) in regard to students' final course grades in a remedial mathematics course (Survey of Algebra)?

In Part II of this study, the investigator analyzed data gathered from interviews with students to address the following research question: How do students describe their experiences and perceptions using asynchronous CAI for a remedial mathematics course (Survey of Algebra)?

Definition of Terms

Asynchronous computer-assisted instruction allows individual students to learn different material at different times and in different locations (Kinney, 2001b). Compare to *synchronous computer-assisted instruction.*

Community colleges, also commonly referred to as *two-year colleges, junior colleges,* or *vocational/technical colleges*, are institutions where the highest level of offering is at least two but less than four years (below the baccalaureate degree; USDE, 2003). Academic programs at community colleges typically include specific career and technical areas as well as transfer programs for students intending to go on to earn baccalaureate degrees. Community colleges typically have open-door admission policies.

Computer-assisted instruction (CAI) is instruction that utilizes the computer as a teaching or learning tool. Software is used to determine students' background knowledge and readiness, introduce new information, provide practice and feedback, and assess students using tests or quizzes. CAI may be used alone or in combination with human instruction, and also is referred to as *computer-aided instruction, computer-based instruction, computer-directed instruction, computer-enriched instruction, computer-enhanced instruction, computer-managed instruction, computer-mediated instruction, reform computer-assisted instruction, artificial-intelligence based instruction, computer-based education,* and *computer-assisted learning*. For this study, CAI refers to courses that used an adaptive computer software program called *Interactive Mathematics* by Academic Systems Corporation. (See Chapter 3 for a more detailed description of *Interactive Mathematics* by Academic Systems Corporation.)

Developmental education is "a sub-discipline of the field of education concerned with improving the performance of students" (College Reading and Learning Association [CRLA], 1991, p. 4) or "a field of practice and research within higher education with a theoretical foundation in developmental psychology and learning theory" (National Association for Developmental Education [NADE], 2001, Definition of Developmental Education section, paragraph 1). Developmental education "promotes the cognitive and affective growth of all postsecondary learners, at all levels of the learning continuum" and includes learning assistance; personal, academic, and career counseling; academic advisement; and coursework (NADE, 2001, Definition of Developmental Education section, paragraph 1). Developmental education also is commonly referred to as *remedial education, compensatory education, special studies, preparatory studies, pre college-level education, academic support programs, foundational education, learning assistance, refresher courses,* and *basic skills instruction.*

Developmental mathematics, also commonly referred to as *remedial mathematics*, includes mathematics coursework at a level below college algebra. (These terms will be used interchangeably throughout this study.)

Developmental program describes "an organized system for delivering instruction, academic support, and personal development activities to college students" (CRLA, 1991, p. 4). See *remedial programs*.

Developmental students are "students assessed as having potential for success if appropriate educational opportunities are provided" and "students who, while meeting college admissions requirements, are not yet fully prepared to succeed in one or more introductory courses" (CRLA, 1991, p. 5). See *remedial students.*

Four-year institutions are institutions where the highest level of offering is four years or more (baccalaureate or higher degree; USDE, 2003).

Learning assistance describes "supportive activities, supplementary to the regular curriculum, that promote the understanding, learning, and remembering of new knowledge, remediation for prescribed entry and exit levels of academic proficiency, and the development of new skills" and may include "study skills instruction, tutoring, reviews, supplemental instruction, study groups, special topic workshops, exam preparation, and various types of self-paced instruction, including computer-assisted instruction" (CRLA, 1991, p.6).

Remedial (education) courses include "courses in reading, writing, or mathematics for college-level students lacking those skills necessary to perform college-level work at the level required by the institution" (USDE, 2003, p. iii). Also referred to as *developmental* *(education) courses*. Courses at the remedial level often are credit-bearing but do not count toward an associate or baccalaureate degree.

Remedial programs include "a group of courses and/or activities to help learners needing remediation to achieve basic skills in their identified deficit area" (CRLA, 1991, p. 9). See *developmental program*.

Remedial students are "students who are required to participate in specific academic improvement courses/programs as a condition of entry to college" (CRLA, 1991, p. 9). See *developmental students*.

Synchronous computer-assisted instruction requires all students to learn the same material at the same time and in the same location (Kinney, 2001b). Compare to *asynchronous computer-assisted instruction*.

Traditional instruction refers to an instructional delivery method that utilizes primarily lecture. In mathematics courses, the instructor typically first answers questions about previously assigned homework. S/he then presents new material and examples to the entire class, usually on a board or using an overhead projector. Students individually complete drill and practice exercises during class time and as homework. Courses taught using traditional instruction usually are held on a specific day and at a specific time, and students are expected to progress at the same pace.

Delimitations

This study was delimited to students at one public community college in a medium-sized city in the western United States. Part I of the study was delimited to those students whose gender, age, and final course grades in Survey of Algebra (and College Algebra, if applicable) were available from the institution's computerized student information system. Part I also was delimited to a three-year time period: 2002 to 2004. Part II of this study was delimited to only those students who earned a final grade in Survey of Algebra in an *asynchronous CAI* section. (Students who withdrew from the course were not included in Part II.) Part II was further delimited to a one-year time period: 2004.

Limitations and Assumptions

This study was limited by a number of factors. First, it focused on one institution; caution should be taken when generalizing results. This study was limited to one asynchronous CAI program. Interactive multimedia software programs available today vary widely, and the quality of *Interactive Mathematics* by Academic Systems Corporation compared to other proprietary software applications designed for computer-assisted mathematics instruction has not been determined.

For both parts of the study, it was assumed that students' final course grades were accurately entered into the college's computerized student information system. It was assumed that students were accurately placed into an appropriate level of mathematics, whether by using placement test score, standardized test score, grade of C or better in a lower-level mathematics course, or other criteria. It was assumed that those placement tools were valid and reliable. It was further assumed that final course grades were assigned objectively.

Part I of this study used an *ex-post-facto* design and was comparative in nature. Students were not randomly selected, nor randomly assigned, to a particular method of instruction. With self selection, some students are more likely than others to select and succeed in a specific learning environment. Students who register early are more likely to have a choice of instructional method, while late registrants may have less choice. In Part II of this study, it was assumed that students were honest in their responses to interview questions and it also was assumed that students who did not participate in interviews were similar to those who did.

This study did not take into consideration a number of possible confounding student variables that can positively or negatively impact students' final course grades and perceptions, including, but not limited to, students' level of education, area of study/major, course load (full time or part time), prior knowledge of mathematics, completion of lower-lever mathematics courses, learning style, comfort level and prior experience with computers, maturity, motivation to succeed, goals, family support, number of dependents, socioeconomic status, utilization of learning assistance services, and work status (full time, part time, or not working).

Prior to fall 2004, course sections offered at the institution during fall, winter, and spring quarters lasted approximately ten weeks and course sections offered during summer quarters lasted approximately eight weeks. Starting fall 2004, the institution switched to 15-week semesters, although one traditional section of Survey of Algebra that was included in this study was offered in a compressed format lasting approximately six weeks. Investigating the impact of different section lengths was beyond the scope of this study.

In addition, except for considering whether courses were taught using traditional instruction or asynchronous CAI, the researcher did not take into account other differences in individual course sections, including but not limited to: attendance policy, grading policy, amount of time spent in lecture, emphasis placed on specific concepts, use of computers in traditional sections, textbooks and other course materials, sequence in which concepts and skills were introduced, presence or absence of group work, testing format, class size, campus, time of day, days of week, length of class sessions, etc. Differences in instructors' teaching styles, years of teaching experience, status as full time or adjunct, and expertise with asynchronous CAI or traditional instruction also were beyond the scope of this study.

Significance of the Study

This study was important for several reasons. First, it adds to the limited body of research that specifically addresses the effectiveness of using asynchronous CAI vs. traditional instruction in a community college remedial mathematics course. Also, this investigation addressed students' performance in a subsequent college-level mathematics course based on whether they completed the remedial course in a traditional or asynchronous CAI section. This study analyzed whether final course grades differed based on students' gender and/or age and gathered qualitative information on students' experiences in and perceptions about a remedial mathematics course taught using asynchronous CAI.

Results of this study could help improve practice in a number of ways. Administrators, department chairs for developmental mathematics and college level mathematics, instructors, and instructional designers at the participating institution may use the results to help determine whether goals of the developmental mathematics program are being met. They have more evidence to help determine the effectiveness of using asynchronous CAI versus traditional instruction for Survey of Algebra and whether students' final course grades are different based on gender and/or age. Results also shed light on whether the instructional delivery methods offered at the developmental level impacted students' success in subsequent, college-level mathematics course. This information could aid academic advisors at the institution as they help students choose from various instructional delivery methods.

Finally, data from interviews provides more detailed information about students' experiences in and perceptions about a remedial mathematics course taught using asynchronous CAI at the participating institution. The qualitative analysis of interview data provides important information that can be used to improve teaching and learning using asynchronous CAI – and even using traditional instruction – at the institution.

On a broader scale, results of this study add to the body of literature that may help instructors, instructional designers, department chairs, administrators, advisors, and students at other community colleges – and possibly at four-year institutions and in K-12 education - make decisions about instructional delivery method. For example, K-12 educators could conduct further research to determine if conclusions from this study transfer to younger populations of students studying mathematics. Mathematics instructors at other community colleges could examine whether the results of this study are consistent with findings at their own institutions, and instructors at all levels could draw from this research as they look at possibilities for utilizing asynchronous CAI in other content areas. The design and results of this study also could assist personnel at other institutions who are in search of an effective evaluation model for use with asynchronous CAI.

From a policy standpoint, results of this study may help decision-makers at the departmental, institutional, state, and national levels make determinations about what types of instructional delivery methods should be available for students at post-secondary institutions where developmental mathematics is taught. If the larger body of research, including this study, indicates that different instructional delivery methods have varying levels of effectiveness for different types of students, educational leaders could decide not to choose one delivery method over another, but to offer several options from which students may choose.

Investigator's Perspective

This investigator earned a master of art degree in Higher Education Administration – Student Development, with a cognate in Counseling. She has worked in the field of higher education for approximately nine years, primarily in student affairs, including admissions and recruiting; residence life; academic, financial aid, and career advising; and resource development (proposal writing and grant management). She also has worked as a substitute teacher (early childhood through high school), taught English as a second language, and tutored high school and community college students in a variety of subjects, including developmental mathematics. She has worked at four community colleges in Colorado, and was the assistant director for a federally funded college-preparatory program for high-school students from low-income, first-generation backgrounds.

The investigator has a strong interest in developmental education, is supportive of the community college mission of access and opportunity, and believes that students are most successful when they are able to choose from a variety of instructional delivery methods. With respect to the application of computers to teaching and learning, she does not believe that CAI is a panacea; nor should it replace human instruction entirely.

However, the use of computers may be appropriate for certain types of students and in certain situations.

CHAPTER 2 – REVIEW OF LITERATURE

Chapter 2 begins with a listing of professional organizations and high-quality publications that focus exclusively or in part on developmental education. These publications and organizations' websites were the primary sources of much of the information provided in this chapter. Next, background information on developmental education is provided, including definition and scope; history; recent controversy; and student demographics, enrollment, and success. Remedial mathematics is then described in terms of definition and scope and student enrollment and success. Leading documents and legislation related to mathematics education and achievement are reviewed, and the role of technology in mathematics instruction is discussed.

Next, a description of CAI is provided, along with references to research on its effectiveness. The relationship between CAI and learning theory is discussed. The advantages and disadvantages of CAI for institutions are reviewed briefly, as are advantages of CAI for students. Potential drawbacks for students related to the use of CAI also are discussed. Studies focused specifically on the use of CAI in remedial mathematics courses are reviewed, including studies that compared the effectiveness of CAI versus traditional instruction and studies that focused on identifying specific factors of CAI that may be related to student success.

Information included in Chapter 2 was drawn from a variety of sources, including: empirical studies, meta-analyses, and review articles published in peer-reviewed journals; books and other documents published by leaders in the field of developmental education, professional organizations focused on education, and government agencies; and dissertations. A limited number of documents from Educational Resources Information Center (ERIC) are also referenced.

Leading Professional Organizations and Publications Focused on Developmental Education

Several national organizations and centers have gained recognition as leaders in the field of postsecondary developmental education. The National Center for Developmental Education (NCDE) and the National Association for Developmental Education (NADE) focus specifically on the field, while other organizations are broader in nature but have collected data and conducted research related to developmental education. Examples include USDE's National Center for Education Statistics (NCES), the National Center for Postsecondary Improvement, the American Association of Higher Education, the American Association of Community Colleges, the American Council on Education, the American Educational Research Association, the State Higher Education Executive Officers, and the Education Commission of the States.

There also are numerous reputable, peer-reviewed journals that publish empirical studies, meta-analyses, opinion articles, and suggestions for policy and practice related to developmental education. Several publications are listed in Table 1.1.

Background on Developmental Education

Definition and Scope of Developmental Education

Developmental education has evolved into a field of its own as postsecondary students and institutions have become more numerous and diverse. However, there is no unanimous agreement as to the scope of the field or the terms that should be used to

Table 2.1

Publications Covering Postsecondary Developmental Education

Title	Publisher
Research in Developmental Education	The National Center for Developmental Education
Journal of Developmental Education (formerly Journal of Developmental and Remedial Education)	The National Center for Developmental Education
Research and Teaching in Developmental Education	New York College Learning Skills Association
Community College Journal	American Association of Community Colleges
Community College Review	North Carolina State University
Community College Journal of Research and Practice	Taylor & Francis Group
Journal of Applied Research in the Community College	American Association of Community Colleges, National Council for Research and Planning
New Directions for Community Colleges	Wiley Periodicals, Inc., Jossey-Bass
Chronicle of Higher Education	The Chronicle of Higher Education
Journal of Higher Education	Ohio State University Press
Change	American Association of Higher Education
Review of Higher Education	Association for the Study of Higher Education
Research in Higher Education	Kluwer Academic Publishers
Review of Educational Research	American Educational Research Association

describe it. *Developmental* and *remedial,* the two terms most commonly used in the literature, are used interchangeably. A review of the literature suggests leaders in the field tend to describe coursework as remedial, while developmental education is a part of higher education that includes remedial coursework as well as other activities.

NADE (2001*)* defines developmental education as "a field of practice and research within higher education with a theoretical foundation in developmental psychology and learning theory. It promotes the cognitive and affective growth of all postsecondary learners, at all levels of the learning continuum" (Definition of Developmental Education section, paragraph 1). The key goals of developmental education, according to NADE, are:

- To preserve and make possible educational opportunity for each postsecondary learner.
- To develop in each learner the skills and attitudes necessary for the attainment of academic, career, and life goals.
- To ensure proper placement by assessing each learner's level of preparedness for college coursework.
- To maintain academic standards by enabling learners to acquire competencies needed for success in mainstream college courses.
- To enhance the retention of students.
- To promote the continued development and application of cognitive and affective learning theory. (Goals of Developmental Education section, paragraph 1).

Martha Cassaza (1999), former president of NADE, identified four assumptions underlying developmental education, including that it (1) is a comprehensive process; (2) focuses not only on the learner's intellectual growth, but also social and emotional development; (3) assumes that all learners have talents; and (4) is not limited to learners at any specific level. She argued, "We are all developmental learners depending on the context in which we find ourselves" (p.7).

While Cassaza and NADE contend that developmental education applies to all post-secondary learners, regardless of level, NCDE (n.d.) takes a narrower view:

> The field of developmental education supports the academic and personal growth of underprepared college students through teaching, counseling, advising, and tutoring. The clients of developmental education programs are traditional and nontraditional students who have been assessed as needing to develop their skills in order to be successful in college. (Background section, paragraph 1)

USDE (2003) defines remedial courses as "courses in reading, writing, or mathematics for college-level students lacking those skills necessary to perform college-level work at the level required by the institution" (p. iii). Courses in study skills, critical thinking, English as a second language, and adult basic education (preparation for taking the GED) also are sometimes considered remedial or developmental. Other activities that comprise developmental education include assessment, placement, orientation, tutoring, supplemental instruction, computer-aided instruction, mentoring, peer support, early alert systems, and personal, academic, and career counseling or advising (Boylan, Bonham, & Bliss, 1994; Cassaza, 1999; Ignash, 1987; Kozeracki 2000; Massachusetts Community College Developmental Education Committee, 1998; NADE, 2001; Weissman, Bulakowski, & Jumisko, 1997).

Students who participate in remedial coursework and other developmental education activities are referred to as *underprepared, remedial, developmental, low-achieving, high-risk,* or *disadvantaged* (Boylan, Bonham, & White, 1999; Farmer & Barham, 2001; Institute for Higher Education Policy [IHEP], 1998; Kozeracki, 2002; Roueche & Roueche, 1993, 1999). The terms listed above will be used interchangeably throughout this study.

History of Developmental Education

The emergence of developmental education and underprepared students in the United States' system of higher education is often associated with the movement during the 1960s toward egalitarianism and open admission policies for public colleges and universities (Boylan & White, 1987; Brier, 1984, 1985). In fact, however, developmental education has existed for centuries. As Brier (1984) argues, "The issues involving underprepared college students and higher education's responsibility to provide appropriate educational opportunities for these students have been an integral part of the development of higher education in the United States" since the very beginning (Brier, 1984, p.2).

During the 17th century, most scholarly books were written in Latin and courses were taught primarily in Latin as well. As a result, Harvard College, the nation's first institution of higher education, provided tutors so that incoming students could learn Latin. Considered to be the earliest providers of developmental education in the US, Latin tutors were prevalent into the 18th century until after the American Revolution, when textbooks and instruction in English became more widespread (Boylan & White, 1987).

During the first half of the 19th century, higher education became available to an increasing number of people throughout the country. Nearly every state established new institutions during that time, known as the era of Jacksonian democracy. After the Civil War, the Morrill Act resulted in another rapid expansion in the number and type of institutions of higher education. State land grant colleges, technical colleges, and colleges for women and African Americans began to appear. With the new variety of colleges and universities came substantial numbers of underprepared students. The most common deficiencies - spelling, writing, mathematics, and study skills - were the same areas in which today's students are deficient. Reports also indicate that students were deficient in geography and unprepared for the level of socialization expected in higher education (Boylan & White, 1987; Brier, 1985).

Several reasons have been cited for the admission of large numbers of underprepared students throughout the 19th century. The number of postsecondary institutions had increased more rapidly than had the number of secondary schools, resulting in too many openings in higher education and too few adequately prepared secondary students. Because institutions were largely self-funded, they relied on enrollment to generate enough revenue to operate. Therefore, admitting underprepared students became a financial necessity. A pervasive belief in egalitarianism and educational opportunity also fueled the push to admit underprepared students. Finally, college curricula and admission requirements changed rapidly, and often were different from one institution to the next, making it difficult for secondary students to prepare for college more generally (Boylan & White, 1987; Brier, 1985).

Open admission institutions existed during the 19th century throughout every region of the country, and in many cases, students were admitted to college conditionally, much like students today. In 1879, 50% of applicants to Harvard did not pass a written exam and were admitted on a conditional basis. As a result, the university provided extra support to prepare students for college-level classes. Individual tutoring was a common remedy for underprepared students, and some colleges had more faculty and students involved in tutoring than were involved in college-level courses. The University of

Wisconsin established the first college preparatory department in the country in 1849, and a report to the National Council of Education in 1889 indicated that only 65 of 400 institutions did not have preparatory departments (Boylan & White, 1987; Brier, 1985; Cassaza, 1999).

Preparatory departments, or academies, resembled secondary schools located within colleges. They were operated by the college and shared college facilities and faculty. Students in preparatory departments were even considered college students, although they were required to complete six rather than four years of study to earn an undergraduate degree. Many institutions that did not have an entire department devoted to preparatory studies still offered pre-college courses, tutoring, and/or extra class sessions for academically deficient students. In some cases separate tutoring schools were formed, offering tutoring in college and pre-college subjects. Intensive courses also were offered, designed to prepare students to take college entrance exams (Brier, 1985).

Institutional pleas for adequately prepared students were not uncommon throughout the 19th century, and even selective institutions such as Cornell University and Vassar College admitted underprepared students, despite projecting an image of high academic quality and admission standards. Discussion about policies and procedures regarding the admission of academically deficient students took place both within institutions and publicly, and faculty, alumni, and students expressed embarrassment at having underprepared students at their institutions. While some believed it was important that institutions serve underprepared students, others did not feel colleges should offer academic work at a subcollegiate level. An informal hierarchy existed between faculty and students involved in preparatory work versus those who taught or were enrolled in college courses (Boylan & White, 1987; Brier, 1985).

Controversy around the admission of underprepared students led to at least two positive developments throughout the country. Postsecondary institutions strengthened their formal relationships with secondary schools in an effort to improve secondary education standards and reduce or eliminate the need for preparatory services. Standardized admission requirements also resulted from improved communication between secondary schools and postsecondary institutions (Boylan & White, 1987; Brier, 1984, 1985).

Not long after the beginning of the 20th century, postsecondary institutions of all types were offering remedial courses, most of which focused on reading and study skills. In some cases, the courses carried college-level credit. The popularity of those courses led to the hiring and training of full-time staff dedicated entirely to teaching remedial courses. With financial help through the GI Bill of Rights, more than one million veterans enrolled in higher education shortly after the end of World War II. More women, students with special needs, and students from low-income backgrounds enrolled in higher education around the same time, partly due to the Civil Rights Act of 1964 and the Higher Education Act of 1965. To meet the increasingly diverse needs of students, support systems grew and became more comprehensive, including guidance centers, reading and study-skills programs, and tutoring services (Cassaza, 1999; Kulik, Kulik, & Schwalb, 1983).

The 1970s saw an increase in the number of students who were among the first generation in their families to pursue higher education, and throughout the 1990s, students became even more diverse, in terms of cultural and ethnic background, primary language spoken in the home, prevalence of learning and physical disabilities, age range, etc. Cassaza (1999) summarized the trend in higher education in the following way:

> Students came through the doors with a variety of learning profiles, levels of preparation, goals, and talents. No longer could they be molded to fit the needs of the institution; rather, institutions had to figure out how to meet the wide ranging needs of the students. (p. 4)

One way of meeting those wide ranging needs has been to expand the availability of developmental education services. In fall 2000, 76% of all higher education institutions in the US that enrolled freshmen offered remedial coursework, while 98% of public two-year colleges offered such courses (USDE, 2003).

Recent Controversy Surrounding Remediation

Developmental education has been tied to many hotly-debated social issues, such as affirmative action, diversity, access, and opportunity, and it has been discussed in connection to economics and workforce development (McCabe & Day, Jr., 1998; Roueche & Roueche, 1993, 1999). The following is a list of questions related to remedial courses that have received the most attention from legislators, educators, and taxpayers in recent years:

What is remedial education?

Who is participating in remedial education?

Why is the need for remediation so high?

Is remediation effective?

What is the financial cost of remediation?

Who should pay for remediation?

Who should provide remediation?

What are the benefits of remediation (to the individual, society, etc.)?

What are the consequences of not providing remediation?

(Boylan, Bonham, & White, 1999; IHEP, 1998; McCabe & Day, Jr., 1998; Roueche & Roueche, 1993, 1999)

Debate surrounding the questions of who should provide and who should pay for remedial courses has taken on renewed vigor in recent years, and a number of states have developed policies as a means of controlling the provision of remedial courses. In particular, states have begun to phase out remedial education at four-year institutions, placing more pressure on the nation's community colleges to provide remediation for more students. Educators and legislators have identified the community college as the most appropriate home for remedial education because of its mission, history, and open-door admission policy (Crowe, 1998; Education Commission of the States, 2002; Gumport & Bastedo, 2001; Ignash, 1997; Kozeracki, 2002; Lively, 1993; Mazzeo, 2002; McMillan, Parke, & Lanning, 1997; Mills, 1998; National Conference of State Legislatures, 2001; Schmidt, 1998; Shaw, 1997; USDE, 2003; Weissman, Silk, & Bulakowski, 1997; Zhang, 2000).

Student Demographics, Enrollment, and Success in Remedial Courses

According to USDE (2003), 28% of entering freshmen in fall 2000 participated in remedial coursework. That figure was 42% for freshmen at public two-year colleges. Students who participate in remedial education do not fit a single profile. Boylan (2001) provided the following colorful description of developmental students:

> They are the single parents who struggle to make day care arrangements allowing them to attend classes. They are the hourly laborers who hope that taking classes or getting a degree will serve as a stepping stone to better employment. They are the children of the poor and sometimes they are the parents of poor children.

> They are the displaced workers who use college courses to retrain for new jobs. They are the middle class young adults who seldom paid attention in their college preparatory high school courses. They are the traditional age students who failed to take the courses they should have in high school. They are the older adult students who took the right courses but put fifteen years between high school graduation and college. Who are the developmental students? They are a lot like the rest of us. (p. 21)

Developmental students vary in demographic characteristics, background experiences, educational goals, and career goals. Two-thirds are non-Hispanic white, slightly more than half are women, fewer than half are married, one fifth speak English as a second language, most intend to earn a degree, most attend school full time, over one-third work full time, and about half are financially independent. They range in age from below 18 to over 60 years. While most are classified as freshmen, 46% are sophomores, juniors, or seniors. For the most part, developmental students do not differ significantly from other postsecondary students. However, minority students and students from low-income backgrounds are disproportionately represented in developmental education (Farmer & Barham, 2001; Ignash, 1997; IHEP, 1998; Knopp, 1996; McCabe & Day, Jr., 1998; Roueche & Roueche, 1993, 1999; Saxon & Boylan, 1999).

Findings from the past 15 years are inconsistent regarding student success in remedial courses. Data collected by USDE (1991) from fall 1989 indicate that between 67 and 77% of students passed their remedial courses. However, USDE (1996) also found that more than 25% of community college students who were required to take remedial courses never completed that coursework. Drawing from USDE data, Adelman (1998) found that only between 18 and 24% of students who took three or more remedial courses eventually went on to earn bachelor degrees, compared to 45% and 54% of students who took one or no remedial courses, respectively. Boylan, Bliss, and Bonham (1993) reported that, in general, minority students participating in developmental education are retained at lower rates than non-Hispanic white students. However, this difference also appears in the non-developmental population.

Researchers estimate that, while the overall proportion may not increase, the total number of students participating in remedial coursework will increase in the future due to the increase in the nation's overall population and the increase in the number of individuals participating in postsecondary education (Ignash, 1997; IHEP, 1998; McCabe & Day, Jr., 1998).

Background on Remedial Mathematics

Definition and Scope of Remedial Mathematics

In fall 2000, 71% of postsecondary institutions offered remedial mathematics courses, while only 68% and 56% offered remedial courses in writing or reading, respectively. Ninety-seven percent of public community colleges offered remedial mathematics courses that year (USDE, 2003). Despite differences in particular course names, the general consensus regarding remedial mathematics is summed up in the American Mathematical Association of Two-Year College's ([AMATYC], 1993b) definition: "the portion of a college's mathematics curriculum designed for students not yet ready for college-level mathematics, traditionally defined as college algebra and beyond" (p. 34). That may include computation/arithmetic, beginning/introductory/elementary algebra, intermediate/basic algebra, trigonometry, geometry, pre-calculus, vocational math, and business math (Akst, 1986; Massachusetts Community College Developmental Education Committee, 1998; McDonald, 1988).

Student Enrollment and Success in Remedial Mathematics

In fall 2000, 60% of all students studying mathematics in community college mathematics departments, and 14% of all students studying mathematics in four-year college and university mathematics departments were enrolled in remedial courses (Lutzer, Maxwell, & Rodi, 1992). According to USDE (2003), 22% of all entering college freshmen in fall 2000 enrolled in remedial mathematics courses, and 35% of freshmen at public community colleges enrolled in remedial mathematics, up from 32% in 1995. Marilyn Mays (in an interview with Darken, 1995), former president of AMATYC, suggested 75% of American college students enroll in mathematics courses below calculus.

That may not be surprising, given that among high school graduates in 1998, only 41% had completed at least one course in advanced mathematics (beyond algebra II and geometry I). Even as recently as 2000, only 17% of 12^{th} graders scored at or above the *proficient* level and 35% scored below the *basic* level in mathematics on the National Assessment of Educational Progress (USDE, 2002). Until achievement levels increase among secondary students, post-secondary institutions will continue to admit and serve students with deficiencies in mathematics. And even then, adult students with "faded mathematical backgrounds" (AMATYC, 1993b, p. 34) will probably continue to enroll in remedial courses.

Comprehensive data on student success in developmental mathematics is limited. Most studies have focused on one or a few institutions with results suggesting anywhere from 26% to 84% of students passed their remedial mathematics courses (Bell, 1998; Best & Fung, 2001; Eldersveld, 1983; McDonald, 1988; Miles, 2000; Nagarkatte, 1988;

Shaw, 1997; Waycaster, 2001a; Weissman, Bulakowski, & Jumisko, 1997; Wepner, 1987). Researchers also found that between 35% and 89% of students who took remedial mathematics courses later passed their first college-level mathematics course (Bell, 1998; Best & Fung, 2001; Boylan & Bonham, 1992; Waycaster, 2001a; Wepner, 1987). Clearly, these results are too varied for researchers and practitioners to draw general conclusions about the effectiveness of remedial mathematics courses when measured by pass rates at the remedial and college levels.

Leading Documents and Legislation Related to Mathematics Education and Achievement

In 1983, the National Commission on Excellence in Education disseminated *A Nation at Risk: The Imperative for Educational Reform*, warning Americans that "the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people" (p. 1, paragraph 2). Although the report focused primarily on high schools, it also touched on elementary and higher education. In 1995, USDE drew attention more specifically to American students' low achievement in mathematics and science compared to students in other countries in a report entitled *Trends in International Mathematics and Science Study* (TIMSS).

As a result of such reports and pressure from private industry, local community members, international competitors, educators, parents, and students themselves, the U.S. government and numerous professional organizations have taken a leading role in recent decades in developing standards and goals for comprehensive education reform in America. In particular, concern about students' achievement in mathematics and science has been at the forefront of discussion. In 1991, Congress passed the *America 2000 Excellence in Education Act* designed to help America attain a set of National Education

Goals by the year 2000. Then in 1994, Bill Clinton signed into law the *Goals 2000: Educate America Act.* Both initiatives included strategies to ensure that by the year 2000, students in the U.S. would be the world leaders in mathematics and science achievement.

The U.S. Department of Labor appointed a commission in the early 1990s to determine the skills needed to be successful in the workplace. In 1991, the Secretary's Commission on Achieving Necessary Skills (SCANS) published *What Work Requires of Schools: A SCANS Report for America 2000* as a complement to the *America 2000 Excellence in Education Act*. The SCANS report included eight areas deemed essential for effectiveness in the workplace. Embedded in each of the three foundations (basic skills, thinking skills, and personal qualities) and in the five competencies (resources, interpersonal, information, systems, and technology) were numerous references to critical mathematics skills.

Since its founding in 1920, the National Council of Teachers of Mathematics (NCTM) has been committed to ensuring high quality mathematics education in the U. S. Throughout the past 15 years, NCTM has published numerous influential documents designed to guide mathematics education from pre-kindergarten through grade 12, including: *Curriculum and Evaluation Standards for School Mathematics* (1989), *Professional Standards for Teaching Mathematics* (1991), *Assessment Standards for School Mathematics* (1995), and *Principles and Standards for School Mathematics* (2000).

The Mathematical Sciences Education Board (MSEB), located within the National Research Council (NRC), which was organized in 1916, also published critical documents in 1989 and 1991. *Everybody Counts* (1989) called for mathematics reform from kindergarten through graduate school, while *Moving Beyond Myths: Revitalizing Undergraduate Mathematics* (1991) focused specifically on undergraduate mathematics education.

The American Mathematical Association for Two-Year Colleges (AMATYC), formed in 1974, is an organization focused on the improvement of mathematics instruction in the first two years of college. AMATYC has compiled and disseminated a number of important documents, including *Guidelines for the Academic Preparation of Mathematics Faculty at Two-Year Colleges* (1992), *Guidelines for Mathematics Departments at Two-Year Colleges* (1993a), and *Crossroads in Mathematics: Standards for Introductory College Mathematics Before Calculus* (Crossroads, 1995).

Technology in Mathematics Instruction

In each of its publications mentioned above, AMATYC addressed the need for technology to be a central component in all mathematics reform, and argued that faculty and students should have access to computers, campus-wide learning networks, and appropriate software. In *Crossroads,* AMATYC (1995) claimed, "Technology is changing and will continue to change the way mathematics is done around the world" (Chapter 4, Technology Section, paragraph 1).

In that same document, the first standard for pedagogy is titled *Teaching with Technology* and emphasizes that instructors must become role models with respect to technology: "Mathematics faculty will model the use of appropriate technology in the teaching of mathematics so that students can benefit from the opportunities it presents as a medium of instruction" (AMATYC, 1995, Chapter 2, Standards for Pedagogy Section, paragraph 1). AMATYC argued that computer software can help students learn concepts and solve mathematical problems, and that using technology in the mathematics classroom should help students prepare for future encounters with both mathematics and high-quality technology.

AMATYC believes the use of computers should allow students to learn at a more individualized pace and should eliminate some of the fear of being judged by peers and instructors that is felt in more traditional mathematics classrooms. The authors of *Crossroads* also believe that utilizing technology in the mathematics classroom does not have to be exceptionally time-consuming, but instead could free up time for true learning (AMATYC, 1995).

Recently, AMATYC (n.d.) began the *Crossroads Revisited Project*, intended to gain feedback about the impact of the *Crossroads* document. The association plans to update and build upon the original document according to recommendations solicited through a survey and questionnaire. Faculty respondents have indicated that greater use of technology was among the most common changes that occurred as a result of the original document. However, respondents also indicated that technology was not addressed adequately enough in the first document, leading AMATYC to include technology as one of the top six issues to be addressed in the revision.

Other government and professional organizations also have published documents and made recommendations regarding the role technology should play in mathematics reform. In *Moving Beyond Myths: Revitalizing Undergraduate Mathematics* (NRC, 1991), MSEB claimed that instructional methods were a major problem in undergraduate mathematics and that the traditional teaching model of lecture, template exercises, and isolated study was flawed. Instead, MSEB encouraged professors of mathematics to introduce computers into the classroom and replace lectures with more effective instructional methods. Also, IHEP (1998) released a report entitled *College Remediation: What it is: What it costs: What's at Stake* that reviewed the status of remediation in higher education and included recommendations for improvement. Using technology to enhance the teaching-learning process was among three major strategies IHEP suggested to improve the effectiveness of remediation.

Computer-Assisted Instruction (CAI)

Description and Effectiveness of CAI

Computer-assisted instruction (CAI) is considered a non-traditional instructional method and has been compared to the inventions of writing and printing in terms of its revolutionary impact on education (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. The computer also can re-present information, often adapting to a student's preferred learning style. CAI may be used to help students learn and retain facts, develop skills (procedural knowledge), or develop conceptual understanding (Kinney, 2001b).

CAI may be implemented as synchronous instruction, where many students learn the same material at the same time and in the same location. In a full implementation environment, the computer is the primary medium of instruction. CAI also may be offered in a hybrid environment, where students receive some direct instruction from a faculty member and some instruction from the computer (Kinney, 2001b).

CAI also may be delivered as asynchronous instruction, which is the focus of the current study. With asynchronous CAI, individual students learn different material at different times and in different locations. Asynchronous CAI may be used in distance learning courses, where students are never required to come to campus and instead complete the course using computers available to them at home, work, or in other locations. Asynchronous CAI also is often available in open labs staffed by instructors, lab assistants, and/or tutors. Students may be required to come to campus one or more times to work in the lab or may be given the option to use computers in the lab or off campus. Attendance policies vary for courses delivered using asynchronous CAI. Interested readers should consult Kinney (2001b) for a discussion of various CAI delivery models, including advantages and disadvantages of each, and Kulik and Kulik (1991) and MacDonald and Caverly (1999) for a review of the evolution of CAI software for developmental education.

The terms *computer-aided instruction, computer-based instruction, computer-directed instruction, computer-enriched instruction, computer-enhanced instruction, computer-managed instruction, computer-mediated instruction, reform computer-assisted instruction, artificial intelligence based instruction, computer-based education,* and *computer-assisted learning* also have been used in the literature in addition to *computer-assisted instruction*. Although these terms may have different meanings for experts, they appear to be used somewhat interchangeably (Glickman & Dixon, 2002; Kulik & Kulik, 1986, 1987; Kulik, Kulik, & Schwalb, 1986; Sadatmand, 1994).

Several meta-analyses on the effectiveness of CAI have been conducted over the past 20 years. In general, results of meta-analyses conducted by Kulik and Kulik (1986, 1987, 1991) and Kulik, Kulik, and Schwalb (1986) have suggested CAI has small but significant positive effects for adults, including improved examination scores, reduction in the amount of time needed for instruction, and improved attitudes towards instruction and computers. Effects were less clear, however, for mathematics and hard sciences than for other subjects, and were smaller for studies of long duration and studies in which the same instructor taught the experimental and control classes. Random versus quasi-experimental studies and differences in time on task did not appear to produce markedly different results. A meta-analysis conducted by Christmann and Badgett (2000) also indicated college students who were exposed to traditional instruction supplemented with CAI attained higher academic achievement than did students receiving only traditional instruction. Again, however, the overall mean effect size was small.

Relationship Between CAI and Learning Theory

CAI often is described in terms of its theoretical foundations. It is commonly associated with behaviorism, constructivism, and mastery learning, each of which is described briefly below.

Behaviorism. CAI has been linked to B. F. Skinner's theory of behaviorism, in which an individual's behavior is shaped by environmental antecedents and consequences. Skinner believed humans are more likely to repeat those behaviors for which they receive positive reinforcement from their environment and reduce or eliminate those behaviors for which they receive negative reinforcement. He believed reinforcement that quickly followed performance was most powerful and that positive reinforcement was more effective than punishment. Drill and practice components of CAI are based on the principles of behaviorism. The computer provides immediate feedback to students during drill and practice activities, thereby reinforcing correct responses and discouraging incorrect responses (Bergquist, Gould, & Greenberg, 1981; Cassaza & Silverman, 1996; Hamtini, 2000; Kulik & Kulik, 1986, 1991; McMillan, Parke, & Lanning, 1997; Silverman & Cassaza, 2000).

Constructivism. In recent years, CAI also has been linked to constructivism. Constructivism is not a single theory but a term used to describe approaches to learning that assume knowledge is *constructed* rather than simply acquired. Piaget, Bruner, and Vygotsky are among the most well-known individuals whose theories include principles of constructivism, and Ernst von Glasersfeld has influenced constructivist principles in mathematics and science education in particular. Interactive CAI programs have been tied to constructivism in that students are at the center of learning process. Rather than being passive recipients of instruction, they are actively involved in constructing knowledge and monitoring their own progress (Driscoll, 2000; Hamtini, 2000; Hashway, 1990; Silverman & Casazza, 2000).

Mastery learning. Many CAI programs reflect the concept of mastery learning, which is predicated upon the notion that almost all students are capable of mastering what they are taught. With a mastery learning approach, students continue in a given module until all objectives have been mastered. Mastery learning typically consists of short units of instruction, formative evaluation, alternative learning procedures (e.g., audio-visual materials, programmed instruction), and summative evaluation. Bloom's *Learning for Mastery* and Keller's *Personalized System of Instruction* are two major mastery learning theories that emphasize early and frequent feedback on performance (Bergquist, Gould, & Greenberg, 1981; Block, 1971; Brothen, 1996; Kulik & Kulik, 1991).

Kulik (reported in an interview with Bonham, 1990) conducted a careful review of research findings and concluded that individualized mastery-oriented instructional methods are effective for developmental students. Of 100 separate studies, Kulik found that over 90% reported gains in student learning when students switched from a traditional classroom environment to an individualized, mastery learning approach. Student exam scores typically increased from the 50^{th} to the 70^{th} percentile, with even greater increases for weaker students.

Advantages of CAI for Institutions

CAI may have a number of advantages for institutions over delivering instruction through lecture. For example, Kulik and Kulik published the results of meta-analyses that found CAI can reduce instructional time by as much as one-third (1986, 1991). Web-based computerized systems are easier to update than traditional teaching tools such as textbooks (Katsutani, 2001), which can save institutions the time and cost involved with frequently replacing teaching manuals and textbooks. CAI programs may be combined with other instructional media and may reduce demands on instructors, such as recordkeeping, test administration, and selecting or producing materials. And, institutions that use asynchronous CAI may expand their service area and increase enrollment because they are able to reach geographically remote populations, offer classes that would otherwise be canceled due to low enrollment, and meet the scheduling needs and preferences of diverse students (Clark & Clark, 1984; Kinney, 2001b; McMillan, Parke, & Lanning, 1997; Miles, 2000).

Disadvantages of CAI for Institutions

CAI may have disadvantages for institutions as well. For instance, asynchronous CAI courses that are structured as open-entry/open-exit may be incompatible with an institution's procedures related to registration and scheduling. In this case, the institution has to figure out what to do, for example, when a student is not finished with a course by end of the term. Asynchronous CAI also may make it difficult to promote regular attendance among students. Technological difficulties can slow student progress and increase frustration on the part of students and faculty, so institutions using CAI must commit to providing sufficient technical support for troubleshooting. Another potential problem has to do with grade inflation. Because students must show evidence of having mastered course material in order to complete a CAI course that is built around the concept of mastery learning, all course completers are likely to receive As. One way to avoid this situation is to assign final grades based on a combination of factors, such as attendance, unit quizzes or tests, homework, and the final exam (Bailey & Chambers, 1996; Kinney, 2001b; Kulik & Kulik, 1991; Miles, 2000; Olsen, 1999.

The literature includes conflicting information regarding the cost of CAI. McMillan, Parke, and Lanning (1997) cited others who have claimed that keeping up with the latest technology can be cost-prohibitive for institutions. However, they also cited scholars who found technology to be a cost-effective alternative to traditional instruction. Bailey and Chambers (1996), Clark and Clark (1984), Miles (2000), and Olsen (1999) also report that CAI can reduce costs.

Advantages of CAI for Students

What is it about CAI that may contribute to student success in the mathematics classroom? The fact that it provides an alternative to traditional instruction is one possibility. As Seese (1994) argued, CAI offers "an option to the traditional classroom situation which, in many cases, has not worked for students in the past" (p.7). Numerous authors have identified factors related to the effectiveness of CAI for adult education, including that it can provide students with flexibility and convenience; individualized learning; self paced instruction; clarity and structure; impartiality; immediate and frequent feedback; active learning and involvement; variety and appeal; increased privacy and less threat or stigma; and individual assistance from the instructor. Each of these factors will be described below in more detail, followed by references to review articles from peer reviewed journals, studies published in peer reviewed journals, and/or dissertations related to the topic.

Flexibility and convenience. Asynchronous CAI offers students flexibility and convenience that may be unavailable in a traditional class that meets on specific days and at specific times. With many asynchronous CAI programs, students need only have access to a computer, and are able to work from any of a number of locations, including home, the workplace, the institution's mathematics lab or computer lab, or other facilities that make computers available to the public. Students may choose the time of day they work on course material. Those who work a full-time job may study during the lunch hour. Students with children may work at night after their children are in bed. Those who are most alert in the middle of the night may choose to study mathematics at that time. Students may even change their study schedule and/or location from one week to the next (Brothen, 1998; Fleming, 2003; Hardiman & Williams, 1990; Katsutani, 2001; King & Crouse, 1997; MacDonald & Caverly, 1999; McMillan, Parke, & Lanning, 1997; Miles, 2000; Perez & Foshay, 2002; Summerlin, 2003).

Individualized learning. Asynchronous CAI allows students to participate in a learning environment that is individualized and responsive to their particular needs. With asynchronous CAI, a student may progress quickly through a module with content that is either already familiar to the student or can be easily mastered. S/he also may spend extra time reviewing concepts and practicing skills that are more difficult, and the computer has his/her undivided attention in a manner that is not possible in a traditional classroom with one instructor and many students. Also, some of the more sophisticated asynchronous CAI programs are able to adapt to students' particular learning styles (Bonham, 1990; Fleming, 2003; Hardiman & Williams, 1990; King & Crouse, 1997; Kitz & Thorpe, 1995; Miles, 2000; Nagarkatte, 1989; Nicol & Anderson, 2000; Perez & Foshay, 2002).

Self paced instruction. Because asynchronous CAI provides individualized instruction, it also is typically self-paced. In a traditional class, all students are required to progress at nearly the same rate, completing the same homework assignments and taking quizzes and tests according to a set schedule. In addition to being able to move quickly through modules that are easy and slower through content that a student finds difficult, students who participate in asynchronous CAI may choose for themselves how quickly they intend to complete an entire course. A student who is only taking one course may move very quickly through the material and might even finish well before the end of the institution's term. On the other hand, students who struggle with mathematics and/or school in general may plan to take more than one term to progress through a single course. Other students who are registered for several courses during the same term may put extra energy into the asynchronous CAI course at times when their other courses have fewer deadlines. They then may need to devote less attention to the asynchronous CAI course during mid-term week or when they have several assignments due for other courses (AMATYC, 1995; Fleming, 2003; Hardiman & Williams, 1990; King & Crouse, 1997; Kinney, 2001a; Kitz & Thorpe, 1995; MacDonald & Caverly, 1999; McMillan, Parke, & Lanning, 1997; Nagarkatte, 1989; Nicol & Anderson, 2000; Perez & Foshay, 2002; Villareal, 2003).

Clarity and structure. Compared to traditional instruction, CAI may appear to students to be clearer and more explicit, sequenced, and structured. Tutorials, drill-and-practice sessions, and assessments are pre-programmed and although they have been developed by humans, they are less subject to human variables that sometimes make teaching and learning difficult. From one day to the next, instructors may be more or less enthusiastic, prepared, knowledgeable, and/or patient. That variability, inherent in human instruction, is minimized with CAI, where the order of assignments and progression through topics that build on one another is not susceptible to personality, whim, or external circumstances. Students simply move from one module to the next and even from one activity to the next within a given module (Kitz & Thorpe, 1995; Kulik & Kulik, 1987; Plomp, Pilon, & Reinen, 1991).

Impartiality. Another potential advantage of CAI is that it may be viewed by students and educators as more objective or impartial than human instructors. The computer is programmed to grade and give feedback on a given problem in the same manner for any student who attempts that particular problem. Even the most well-meaning instructor may inadvertently grade problems differently for different students, or may provide different students with different explanations and feedback on the same topic. Often unbeknownst to the instructor, his/her response to a given student is colored by past experiences with that student. The computer, on the other hand, is able to "forget students' past failures" and be "infinitely patient" (Bergquist, Gould, & Greenberg, 1981; Brothen, 1998; Kitz & Thorpe, 1995; Kulik & Kulik, 1987).

Immediate and frequent feedback. Students typically receive immediate and frequent feedback with CAI, something that is often lacking in traditional instruction. Instructors often have several classes of 30 or more students and are simply unable to keep up with grading homework and assessments in a timely and thorough manner. By the time a student receives a graded test, s/he may be halfway through the next chapter and often there is little time to meet with the instructor to address deficiencies. With CAI, feedback is immediate and the computer provides explanations that are specific to a given student's weaknesses (Best & Fung, 2001; Brothen, 1998; Cornell, 1996; Glickman & Dixon, 2002; Hardiman & Williams, 1990; Katsutani, 2001; King & Crouse, 1997; Kinney, 2001a; Kitz & Thorpe, 1995; Kulik & Kulik, 1987; Nagarkatte, 1989; Nicol & Anderson, 2000; Perez & Foshay, 2002).

Active learning and involvement. In most cases, CAI requires students to be involved and active in the learning process. A student who sits in the back of a traditional classroom may be mentally absent for minutes at a time or for the entire class period. S/he may even be doing homework for other classes. With CAI, neither the instructor nor classmates may carry the student through the material. Without active responses and input from the student, the software program will simply not function (Bailey & Chambers, 1996; Fleming, 2003; Glickman & Dixon, 2002; Hardiman & Williams, 1990; King & Crouse, 1997; Kinney, 2001a; Kulik & Kulik, 1987; MacDonald & Caverly, 1999; Robinson, 1995; Villareal, 2003).

Variety and appeal. In recent years, software developers have been able to produce CAI programs with a tremendous amount of variety and appeal. These programs capture students' interest and encourage their involvement. In addition to text, programs typically include multimedia effects such as graphics, pictures, animation, video, sound, and motion. Particularly for younger students who have grown up in an information- and entertainment-rich era, the variety inherent in many CAI programs is able to hold their attention in a way that textbooks and instructors often cannot (Bailey & Chambers, 1996; Bergquist, Gould, & Greenberg, 1981; Best & Fung, 2001; Fleming, 2003; Hardiman & Williams, 1990; King & Crouse, 1997; Kitz & Thorpe, 1995; Kulik & Kulik, 1987; MacDonald & Caverly, 1999; Nagarkatte, 1989; Nicol & Anderson, 2000; Perez & Foshay, 2002; Robinson, 1995).

Increased privacy and less threat or stigma. In addition to being appealing and engaging, CAI courses offer students more privacy and subsequently a less-threatening environment than the traditional classroom. Sitting at individual computers in a lab, or working from home, students may not feel singled out to the degree they would if they were asked by the instructor to answer a question or work a mathematics problem in front of an entire class of peers. Students may feel more comfortable asking for help and reviewing difficult material if they know their classmates will not all be listening and watching. Also, because computers are constantly evolving and widely used during many individuals' free time, CAI somehow has less stigma attached than do developmental textbooks (AMATYC, 1995; Bergquist, Gould, & Greenberg, 1981; Hardiman & Williams, 1990; Kitz & Thorpe, 1995; Perez & Foshay, 2002).

Individual assistance from the instructor. With CAI, the instructor's role changes from one of information deliverer to learning manager, collaborator, or facilitator. According to Cornell (1996), technology can be used to allow instructors to "provide students with more, not less, attention" (p.4). Because the instructor does not have to be the primary information source in a CAI course and does not have to spend a great deal of time grading students' work, s/he is free to work with students individually. Students who understand the computer's explanation and are progressing through the material at an acceptable rate may not need assistance from the instructor for one or more days at a time. On the other hand, a student who is having a particularly difficult time grasping a concept may seek out the instructor for a different explanation or the opportunity to simply discuss the material with another human (Glickman & Dixon, 2002; King & Crouse, 1997; Kinney, 2001a; Miles, 2000; Nicol & Anderson, 2000; Villarreal, 2003).

Summary. Together, many of the factors described above that differentiate CAI from more traditional instruction may lead students to have better attitudes toward learning, more positive academic self concepts, a greater sense of control over the learning process, and increased motivation. Those affective factors, in turn, may positively impact students' academic achievement and success (Bailey & Chambers, 1996; Fleming, 2003; Glickman & Dixon, 2002; Hardiman & Williams, 1990; King & Crouse, 1997; MacDonald & Caverly, 1999; Nicol & Anderson, 2000; Reglin, 1989; Robinson, 1995).

Potential Drawbacks of CAI for Students

Using technology in mathematics instruction also may have disadvantages for students. AMATYC (1995) cautioned against the potential overuse of technology: "Technology should be used to enhance the study of mathematics but should not become the main focus of instruction" (Chapter 2, Standard I-6: Using Technology Section, paragraph 3).

Students who have limited access to a computer and/or the internet may find that courses taught using asynchronous CAI are not convenient. Open labs may be overcrowded at some times during the week and underutilized at others, making it difficult to ensure students receive sufficient one-on-one assistance (Kinney, 2001b). Also, technological problems can be disruptive and frustrating for students and instructors (Bailey & Chambers, 1996; Olsen, 1999).

Another potential drawback of CAI has to do with the novelty effect: while the computer as a medium of instruction may initially be more interesting and engaging to learners, its impact and positive effects may wear off rather quickly (Kulik & Kulik, 1991; Plomp, Pilon, & Reinen, 1991; Tilidetzke, 1992). According to Summerlin (2003), it is important to factor in how long it takes students to learn to use a computer and a particular software program. Yadrick and Regian (1996) claimed that students may experience increased cognitive load if they have to learn a new instructional system in addition to learning new content. Fewer mental resources are available to concentrate on learning the material when energy must be expended simultaneously to learn how to use the software and/or hardware. Students may advance through the basic skills presented at the beginning of a course – at the same time they are learning to use the software and/or hardware – without ever really learning those foundational skills, which will be critical for advanced learning. Foundational skills are particularly important for mathematics.

Students who lack motivation or discipline or have poor time management skills may not function well in an environment where setting the pace and sticking to a schedule is left largely to the student's own discretion (Brothen, 1996; Kinney, 2001a, 2001b; Kulik & Kulik, 1991; Villarreal, 2003). Although students may have access to instructors, lab assistants, and/or tutors, they may encounter a different person each time they use the open lab and may never feel like they have a single person to contact for help. Finally, asynchronous CAI may limit opportunities for students to work in groups and communicate with peers (Kinney, 2001b).

Research on CAI in Remedial Mathematics Courses

A number of studies have been conducted to measure the effectiveness of using CAI in remedial mathematics courses at the postsecondary level. Measures of effectiveness have included students' final examination scores, follow-up examination scores, course completion rates, course withdrawal rates, course pass rates, course attendance rates, pass rates in subsequent mathematics courses, retention in college, graduation, and time needed for instruction. In some cases, CAI has been compared to other instructional delivery methods/media. Some studies have addressed affective issues such as students' attitudes towards mathematics, confidence in learning mathematics, mathematics anxiety, motivation in mathematics, and attitudes about the usefulness of mathematics. Other studies have attempted to identify specific elements of CAI that are related to student success.

This section will review research that focused on the effectiveness of CAI versus traditional instruction in remedial mathematics courses. Research that attempted to identify specific factors related to student success using CAI in remedial mathematics courses also will be reviewed. Studies included in this section were primarily identified through searches of Education Resource Information Center (ERIC) and Dissertation Abstracts International (DAI) databases. Additional studies were located through a review of the reference lists from articles and dissertations collected in the literature search process. Studies that were published prior to 1990 will not be included. Within each subsection, studies will be ordered from oldest to most recent.

Studies Focused on Effectiveness of Using CAI in Remedial Mathematics Courses

Posttest-only with nonequivalent groups design. Six studies were identified that used a posttest-only with nonequivalent groups design. Garrett (1995) reported on a study conducted at Florence-Darlington Technical College in South Caroline during fall 1992. The study compared student performance in Developmental Studies Math taught using CAI versus traditional instruction. Two sections of the course were offered and it was not until after students had registered that it was decided which section would be taught using CAI. The same instructor taught both sections and covered the same content. No significant differences were found in the proportion of students who completed the course, passed the course, or earned a C grade or better. The group that received traditional instruction had significantly higher final grades, however.

Sadatmand (1994) conducted a quasi-experimental study to assess the effects of CAI on students' learning abilities in elementary and intermediate algebra during one semester at Grossmont College. The control group consisted of students enrolled in traditional lecture-based sections that met five hours a week, while students in the experimental group received four hours each week of lecture and used the computer laboratory two hours a week for drill and practice, tutorial, and immediate feedback. Mathematics instructors at the college developed the software used by the experimental group. Results indicated students in the CAI group scored higher than the respective control group on the final exam for elementary algebra and intermediate algebra, although the difference for intermediate algebra was not significant. Within groups, there were no significant differences in final exam scores between males and females, although males scored higher in all but one group.

Ford and Klicka (1998) conducted a quasi-experimental study at Bucks County Community College to compare outcomes for students enrolled in fundamentals of mathematics and basic algebra over a two-year period. Course delivery methods included self-paced CAI, CAI with lecture, and traditional instruction. Outcomes measures included course pass rates (C or better), course completions rates, final examination pass rates (C or better), earning an A or B on the final examination, pass rates in subsequent mathematics course, and college retention rates to the next semester. Both types of CAI sections utilized the textbook that accompanied the computer software, while the traditional sections used a different textbook.

For the fundamentals of mathematics course, students in the traditional sections had significantly higher course completion rates than students taught via the two CAI methods. For the basic algebra course, students taught in the traditional sections had significantly higher course pass rates and course completion rates than students in the self-paced CAI sections. However, students in both types of CAI sections had significantly higher final examination pass rates than did students in the traditional sections. The results of this study may have been confounded by the fact that some students in the self-paced CAI sections took more than one semester to complete the course and earned a grade of F for the first semester. Had these students only been counted during the second semester in which they enrolled in the course, overall outcomes for the self-paced CAI courses may have been higher. Also, students who did not do well early in the semester in the traditional sections were allowed to switch into the self-paced CAI sections (Ford & Klicka, 1998).

At the University of Minnesota, Kinney (2001a) conducted a quasi-experimental study to compare student outcomes in elementary algebra and intermediate algebra courses taught using either CAI or a traditional lecture format. Software developed by Academic Systems was used in the CAI sections. There were no significant differences in final exam scores for either course between students in traditional sections and CAI sections. Nor were there any significant differences in course pass rates (D or higher) or attendance rates. However, students in traditional sections were significantly more likely to withdraw from class.

Waycaster (2001b) collected data from five colleges in the Virginia Community College System (VCCS) to determine what teaching methodologies and practices were most effective for students in remedial mathematics courses. Courses included in the study were basic arithmetic, basic algebra I, and basic algebra II. Method of instruction (traditional lecture/lab or individualized CAI) was one independent variable, and success rates in remedial mathematics courses and in subsequent college-level mathematics courses were among the dependent variables, along with retention after three years and graduation. Ten instructors and fifteen course sections were included in the study, and data were collected from a period of seven years (1993 to 2000). No significant differences were found between instructional methods in terms of course pass rates, pass rates in subsequent college level math courses, retention rates over a three-year period, or graduation rates. Interestingly, however, the passing criterion for developmental mathematics course sections delivered in the CAI format varied from 75% to 80%, which was higher than the passing criterion of 70% for course sections taught in the traditional format. The researcher did not adjust for that difference when calculating success rates and results were not tested for statistical significance. Waycaster concluded that success rates seemed to be independent of the specific method of course delivery.

Summerlin (2003) conducted a quasi-experimental study to compare the effectiveness of CAI versus traditional instruction for community college students enrolled in intermediate algebra at Northwest Vista College. Effectiveness was measured by course success rates, achievement test scores, and grades in a subsequent college-level mathematics course. In addition to course format, other independent variables included age, gender, ethnicity, and reading ability. Students in the experimental group completed an off-line home study course and used the Internet to communicate with the instructor and with classmates and to turn in assignments. They also participated in two face-to-face meetings on campus, one on the first day of the course, and the other to complete the final exam. The experimental group used Academic Systems Corporation software and WebCT by Microsoft. Course content for both groups was the same, although the final exam was not standardized across groups. Results indicated students in the control group were significantly more likely to earn a passing grade in the developmental course and in the subsequent college-level mathematics course (College Algebra). Achievement test scores were not significantly different for the two groups, however, and multiple regression analysis revealed that none of the other independent variables was a significant confounding or contributing factor.

Pretest-posttest nonequivalent comparison group design. Five studies were located that used a pretest-posttest nonequivalent comparison group design. Williams (1996) conducted a study in which CAI was used as a supplement in a remedial mathematics course at a community college. This study was conducted over one semester and the researcher analyzed the relationship between method of instruction (traditional or traditional with CAI as supplement) and students' self concept, course completion rates, and final course grades. Students also were grouped by age (younger than 21, 21 and older). CAI consisted of a DOS-based computer program and course sections were labeled as CAI if the instructor set aside a minimum of one–third of class time for students to work on the computer. CAI took place in a lab on campus that was open to all students, remedial and non-remedial. A self-concept scale was administered as a pre- and post-test to measure self concept.

Results indicated no improvement and no significant difference in students' self concept between the CAI and traditional environments. However, students in the CAI group earned significantly better grades than students in the traditional group; this was true for the entire CAI group and for older students in the CAI group. There were no significant differences in grades between the CAI and traditional group for students who were younger than 21. Students in the CAI group had significantly higher course completion rates than students in the traditional group although there were no significant differences in course completion rates when students were compared by age group (Williams, 1996).

French (1997) conducted a study to compare student achievement and attitudes towards mathematics when instructed in either a traditional instructional setting or in a setting that combined CAI with traditional instruction. Students were enrolled in a precalculus course at the Community College of Philadelphia during spring semester 1996 and did not know at the time of registration which instructional method would be used in their section. Students in both sections included in the study were taught by the same instructor, used the same text, and completed the same homework and assessments. Students in the treatment group spent an average of 55 minutes per week in the CAI laboratory environment, where they worked in groups on two types of interactive software, including Mathwright Interactive software and Larson and Hostetler Tutorial software.

Students were administered pretests and posttests to measure achievement and attitude toward mathematics. The Aiken-Dreger Mathematics Attitude Scale was used to measure students' attitudes toward mathematics. An open-ended questionnaire assessing students' attitudes towards instructional method was administered toward the end of the term and six randomly-selected students also were also interviewed at that time (French, 1997).

Pretest scores indicated no significant differences between the groups on achievement or attitude toward mathematics. Both groups had significantly higher achievement scores on the posttest than on the pretest, and although that difference was significantly greater for the CAI group, there were no significant differences in average gain scores for the two groups. There also was no significant difference on a quantitative measure of changes in students' attitudes towards mathematics, although a qualitative measure indicated students in the CAI group had significantly more positive attitudes towards mathematics. Due to high attrition, the number of students included in this study was low and results should be interpreted with caution (French, 1997).

Hamtini (2000) conducted a study to compare achievement and attitudes of students enrolled during fall semester, 1999, in traditional and CAI sections of remedial algebra at a public university in the southern U.S. Pre- and post-tests of mathematics achievement and attitude towards mathematics were administered and interviews were conducted with a subset of students. The same instructor taught all sections and *Interactive Math* by Prentiss Hall was the software used in CAI sections. Some lecture was included at the beginning of each class period for CAI sections. Although both groups experienced increased mathematics achievement, results suggested students in the traditional sections had significantly greater gains. Students in the traditional group did not demonstrate improved attitudes towards mathematics, however, while students in the CAI sections had significant positive changes in attitude towards mathematics.

Glickman and Dixon (2002) conducted a quasi-experimental study to compare the effectiveness of CAI versus traditional lecture-based instruction for students enrolled in remedial mathematics. Students were enrolled in intermediate algebra and data were collected from two community colleges. Students self selected into one of four course sections, two taught using CAI and two taught using traditional lecture-based instruction. Each participating college taught one CAI section and one lecture-based instruction section. Students in the CAI sections used the *Interactive Mathematics* program by

Prentiss Hall. Although the content covered in all sections was the same, instructors in the CAI sections emphasized conceptual understanding while instructors in the traditional sections emphasized procedural skill instruction. A pretest of procedural skills was used as a covariate to control for initial differences among students. Posttests included a conceptual test and a test of procedural skills. A questionnaire designed to measure students' attitudes toward mathematics was administered at the beginning and end of the semester. The questionnaire included scales related to students' confidence in learning mathematics, mathematics anxiety, motivation in mathematics, and students' attitudes about the usefulness of mathematics.

The sample size included 100 students at the beginning of the semester, including 39 students in the CAI group and 61 students in the traditional group; 81 students were retained through the end of the semester, although 14 were eliminated from the study because they did not complete the questionnaire. Results indicated students in the CAI group scored much higher on conceptual understanding; that difference was statistically significant. There was no significant difference between groups on measures of students' procedural skills or attitudes toward mathematics, although a t test showed students in the CAI group did show a significant decrease on the mathematics anxiety scale and a significant increase on the confidence in learning mathematics scale from the beginning to the end of the semester. Although differences in retention were not tested for significance, attrition in the CAI group was lower (15%) than in the traditional group (21%). Glickman and Dixon concluded that the use of CAI may effectively increase students' conceptual understanding without adversely impacting their procedural skill development. They suggested CAI also may lead to affective gains with respect to mathematics (Glickman & Dixon, 2002).

Fleming (2003) also conducted a quasi-experimental study to compare the effectiveness of CAI versus traditional lecture-based instruction for students enrolled in a beginning algebra course at Virginia Highlands Community College during fall semester 2002. Students were randomly assigned to treatment group, but were allowed to switch from one instructional method to the other. Fifty seven students were placed into each group; 41 remained in the CAI section, and 52 remained in the traditional section. Both groups covered the same course objectives, although the traditional group used a textbook, while the computer group used a web-based software program called ALEKS. Students in the CAI group worked at their own pace, either from home or in a college computer lab, and had no scheduled class meetings. Students in the traditional group had significantly higher achievement, based on posttest (final exam) scores, but there were no significant differences between groups on course pass rates, even when taking into account students who withdrew from the course.

Summary of research focused on effectiveness of using asynchronous CAI in remedial mathematics courses. Six of the studies described above were doctoral dissertations, three were published in peer-reviewed journals, one was published in a non peer-reviewed journal, and one was an ERIC document. The studies differed in a number of ways. Different software programs were used in a variety of settings and for different amounts of time. The studies addressed various levels within developmental mathematics and the material was not identical in all cases. The amount and type of interaction students in CAI sections had with peers and instructors varied from one study to the next. In general, results from these studies are not consistent in terms of whether CAI, traditional instruction, or some combination of the two leads to the greatest student success in remedial mathematics courses. Also, the variation in design and analysis make it difficult to compare results and draw useful conclusions across studies. Finally, these studies were all conducted at the institutional level. Caution should be taken when generalizing the results.

Studies Focused on Factors Related to Student Success Using CAI in Remedial Mathematics Courses

Three studies were located that addressed specific factors related to students' success using CAI in remedial mathematics courses. King and Crouse (1997) reported on the use of Academic Systems Corporation software in remedial algebra courses at Brevard Community College. Prior to the implementation of the software at the college, pass rates in remedial algebra courses ranged from 20 to 40%, whereas for the spring 1997 cohort, 57% of students successfully passed the course. Faculty who used the software reported that their students learned more and were equally or more successful even when class sizes increased from 25 to 38. Many students who finished their course before the end of the term were reported to continue attending class to help peers. The improved success rate enabled more students at the college to continue on to college-level coursework. King and Crouse credited the success of the program to flexible schedule and grading formats, strong leadership from faculty and administration, a reduction in the number of topics covered in the courses, required student attendance in the computer lab, and a student recognition program that highlighted successful completers.

Kinney's (2001a) study comparing student outcomes in elementary and intermediate algebra courses taught using either CAI or a traditional lecture format at the University of Minnesota was described above. At the end of the semester Kinney administered a survey to all subjects and conducted focus groups with students enrolled in the CAI sections. Based on survey results, students in the CAI sections were significantly more satisfied with their course. Students in the CAI sections most commonly identified the computer software as the mode by which they best learned mathematics, while students in the lecture sections most commonly identified "doing homework" as the mode by which they best learned mathematics.

Feedback during focus groups indicated students in the CAI sections appreciated being able to control the pace of their learning and valued explanations of concepts and skills as well as feedback provided by the software. They also appreciated the opportunity to receive individual assistance from the instructor. Overall, students reported having chosen the CAI format because it increased their control over their learning, and because they did not want to enroll in a lecture course. Also, they all felt that they understood mathematics better in the CAI setting than they would have in a lecture class (Kinney, 2001a).

Students in the lecture sections indicated in the survey that they preferred instruction from a human and appreciated the opportunity to ask questions and interact with peers. Students in the CAI sections indicated significantly higher confidence in their ability to do mathematics than did students in the lecture sections, although the significance was marginal and students in both groups indicated increased confidence in their ability to do mathematics. Overall, students in both types of classes reported a high degree of satisfaction with their course and improved attitudes about mathematics (Kinney, 2001a).

Perez and Foshay (2002) reported on a study conducted by the League for Innovation in the Community College, PLATO Learning, Inc., and eight community colleges. Several colleges in the study offered remedial mathematics as pure distance learning courses using CAI and others used CAI in a supplemental role. All participating institutions held on-campus orientations for students and some included periodic on-campus class meetings. All colleges used telephone and e-mail as additional means of communication and some also used threaded discussion and class web sites. Each institution provided technical assistance and learner support services for its students and investigators gathered qualitative and quantitative feedback from faculty and students who participated in the project.

Faculty identified the following positive outcomes of using CAI: increased time for individual faculty/learner contact; flexibility with respect to time and location; self-paced, individualized instruction; privacy; appealing, cutting-edge technology; and immediate feedback. Students in the project also identified factors that positively impacted their experience with CAI, including frequent communication with faculty through Web pages and/or e-mail; formal orientation; and alignment of course objectives with online assignments (Perez & Foshay, 2002).

Summary of research on factors related to student success using CAI in remedial mathematics courses. The studies described above suggest several aspects of CAI may be related to student success in remedial mathematics courses, including flexible scheduling, self-paced instruction, increased control, privacy, appealing technology, explanations from the computer of concepts and skills, feedback from the computer, and individual assistance from the instructor. Having a formal orientation and well-aligned course objectives and assignments also were important. However, these studies were fairly small in scope and do not provide sufficient evidence for educators and researchers to make generalizations about which elements of CAI are most critical for student success in remedial mathematics courses.

Summary

According to Kulik (in an interview with Bonham, 1990), the field of developmental education is relatively young and does not have the infrastructure to support research that older fields such as psychology, the natural sciences, and the health sciences have. External funding sources and internal rewards for conducting research in developmental education are not well developed and it is difficult to make sense of the limited research that does exist. And, Kulik argued, "On most questions you can find some studies that show one thing and others that show just the opposite" (p. 17). Interested readers should consult O'Hear and MacDonald (1995) and MacDonald and O'Hear (1996) for discussions of problems with the design, operation, and analyses of research in developmental education that was conducted between 1985 and 1995. This review suggests that recent research on developmental education – mathematics in particular – is still limited, studies still vary in design and analysis, and results are still inconclusive.

With rapid developments in technology and increased opportunities for proprietary companies to participate in the educational market, existing instructional products are updated and new products are introduced regularly. This makes continued investigation of computerized products for developmental education a necessity. Although the study described here did not address the difficulty of making valid comparisons across studies involving different software programs and/or using different research designs, it does add to the limited body of research that specifically addresses the effectiveness of using *Interactive Mathematics* software developed by Academic Systems Corporation for remedial mathematics courses. This investigator examined students' performance in a remedial mathematics course and in a subsequent college-level mathematics course and also gathered information on students' descriptions of their experiences in a remedial mathematics course taught using asynchronous CAI.

More data on the effectiveness of *Interactive Mathematics* software compared to traditional instruction for students in remedial mathematics courses may help educators and students make better decisions about whether and how to use the software in the future. Results from this study also have the potential to provide richer, more meaningful insight into specific factors that may impact student success using *Interactive Mathematics* software for remedial mathematics instruction.

CHAPTER 3 – METHOD

This study included two parts, which were conducted simultaneously. The first part was quantitative and the second part was qualitative. Johnson and Onwuegbuzie (2004) provide a detailed discussion of mixed methods research, stating, "A key feature of mixed methods research is its methodological pluralism or eclecticism, which frequently results in superior research (compared to monomethod research)" (p. 14). They argue that mixed methods research is a pragmatic approach whose goal is not to replace quantitative or qualitative approaches "but rather to draw from the strengths and minimize the weaknesses of both in single research studies and across studies" (pp. 14-15). Using a mixed methods approach for this study allowed for a more comprehensive analysis of the research problem. Results from quantitative analysis helped inform results from qualitative analysis and vice versa. In the end, a mixed methods approach led to a deeper understanding of the problem at hand (Creswell, 2003).

This study was conducted during spring semester 2005. In the first part of the study, the investigator used archived student data to analyze the relationship between instructional delivery method (traditional versus asynchronous computer-assisted), students' gender, students' age, and students' final course grades in a remedial mathematics course (Survey of Algebra) and in a subsequent, college-level mathematics course (College Algebra). In the second part of the study, the investigator focused specifically on asynchronous computer-assisted instruction (CAI), conducting interviews with students to explore in greater detail their experiences and perceptions using asynchronous CAI in Survey of Algebra. Parts I and II are described separately below. Information that was the same for both parts (e.g. site) is described in Part I only.

Part I

Research Questions

In Part I of this study, the investigator addressed the following research questions:

1. Is there a difference between instructional delivery method (traditional versus asynchronous computer-assisted) in a remedial mathematics course (Survey of Algebra) in regard to students' final course grades?
2. Is there a difference between instructional delivery method (traditional versus asynchronous computer- assisted) in a remedial mathematics course (Survey of Algebra) in regard to students' final course grades in a subsequent college-level mathematics course (College Algebra)?
3. Is there a difference between male and female students in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) using traditional instruction?
4. Is there a difference between male and female students in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) using asynchronous CAI?
5. Is there a difference in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) between males who completed the course using traditional versus asynchronous computer-assisted instruction?

6. Is there a difference in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) between females who completed the course using traditional versus asynchronous computer-assisted instruction?
7. Is there a difference between traditional-age students (up to 24 years old) and non traditional-age students (25 years and older) in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) using traditional instruction?
8. Is there a difference between traditional-age students (up to 24 years old) and non traditional-age students (25 years and older) in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) using asynchronous CAI?
9. Is there a difference in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) between traditional-age students (up to 24 years old) who completed the course using traditional versus asynchronous computer-assisted instruction?
10. Is there a difference in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) between non traditional-age students (25 years and older) who completed the course using traditional versus asynchronous computer-assisted instruction?
11. Is there an interaction between instructional delivery method (traditional versus asynchronous computer-assisted), students' gender, and students' age (up to 24 years, 25 years and older) in regard to students' final course grades in a remedial mathematics course (Survey of Algebra)?

Research Design

Part I of this study used an *ex-post-facto* design and was comparative in nature. The main independent variable, instructional delivery method, was active and had two levels: traditional and asynchronous computer-assisted instruction (CAI). The other independent variables, gender and age, were both attribute variables with two levels. For the age variable, students were grouped as traditional (up to 24 years old) and non-traditional (25 years and older). Age was defined as the age of the student on the first day of the term during which s/he enrolled in Survey of Algebra.

There were two dependent variables for Part I: final course grade in Survey of Algebra and final course grade in College Algebra. Not every student included in this study enrolled in College Algebra; therefore, the second dependent variable was only included for a subset of the total population.

Participants and Site

The theoretical population for Part I was all community college students enrolled in Survey of Algebra (also often called Intermediate Algebra). The investigator analyzed data from a convenience sample that included all students who enrolled in Survey of Algebra at one public community college in a medium-sized city in the western United States between 2002 and 2004. The institution includes a main campus and two branch campuses. Data from all three campuses were included in this study; results were not compared by campus, however.

Between 2002 and 2004, 95 sections of Survey of Algebra were taught using the traditional delivery method and 1,604 students enrolled in those sections. Typically, a minimum enrollment of 10 students was required in order for a traditional section to be taught. Twenty-five sections were taught using asynchronous CAI and 176 students enrolled in those sections. The 10 student minimum did not always apply for CAI sections, which explains in part why the ratio of students per section is much lower for the CAI sections. (Note: *section* is an administrative term used in the scheduling process; with respect to the CAI instructional delivery method, students enrolled in a given section did not necessarily have to meet as a group.)

Three-hundred ninety-eight students from Survey of Algebra sections taught using the traditional delivery method and 17 students from sections taught using asynchronous CAI were included for Question 2. These groups were smaller than those used for Question 1 because many students who completed Survey of Algebra did not complete College Algebra for one of the following reasons: (1) their program of study did not require mathematics beyond Survey of Algebra; (2) their program of study permitted them to take a college-level course other than College Algebra, such as Mathematics for Liberal Arts; (3) they did not persist at the institution; or (4) they did not enroll in College Algebra during the time frame included in this study.

The investigator did not take into consideration a number of potentially confounding student variables that can positively or negatively impact students' final course grades, including, but not limited to: students' level of education, area of study/major, course load (full time or part time), prior knowledge of mathematics, completion of lower-lever mathematics courses, learning style, comfort level and prior experience with computers, maturity, motivation to succeed, goals, family support, number of dependents, socioeconomic status, utilization of learning assistance services, and work status (full time, part time, or not working).

Description of Course Format and Content

Through spring quarter 2002, the last mathematics course classified as remedial at the institution under investigation was called *Intermediate Algebra*. The course was renamed *Survey of Algebra* beginning summer quarter 2002. Between 2002 and 2004, the course was alternately identified as MAT 105, 109, and 106. Through summer quarter 2003, the course was offered for five quarter credits, which is equivalent to 3.3 semester credits. From fall quarter 2003 through summer quarter 2003, in preparation for the institution's conversion to a semester system, the course was offered for six quarter credits, which is equivalent to four semester credits. In fall 2004, the course was offered for four semester credits. This study did not address potential differences in student success or perceptions based on differences between course titles, identifying numbers, or number of credits awarded.

Major topics of study in Survey of Algebra include equations, slope, inequalities, systems of equations, polynomials, quadratic equations, rational expressions, rational exponents, radical expressions, graphing, and applications (Aims Community College, 2004). Survey of Algebra is not accepted for credit at most baccalaureate-granting institutions. However, it does meet a requirement for some certificates and associate of applied science degrees.

As a result of including numerous sections taught over the course of several years, there were many possible intervening variables that were not controlled in this study. For example, prior to fall 2004, course sections offered at the institution during fall, winter, and spring quarters lasted approximately 10 weeks and course sections offered during summer quarters lasted approximately eight weeks. Starting fall 2004, the institution switched to 15-week semesters, although one traditional section of Survey of Algebra that was included in this study was offered in a compressed format lasting approximately six weeks. Investigating the impact of different section lengths was beyond the scope of this study.

In addition, except for considering whether courses were taught using traditional instruction or asynchronous CAI, the researcher did not take into account other differences in individual course sections, including, but not limited to: attendance policy, grading policy, amount of time spent in lecture, emphasis placed on specific concepts, use of computers in traditional sections, textbooks and other course materials, sequence in which concepts and skills were introduced, presence or absence of group work, testing, class size, campus, time of day, days of week, length of class sessions, etc. Students' final grades in College Algebra were analyzed according to the type of instructional method used in Survey of Algebra but *not* the type of instructional method used in College Algebra itself. Differences in instructors' teaching styles, years of teaching experience, status as full time or adjunct, and expertise with asynchronous CAI or traditional instruction also were beyond the scope of this study.

Asynchronous CAI. Academic Systems Corporation was founded in 1992 and merged with PLATO Learning in 2003. Its mathematics and English products have been used at over 350 campuses across the nation. Course materials include a book as well as a software program that can be installed on students' personal computers. In *Interactive Mathematics*, each topic is comprised of up to four lessons and each lesson includes the following sections: Overview, Explain, Homework, Apply, and Evaluate. Included in the Overview section is a list of lesson objectives. The software requires student interaction as it presents concepts and skills. It provides immediate feedback with detailed explanations and assessment, and includes a course management system that frees up the instructor's time while allowing him/her to access detailed information about each student's progress. More information about Academic Systems and *Interactive Mathematics* is available at www.academic.com.

Interactive Mathematics was first implemented at the institution under investigation in this study in winter quarter 2002. For the first several terms, it was only used in one section of Survey of Algebra, and only on one campus. Over time, up to four sections have been offered per term, and all three of the institution's campuses now have the software installed on computers in their labs. There has been significant variation, however, in attendance policies for these sections. In some cases, attendance at all class sections, or a minimum number of sessions, has been mandatory. More often, the course has been offered in an open computer lab format, where students were permitted to use the lab as frequently or infrequently as desired. There were specific hours when labs were open for students to work on homework and/or receive help from the instructor. Students also could opt to do all or most of their work for the class from a computer at home or at work. In all cases, students were required to go to campus to take tests, which were completed by hand and developed by the instructors.

Data Collection and Procedure

Data for Part I of this study, including instructional delivery method, final course grade(s), age, and gender were extracted from the institution's electronic student information system. Age and gender data were inputted from students' admission applications. Course section selection was inputted from students' registration forms and was used to identify instructional delivery method. Final course grade(s) were inputted from instructors' final grade rosters.

It was assumed that students accurately completed their application for admission with respect to identification of gender and age. It also was assumed that students' application information and final course grades for Survey of Algebra and College Algebra were accurately entered into the college's electronic student information system. It was assumed that students were accurately placed into an appropriate level of mathematics, whether by using placement test score, standardized test score, grade of C or better in a lower-level mathematics course, or other criteria. It was assumed that those placement tools were valid and reliable. It was further assumed that final course grades were assigned objectively.

Staff from the institution's Institutional Research and Effectiveness department extracted data from the electronic student information system and formatted it in a Microsoft Excel spreadsheet for the investigator's use. Each participant was identified by a unique number, starting with *0001* and ending with *1,780*. This number was not tied to students' actual social security or institutional identification numbers. Final course grades for Survey of Algebra (and College Algebra, if applicable) were coded as *4* for A, *3* for B, *2* for C, *1* for D, and *0* for F, withdrawal (W), or administrative withdrawal (AW). Sixty students whose records indicated one of the following in the "final course grade" column were not included in Part I of the study: incomplete (I), audit (AU), satisfactory (S), or grade not recorded (NR). Participants who did not enroll in College Algebra were not coded in the column identifying their final grade in that course.

Data Analysis

The investigator used Statistical Products and Service Solutions (SPSS), Microsoft Excel, and Microsoft Word to analyze data collected for Part I of the study. Because Part I of this study included data from all students who enrolled in Survey of Algebra between 2002 and 2004 at the institution under investigation, parametric analyses were conducted for the group. However, the investigator also conducted statistical analyses in order to justify conclusions drawn about the theoretical population based upon results from the sample (Fraenkel & Wallen, 1996; Wiersma & Jurs, 2005).

T tests were conducted for questions 1 through 10 using the Bonferroni correction, a statistical procedure designed to reduce the likelihood of making a type one error. There are many ways to compute the Bonferroni; the investigator chose a conservative approach by dividing by the number of primary research questions (10) by the standard alpha level (.05) used for the social sciences, resulting in a downward adjustment to $p = .005$ for each question. (The investigator could have divided the alpha level by the number of research questions related to a specific concept – such as type of instruction, gender, or age – which would have made the calculated value needed to indicate a significant difference much smaller. There has been a great deal of discussion recently related to the value or lack thereof of relying on the .05 alpha level, which became the norm for the social sciences in the early 1900s.) In addition to reporting the p value for each question, the investigator also reported effect sizes (Cohen, 1998). For Question 11, the investigator conducted an ANOVA to check for any interaction between the three independent variables. Results of analyses for Part I are presented as tables, bar graphs, and mean plots.

Part II

Research Question

In Part II of this study, the investigator addressed the following research question: How do students describe their experiences and perceptions using asynchronous CAI for a remedial mathematics course (Survey of Algebra)?

Research Design

Part II was a qualitative exploration. The investigator conducted 12 one-on-one interviews with students and coded and analyzed responses.

Participants and Site

The theoretical population for Part II was all community college students using asynchronous CAI in Survey of Algebra (also often called Intermediate Algebra). The actual participants were those students who completed the course with a letter grade during 2004 at the institution under investigation and volunteered to participate in an interview with the investigator. Those students who earned an incomplete (I), withdrawal (A), or administrative withdrawal (AW) were not contacted.

Twelve sections of Survey of Algebra were taught using asynchronous CAI during 2004. Staff from the institution's Institutional Research and Effectiveness department accessed the electronic student information system to generate a list of the names and contact information of all students who completed the course using asynchronous CAI during 2004. They formatted the information in an Excel spreadsheet for the investigator's use. Seventy-two students who completed the course with a grade of A, B, C, D, or F were invited to participate in one-on-one interviews.

The passage of time between completing the course and participating in the interview may have influenced students' responses about their experiences in Survey of Algebra using asynchronous CAI. Therefore, the investigator chose only to invite students from those asynchronous CAI sections that took place during 2004. Within the group of volunteers who participated in interviews, the investigator did not compare responses according to how recently students completed the course.

Because students from all asynchronous CAI sections offered at the institution during 2004 were invited to participate, it is reasonable to assume that the potential participants were representative of the entire population of students at the institution who take Survey of Algebra using asynchronous CAI. However, Part II of this study only included students who earned a letter grade in Survey of Algebra and who volunteered to participate. It is possible that students who withdrew from, audited, or earned an incomplete in the course are qualitatively different from course completers. It also is possible that volunteers were qualitatively different from non volunteers. Analysis of such potential differences was beyond the scope of this study. Other possible confounding student, instructor, and course format variables that were described above for Part I of the study also may be applicable to Part II.

Measures/Instrumentation

The interview protocol is included in Appendix A. The investigator developed the interview questions after conducting a thorough review of the literature, including reviewing interviews and surveys that were conducted by other researchers in the field. The investigator also consulted with experts in the areas of mathematics and research at the institution under investigation and at Colorado State University. The investigator placed demographic questions and the question about final course grade at the end of the interview so that such information would not bias her interactions with participants during interviews.

Data Collection and Procedure

The investigator served as the interviewer and piloted the interview with two students who were enrolled in Survey of Algebra using asynchronous CAI during spring semester 2005. The interviewer contacted the chair of the developmental mathematics department, and other course instructors, to identify a potential pool of students with whom to conduct the pilot. Those students' telephone numbers were accessed through the institution's electronic student information system. The investigator contacted students by telephone to invite them to participate in a pilot interview. As a result of the pilot interviews, the investigator added questions 2 and 11.

Data collection for the actual study proceeded in much the same way as the pilot interviews. The institution's Institutional Research and Effectiveness department provided e-mail addresses and mailing addresses for all students who completed Survey of Algebra using asynchronous CAI with a grade of A, B, C, D, or F during 2004. The investigator sent a recruiting letter to all potential participants through e-mail and/or the U.S. Postal Service. The recruiting letter is included in Appendix B.

In the recruiting letter, the investigator requested a one-on-one, face-to-face interview with each volunteer, to be held at the institution under investigation or another public venue (e.g., public library). Volunteers whose schedules prohibited meeting with the investigator face-to-face were invited to participate in a telephone interview. Each interview lasted approximately 10 to 15 minutes. The investigator requested permission from volunteers to record interviews on audiotape. The investigator also took some notes during interviews in case there were any problems with the recording. Interview questions were the same for all interviews. However, the investigator occasionally added questions in order to clarify a student's response. Each participant signed a consent form, which is included in Appendix C.

Data Analysis

All recorded interviews were transcribed to facilitate data analysis. The investigator used a systematic process of analyzing and interpreting the data. The process followed the general steps described by Creswell (2003), which included: organizing and preparing the data; reading through all data to obtain a general sense and reflect on overall meaning; coding the data into chunks; generating a description and categories or themes for analysis; explaining how the description and themes would be represented in the narrative; and making an interpretation of the data.

Initially, responses to each interview question were analyzed separately. For the first level of coding, the investigator identified key phrases from the interview transcripts. For the second level of coding, the investigator grouped similar responses from first-level coding and labeled those groups. Each group represents a theme or concept that one or more students mentioned. In addition, the investigator counted the number of students who mentioned each theme, to find out which themes were frequently mentioned and which were only occasionally mentioned. For the third level of coding, the investigator summarized students' responses to each interview question in a few sentences, referring to the themes that were generated most often.

To increase the validity of the findings from interviews, the investigator went back to the interview transcripts and searched for contradictions or discrepancies among students' responses. Next, the investigator took the third-level summaries and discrepant information and reduced them to three paragraphs that broadly summarize students' experiences and perceptions using asynchronous CAI to complete Survey of Algebra. Finally, the investigator identified three themes or aspects of CAI that were most salient across all interviews. Each theme is described and accompanied by exemplary quotes from students who were interviewed. Results of the analyses are included in Chapter 4. Much of the information is presented in tabular form (i.e., matrices), although results also are presented in narrative form.

CHAPTER 4 – RESULTS

The overall purpose of this study was to increase understanding about the impact of instructional delivery method on student success in community college remedial mathematics. In addition, this study was designed to provide richer, more meaningful insight into specific factors that may impact student success using CAI programs for remedial mathematics instruction.

This study had two parts. First, the investigator analyzed the relationship between instructional delivery method (traditional versus asynchronous computer-assisted), students' gender, students' age, and students' final course grades in a remedial mathematics course (Survey of Algebra) and in a subsequent, college-level mathematics course (College Algebra). Second, the investigator focused specifically on asynchronous CAI, conducting interviews with students to explore in greater detail their experiences and perceptions using asynchronous CAI for Survey of Algebra. Results of the study are described below, organized by research question. Results from the quantitative portion (Part I) are described first, followed by results from the qualitative portion (Part II).

Results for Part I – Quantitative Analysis

Part I of this study included 1,720 students who enrolled in Survey of Algebra from 2002 to 2004. Sixty students whose records indicated one of the following in the "final course grade" column for Survey of Algebra were not included in Part I: incomplete (I), audit (AU), satisfactory (S), or grade not recorded (NR). Some students enrolled in Survey of Algebra more than once. In those cases, information from the student's first attempt was included in Part I; information related to subsequent enrollments was not included.

Table 4.1 shows descriptive information for the students who were included in Part I of this study. Almost 92% of students enrolled in Survey of Algebra in sections that used traditional instruction, over 57% were female, and nearly 71% were traditional age. The mean grades for students who used traditional instruction, females, and non-traditional age students were substantially higher than the mean grades for students who used CAI, males, and traditional age students, respectively. At the institution under investigation, a grade of C (2.00) or better is required to move on to the next mathematics course. For each variable, the higher-performing group had a mean grade above 2.00, while the lower-performing group had a mean grade below 2.00. In other words, the mean grade for the higher-performing groups was sufficient to move on to the next mathematics course, while the mean grade for the lower-performing groups was not.

Table 4.2 shows descriptive statistics for final grades in Survey of Algebra when considering all three independent variables together. Of the eight groups, traditional age males who used CAI had the lowest mean grade (0.52), while non-traditional age females who used traditional age instruction had the highest mean grade (2.49). Using 2.00 (grade of C) as the cut-off, four of the eight groups had mean grades sufficient to advance to the next mathematics course.

In the next section, research questions 1 through 10 are restated in pairs (for ease of comparison), followed by reports of the results. The term *highly successful* is used to describe students who earned As or Bs, while Ds, Fs, Ws, and AWs are used as an indication that students were *not successful* in the course. Results from *t* tests are

Table 4.1

Final Grades in Survey of Algebra by Type of Instruction, by Gender, and by Age

Variable	Number	Percent	Mean Grade	SD	Min	Max
Method of instruction						
Traditional instruction	1574	91.51	2.08	1.55	.00	4.00
CAI	146	8.49	1.38	1.55	.00	4.00
Gender						
Male	733	42.62	1.81	1.57	.00	4.00
Female	987	57.38	2.18	1.54	.00	4.00
Age						
Traditional age[a]	1218	70.81	1.88	1.53	.00	4.00
Non-traditional age[b]	502	29.19	2.36	1.60	.00	4.00

[a]A student was considered traditional age if s/he was up to 24 years old on the first day of the term during which s/he enrolled in Survey of Algebra. [b]A student was considered non-traditional age if s/he was 25 years or older on the first day of the term during which s/he enrolled in Survey of Algebra.

reported (p = .005), including effect size (Cohen, 1988), and results also are reported in bar graphs.

1. Is there a difference between instructional delivery method (traditional versus asynchronous computer-assisted) in a remedial mathematics course (Survey of Algebra) in regard to students' final course grades?
2. Is there a difference between instructional delivery method (traditional versus asynchronous computer- assisted) in a remedial mathematics course (Survey of Algebra) in regard to students' final course grades in a subsequent college-level mathematics course (College Algebra)?

As shown in Figure 4.2, a higher percentage of students who used traditional instruction were highly successful in Survey of Algebra, while students who used

Table 4.2

Final Grades in Survey of Algebra by Combination of Type of Instruction, Gender, and Age

Variable	Number	Percent	Mean Grade	SD	Min	Max
		Traditional instruction				
Male						
Traditional age	523	30.41	1.74	1.52	.00	4.00
Non-traditional age	160	9.30	2.29	1.62	.00	4.00
Female						
Traditional age	607	35.29	2.12	1.50	.00	4.00
Non-traditional age	284	16.51	2.49	1.52	.00	4.00
		CAI				
Male						
Traditional age	31	1.80	0.52	0.89	.00	4.00
Non-traditional age	19	1.10	1.63	1.74	.00	4.00
Female						
Traditional age	57	3.31	1.33	1.50	.00	4.00
Non-traditional age	39	2.27	2.00	1.64	.00	4.00

CAI were much more likely to not be successful in the course. This difference is statistically significant [t (1,718) = 5.234, p = .000] and the effect size is medium (d = .45). A slightly higher percentage of students who used traditional instruction for Survey of Algebra than students who used CAI went on to be highly successful in College Algebra, while students who used CAI for Survey of Algebra were much more likely to not be successful in College Algebra. This difference is not statistically significant [t (529) = .967, p = .334] using traditional test methods, but does have a small effect size (d

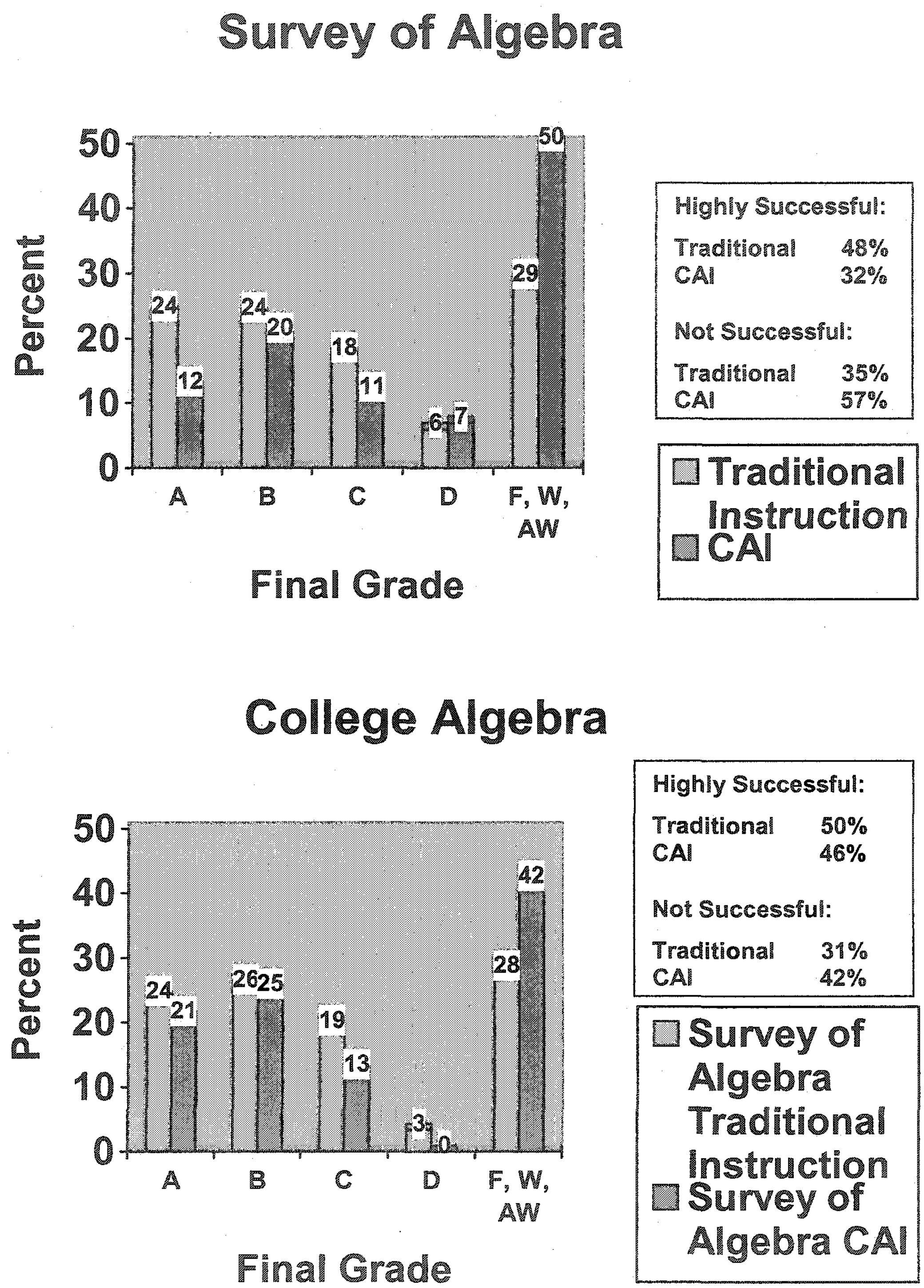
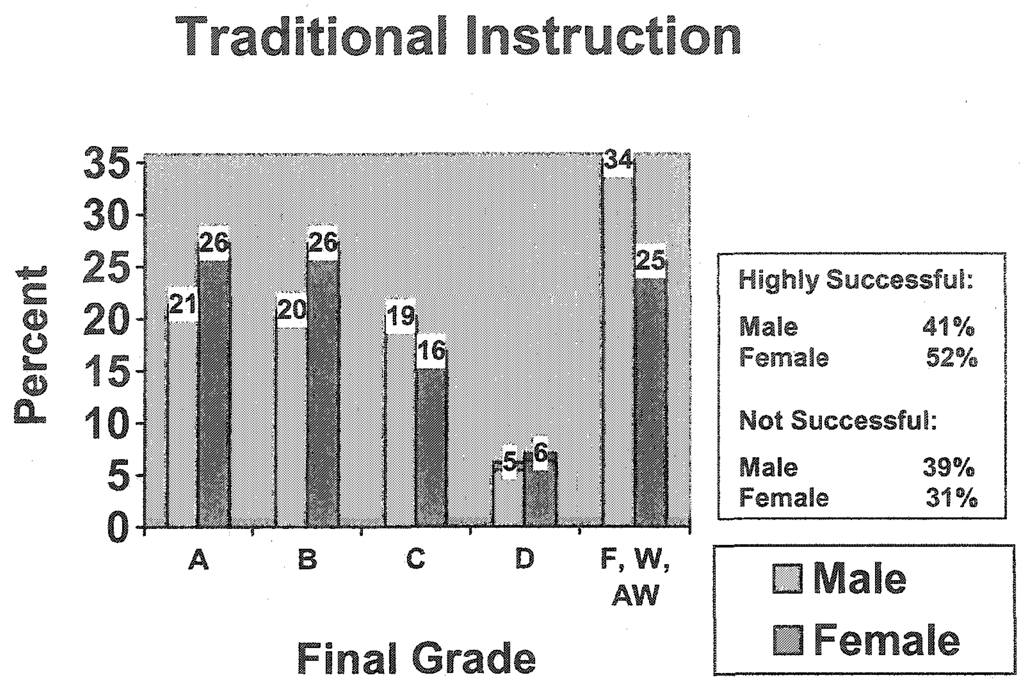


Figure 4.2. Students' final grades in Survey of Algebra and College Algebra by type of instruction used in Survey of Algebra.

= .19). In general, students were more likely to earn As or Bs in Survey of Algebra and College Algebra if they took Survey of Algebra using traditional instruction rather than CAI whereas they were more likely to earn Ds, Fs, Ws, or AWs in Survey of Algebra and College Algebra if they took Survey of Algebra using CAI.

3. Is there a difference between male and female students in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) using traditional instruction?
4. Is there a difference between male and female students in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) using asynchronous CAI?

As shown in Figure 4.3, when taught using traditional instruction, a higher percentage of females than males were highly successful, while males were more likely than females to not be successful in the course. This difference is statistically significant [t (1,572) = -4.681, p = .000]; however, the effect size is small (d = .24). When taught using CAI, females were about twice as likely as males to be highly successful, while males were more likely than females to not be successful in the course. This difference is not statistically significant using the more conservative Bonferroni calculation [t (112.467) = -2.624, p = .010; Levine's test indicated the variances were unequal]. However, the effect size is medium (d = .45). Regardless of type of instruction, females were more likely than males to earn As or Bs in Survey of Algebra while males were more likely than females to earn Ds, Fs, Ws, or AWs.



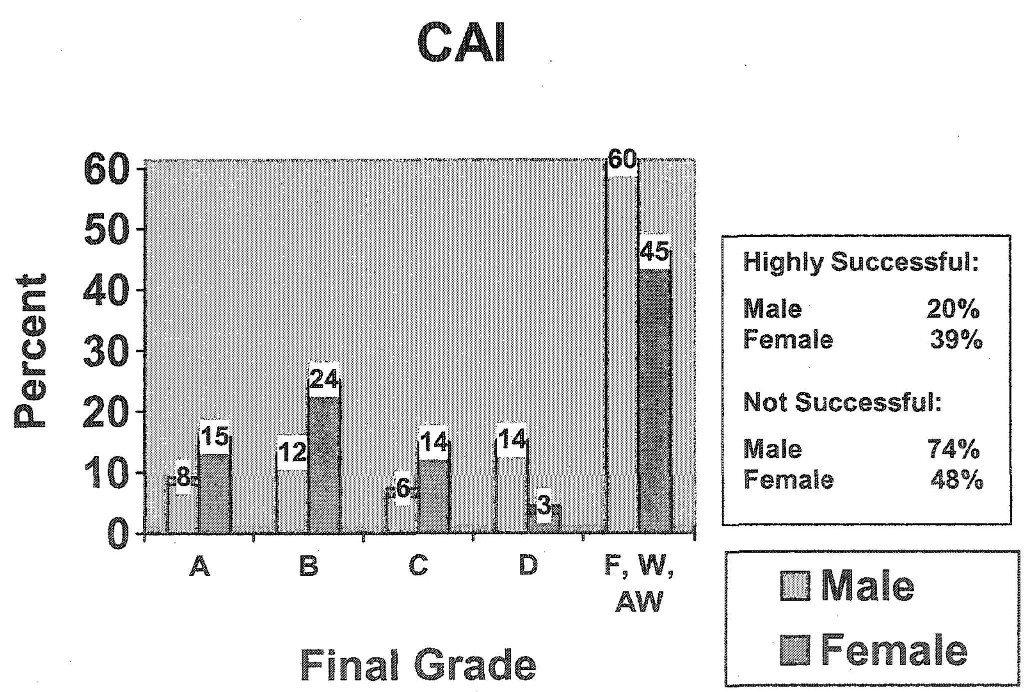
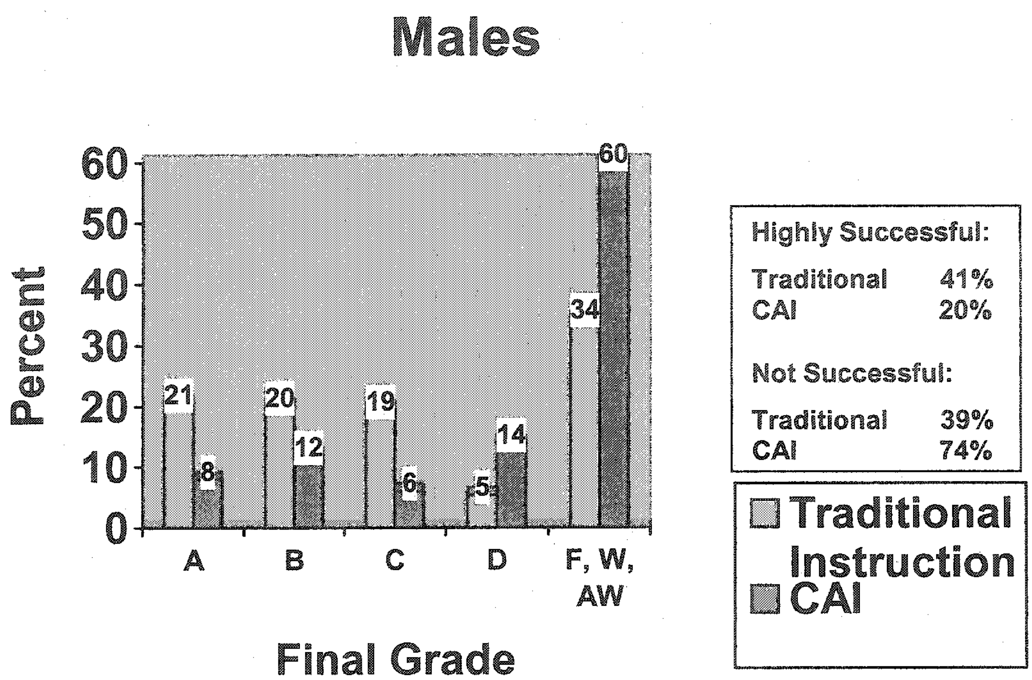


Figure 4.3. Students' final grades in Survey of Algebra using traditional instruction and CAI by gender.

5. Is there a difference in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) between males who completed the course using traditional versus asynchronous computer-assisted instruction?
6. Is there a difference in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) between females who completed the course using traditional versus asynchronous computer-assisted instruction?

As shown in Figure 4.4, males who used traditional instruction were more than twice as likely as males who used CAI to be highly successful, while males who used CAI were almost twice as likely as males who used traditional instruction to not be successful in the course. This difference is statistically significant [t (58.655) = 4.573, $p = .000$; Levine's test indicated the variances were unequal] and the effect size is medium to large ($d = .63$). Females who used traditional instruction were more likely than females who used CAI to be highly successful, while females who used CAI were more likely than females who used traditional instruction to not be successful in the course. This difference is statistically significant [t (985) = 3.857, $p = .000$] and the effect size is small to medium ($d = .41$). Males and females who used traditional instruction were more likely than their same-gender peers who used CAI to earn As or Bs, while males and females who used CAI were more likely than their same-gender peers who used traditional instruction to earn Ds, Fs, Ws, or AWs.

7. Is there a difference between traditional-age students (up to 24 years old) and non traditional-age students (25 years and older) in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) using traditional instruction?



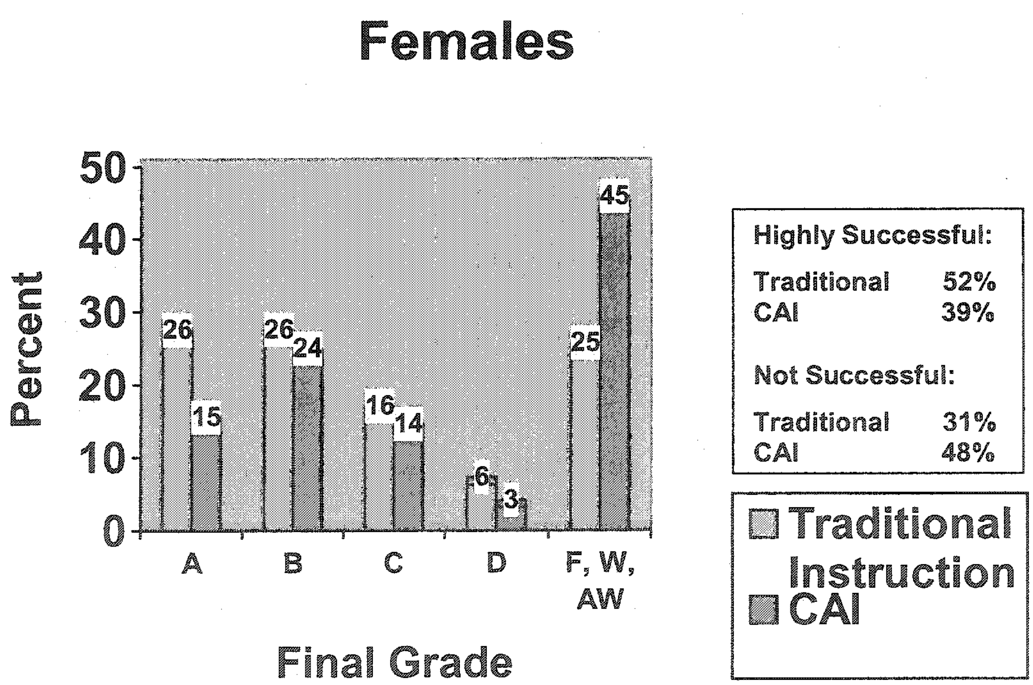


Figure 4.4. Males' and females' final grades in Survey of Algebra by type of instruction.

8. Is there a difference between traditional-age students (up to 24 years old) and non traditional-age students (25 years and older) in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) using asynchronous CAI?

As shown in Figure 4.5, non-traditional age students who used traditional instruction were much more likely than traditional age students to be highly successful, while traditional age students who used traditional instruction were somewhat more likely than non-traditional age students to not be successful in the course. This difference is statistically significant [t (1,572) = -5.504, p = .000] and the effect size is small to medium (d = .31). Non-traditional age students who used CAI were twice as likely as traditional age students to be highly successful, while traditional age students who used CAI were much more likely than non-traditional age students to not be successful in the course. This difference is statistically significant [t (105.558) = -3.169, p = .002; Levine's test indicated the variances were unequal] and the effect size is medium (d = .55). With either method of instruction, non-traditional age students were more likely than traditional age students to earn As or Bs, while traditional age students were more likely than non-traditional age students to earn Ds, Fs, Ws, or AWs.

9. Is there a difference in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) between traditional-age students (up to 24 years old) who completed the course using traditional versus asynchronous computer-assisted instruction?

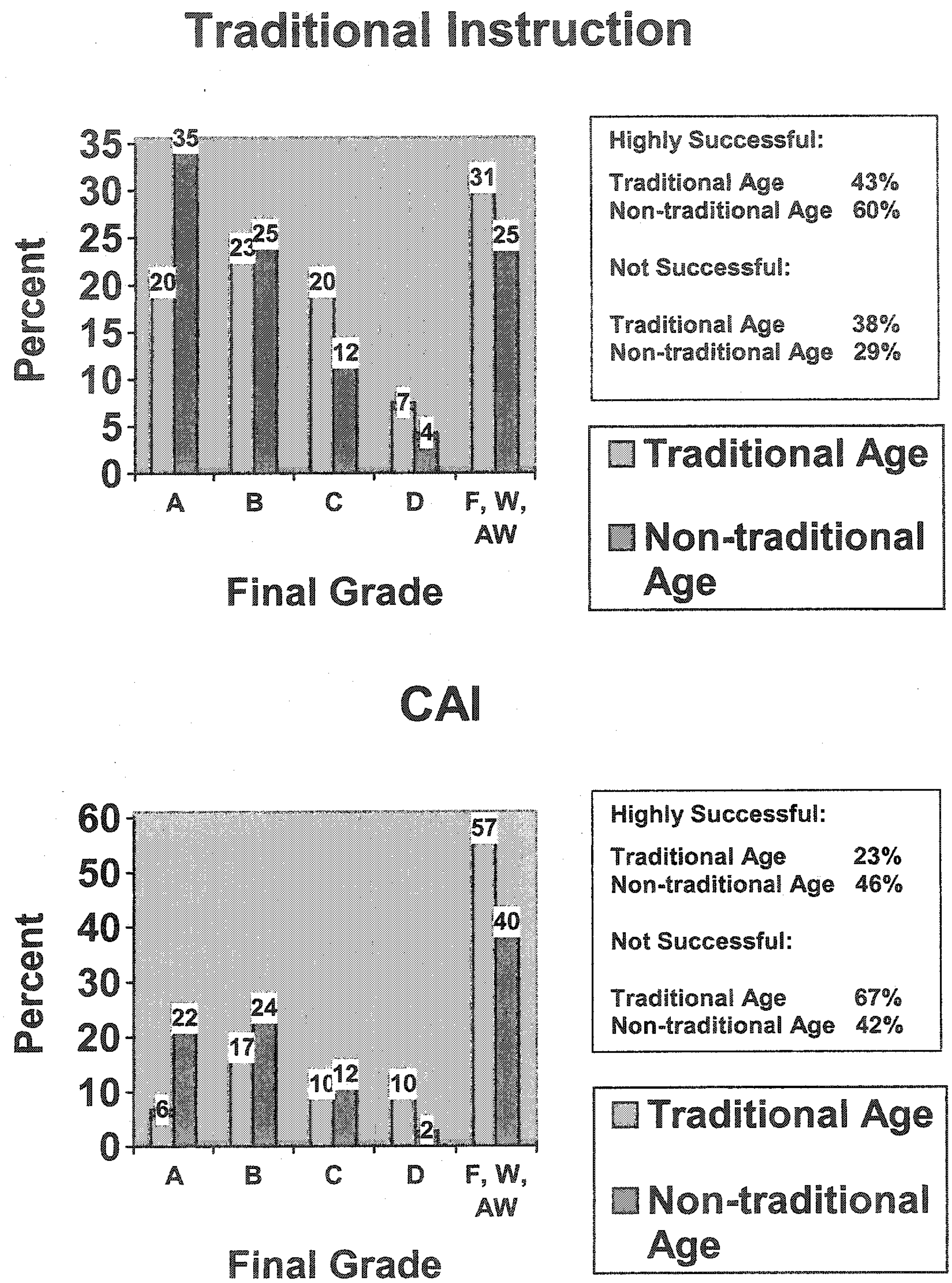


Figure 4.5. Students' final grades in Survey of Algebra using traditional instruction and CAI by students' age).

10. Is there a difference in regard to students' final course grades in a remedial mathematics course (Survey of Algebra) between non traditional-age students (25 years and older) who completed the course using traditional versus asynchronous computer-assisted instruction?

As shown in Figure 4.6, traditional age students who used traditional instruction were almost twice as likely as traditional age students who used CAI to be highly successful, while traditional age students who used CAI were almost twice as likely as traditional age students who used traditional instruction to not be successful in the course. This difference is statistically significant [t (1,216) = 5.384, p = .000] and the effect size is medium to large (d = .62). Non-traditional age students who used traditional instruction were more likely than non-traditional age students who used CAI to be highly successful, while non-traditional age students who used CAI were much more likely than non-traditional age students who used traditional instruction to not be successful in the course. This difference is not statistically significant [t (500) = 2.432, p = .015] and the effect size is small to medium (d = .33). Traditional age and non-traditional age students were more likely than their same-age peers to earn As or Bs if they used traditional instruction and were more likely to earn Ds, Fs, Ws, or AWs if they used CAI.

11. Is there an interaction between instructional delivery method (traditional versus asynchronous computer-assisted), students' gender, and students' age (up to 24 years, 25 years and older) in regard to students' final course grades in a remedial mathematics course (Survey of Algebra)?

For Question 11, the investigator conducted an ANOVA to check for any interaction between the three independent variables. As shown in Table 4.3, the main effects were

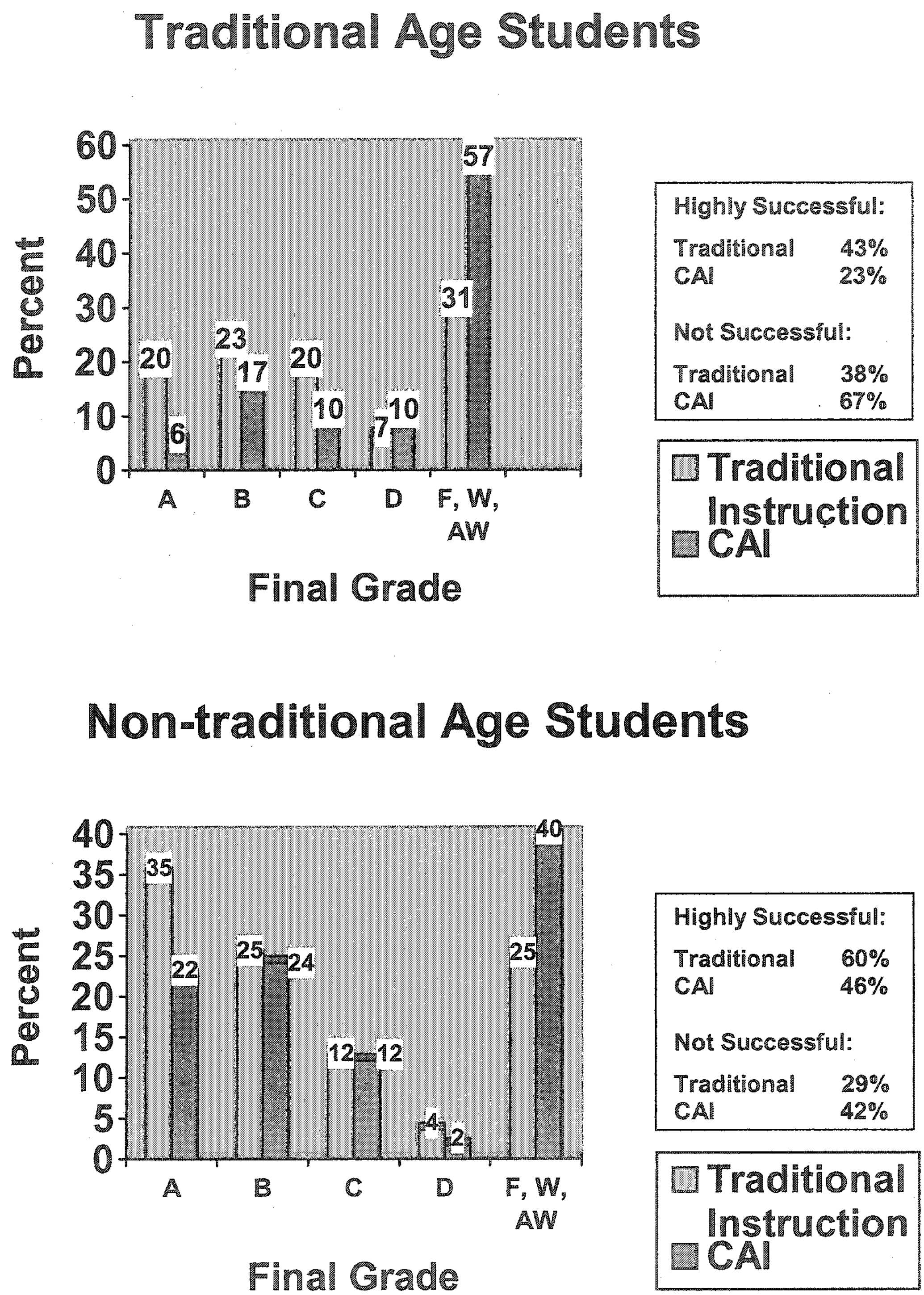


Figure 4.6. Traditional age and non-traditional age students' final grades in Survey of Algebra by type of instruction.

Table 4.3

ANOVA Using Entire Population to Check for Interactions Between Independent Variables

Source	*df*	*F*	*p*
Instructional delivery method	7	30.49*	.00
Gender	1	9.43*	.00
Age	1	22.25*	.00
Instructional delivery method X gender	1	1.14	.29
Instructional delivery method X age	1	2.26	.13
Gender X age	1	1.21	.27
Instructional delivery method X gender X age	1	.22	.64

*$p<.01$.

significant and large. This was not surprising, however, since the main effects were reported earlier as *t* tests. Table 4.3 and the mean plots in Figure 4.7 show clearly that, although the main effects were significant, there were no statistically significant interactions between independent variables.

Summary of Quantitative Analysis

Quantitative data analysis revealed that, when considering each independent variable separately, the mean grades for students who used traditional instruction, for females, and for non-traditional age students were substantially higher than the mean grades for students who used CAI, for males, and for traditional age students, respectively. For each variable, the higher-performing group had a mean grade above 2.00, while the lower-performing group had a mean grade below 2.00. When considering all three independent variables together, traditional age males who used CAI had the lowest mean grade (0.52), while non-traditional age females who used traditional instruction had the highest mean grade (2.49).

In general, students were more likely to earn As or Bs in Survey of Algebra and College Algebra if they took Survey of Algebra using traditional instruction rather than

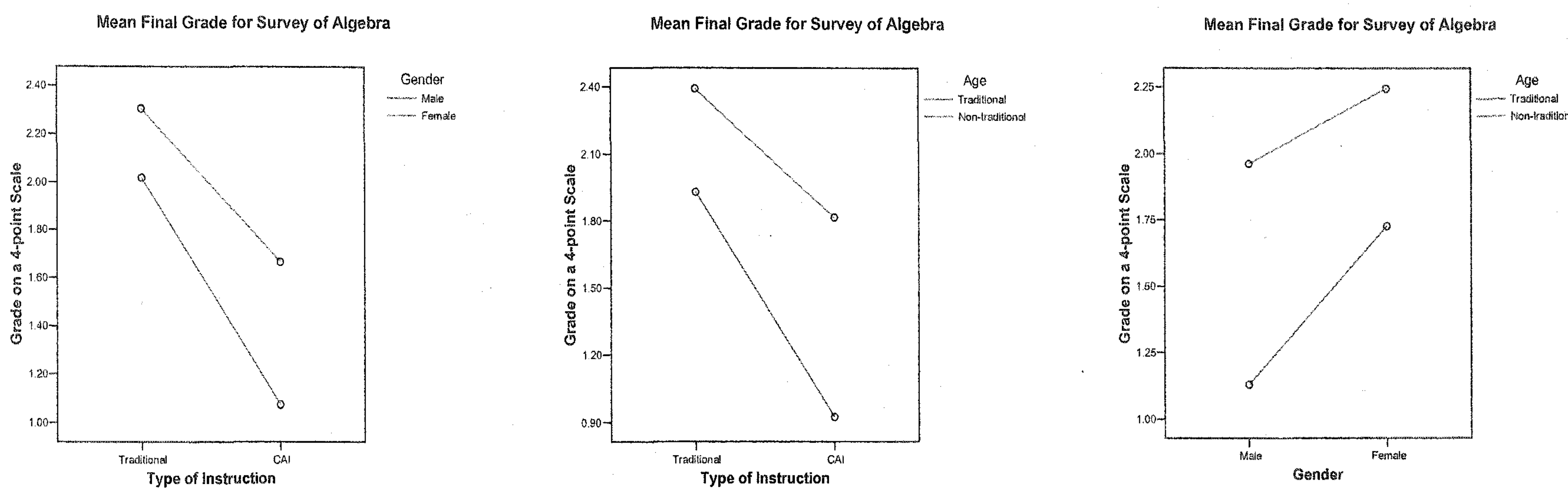


Figure 4.7. Mean plots showing mean final grades for Survey of Algebra by pairs of independent variables.

CAI. Regardless of type of instruction, females were more likely than males to earn As or Bs in Survey of Algebra. Males and females who used traditional instruction were more likely than their same-gender peers who used CAI to earn As or Bs. With either method of instruction, non-traditional age students were more likely than traditional age students to earn As or Bs. Traditional age and non-traditional age students were more likely than their same-age peers to earn As or Bs if they used traditional instruction. Results of t tests indicated that in most cases, the differences were statistically significant. Effect sizes varied from small to medium-large. Finally, although there were large, significant differences in final grade when considering each of the independent variables separately, there were no statistically significant interactions between variables.

Results for Part II – Qualitative Analysis

Table 4.4 provides descriptive information for students who participated in interviews. There were no clear patterns in final grade based upon gender, age, or a combination of gender and age.

Responses to each interview question were analyzed separately. For the first level of coding the investigator identified key phrases from the interview transcripts. Tables 4.5 through 4.16 contain first-level coding results for each question. The tables do not include all of the transcripted information, which totaled over 58 pages. (In some cases, students took the opportunity later in the interview to refer back to an earlier question to add to or elaborate upon their initial responses. A few students added important information after the tape recorder was turned off. The interviewer captured those comments in hand-written notes. Supplemental responses, whether captured on tape or in hand-written notes, also are included in the following tables, where appropriate.

Table 4.4

Descriptive Information for Students Included in Part II

Variable	Count
Gender	3 male
	8 female
Age[a]	5 traditional age (up to 24 years)
	7 non-traditional age (25 years and older)
Final Grade	A - 3
	B - 5
	C - 3
	D - 0
	F - 1

[a]Age was reported as the student's age on the day of the interview.

Bracketed words are the investigator's.)

For the second level of coding the investigator grouped similar responses from first-level coding and labeled those groups (See tables 4.17 through 4.28). Each group represents a theme or concept that one or more students mentioned. In addition, the investigator counted the number of students who mentioned each theme, to find out which themes were frequently mentioned and which were only occasionally mentioned.

It could be argued that to qualify as a *theme*, a specific category of response must have been mentioned by more than one student. While it is true that there is some danger in giving too much weight to responses mentioned by only one individual, it also may be an oversight to disregard potentially significant comments that are unique to one individual. For example, three students may make reference to a given theme as an afterthought while another student may spend a great deal of time and speak emphatically about a topic that no other student mentions.

Table 4.5

Student Responses to Question 1: "What were your reasons for choosing to take Survey of Algebra using computerized instruction?"

Participant	Comments
1	It was the only class that worked out with my schedule.
2	I guess probably the reason I decided to take the class in the first place was just convenience, just because I could do it at my own time, my own pace. Plus, I just wanted to try it; just curious how it would work on line, and test my abilities a little since I hadn't had that much experience with computers.
3	I don't want to come into a class three days a week or whatever on stuff that I already know but just don't know that well.
4	So that I could go on vacation. It was in the summer.
5	I have two small girls who it's hard to leave at home sometimes; they don't always have sitters... I thought that would be a good way to still get a class out of the way, but without having to find babysitters.
6	Just to be at home more. I have children, so I wanted to be at home more. And that was the third time I took that class, and I wasn't getting it in the classroom. [Student took Survey of Algebra twice in past using traditional instruction and withdrew both times shortly before final exam]
7	Well, actually it's because of my work. It's kind of hard for me to get into classes, but I needed to take a math credits class, so that fit my schedule well so I could do the work in my free time at work and at home. Just for time constraints.
8	Because they cancelled my classroom class at that time.
9	I opted to take it on line just to save myself from having to come to campus.
10	I didn't have enough time to go to class, so it was just a way for me to get it done by doing it at home.
11	I liked the online part of it so I didn't have to drive to Fort Lupton every day, because I live in Longmont.
12	Well, I've had quite a few of the instructors there at the college...the instructor that runs the class...he's in the lab all the time... He could help me when I had a lot of questions... It's easier [with CAI] because if you have problems, you can continually go back and get help from the computer...[Student took Survey of Algebra in past using traditional instruction and earned a D]

Table 4.6

Student Responses to Question 2: "Did you receive any advising about taking this class, such as from an instructor or advisor at Aims?"

Participant	Comments
1	No, I didn't discuss it with anyone beforehand, other than [my advisor at Aims] told me that it was a computer class.
2	The first class that I went to…[the instructor] went over the whole thing, how it works and what you need to do.[a]
3	I asked my advisor…if it would be a good idea, and he said it would; it would…reiterate those basic math skills to help you with college algebra. So yeah, he told me that it was probably a good idea.
4	No. Actually…my prior instructor, I talked to him and he said . . . actually, I don't even remember what he said. We talked about it a little bit, but….
5	We had to do…a one-hour thing with [the instructor] before we could even start the class. We had to go in—that was mandatory—for him to explain how the program worked.
6	No…. I was gone for a year [from Aims] and I came back and they had online courses, which they didn't have before. . . I thought, "I'll give it a try." [Student took Survey of Algebra twice in past using traditional instruction and withdrew both times shortly before final exam]
7	My advisor said I could take a math course, and she was aware . . . of my job.... She said, "There's this one offered on line; you should try that one." She wasn't my advisor…She was just some lady that was helping with advising that day.
8	Yes, I did… It was from another instructor… It was a math teacher. [S/he told me to] basically keep on time, keep the schedule…
9	I met with an advisor to go over my schedule, but . . . we didn't talk specifically about this class… We went to an orientation by the instructor. But the [software] program was actually not installed yet, so we couldn't do any kind of hands-on instruction at that point. And that was on the first night of class.
10	Yeah, I think I did in Loveland…but I don't really recall… I think the only thing I can recall is that they said it would be . . . you know, you do it at home. It's an online thing, and that was it.
11	I did see an advisor at the beginning, and the instructor did an orientation in the class.
12	No, I just decided to take the class because…it seemed like it would probably work better for me that way. [Student took Survey of Algebra in past using traditional instruction and earned a D]

Note. In retrospect, Question 2 wasn't worded appropriately to elicit the type of response that the investigator had intended. The investigator had hoped to find out whether students had received advising specifically about the method of instructional delivery (CAI). Several students were unclear in their responses about who they met with and/or what was discussed.

[a]Each section taught using CAI had a mandatory face-to-face meeting the first session of the term. The purpose of the meeting was to explain the software program, course expectations, etc.

Table 4.7

Student Responses to Question 3: "What did you like the most about the class?"

Participant	Comments
1	I liked the flexibility of how it wasn't . . . that you had to get a certain thing done in a certain amount of time. You had time to, if it was tougher than the other stuff, to spend more time on it.
2	I could go at my own pace. You could do it at home. I felt like I had enough support...which is important if you don't understand something. I really liked that I could keep going at my own pace, and I could get ahead.
3	I really liked the fact that you could go at your own pace...I could study it at 12:00 at night...We had a guideline...but...you had two weeks to finish this lesson. And even if you didn't finish it in those two weeks, you could still make it up.
4	I liked it that I could learn at my own pace. I was able to focus more on the book and kind of figure it out in my own head; kind of learn on my own.
5	Just being able to do it when I had time...not having to show up for specific classes.
6	Being able to know exactly what I did on an assignment right away so that I could immediately study what I got wrong before the exams.
7	The flexibility on time was nice. I was able to do the work when I wanted.
8	Oh, nothing.
9	I don't know; I didn't really like the class.
10	That I could go at my own pace. And if I found something I didn't understand, it was very easy to go back and go through the slides that it was showing, or the program.
11	I liked being able to do it when I had a chance to do it instead of having to go to class at specific time. I liked how self-paced it was, too. You could work a lot faster if you wanted to and get it done earlier if you needed to.
12	That it's kind of work at your own pace. That way, there was no exact deadlines... so...if you couldn't make it to something, there was not a really big problem with that. If a test time didn't work for you, you could work it out to where you could take it later.

Table 4.8

Student Responses to Question 4: "What did you like the least about the class?"

Participant	Comments
1	I didn't like how it was put one way [in the computer program], and if you didn't understand it that way, there wasn't a different way that it showed you.
2	The tests...when I had to go take three different chapters or whatever, after a month's time, and go in and take a test...I just don't have very good long-term retention.
3	The lessons took a long time, and they went into...great detail. I found myself playing a lot of catch-up right before the test...The written test didn't really cover what I learned on the program...it was obvious that the instructor made the test up himself separate from the program. [Comment made after tape recorder turned off: The program itself was kind of corny (music, pictures, tying math to real life)]
4	Not having an instructor available for an immediate question.
5	Finding time to do the work...The only thing I would say that I didn't like was, when I went into a lesson that I did understand, you couldn't skip on to the next page if you got that one. You had to wait for [the computer program] to read the whole page before you could go to the next one.
6	The cost...The book and the software are more expensive than... your average math book.
7	The bad part about doing stuff on line is you don't have any interaction with anyone else. So if you have problems, you're kind of on your own. So even through email, there's a time delay on responses.
8	It was too complicated for me...Like, to do it on your own. It was hard to work on your own. And not having a teacher to review, to explain to me when you have a question. By the end of the course, they had problems on the computer, too.
9	I didn't like the "classroom" management. Even though it wasn't in a classroom situation, I didn't think that it was run very well. There wasn't a lot of interaction with the instructor...I just kind of felt like I was left out there by myself...the only way...to contact [the instructor] was to go to his office, and he had very limited office hours...[at times when] I couldn't get there. And those were also the only times we could take the tests.
10	There wasn't anything that I didn't like.
11	Sometimes it was really hard to stay motivated to get it done, to keep up with what I was supposed to have done.
12	Sometimes you go in [the lab] and the computers that have the software, other people are using, and you can't use them...when I load [the software] on my computer at home, I have a lot of problems getting onto the mainframe with that.

Table 4.9

Student Responses to Question 5: "What were the most difficult parts about the class?"

Participant	Comments
1	[The computer] would present it one way, and if I didn't get it, I would have to go to other resources to be able to figure it out and then go back and do it, instead of clicking a different button and having it put a different way.
2	You don't have somebody right there to ask a question if you need it. You have a little bit of a delay.
3	I'd see my schedule and go, "Oh, you have two weeks to do this lesson and this lesson. That's not bad." But when the lessons are two hours each, and you have to...take time to do the lessons and then practice what you learned and do the homework that they recommend...you've really got to schedule it unless you want to do it all at once
4	I didn't find anything difficult.
5	Going in, I didn't always know exactly what to expect on the tests....It was mainly placing a phone call to the instructor and saying, "This is what I had a problem with on this test. Is that going to be reoccurring?" And then, he was more than happy to say, you know, "You need to focus on graphing because there's going to be a lot of that on your next exam."
6	I can't think of much bad about it.
7	Oh, the same thing [as response to Question 4].
8	A lot of problems with the computer. I might log in or something and get kicked out of the system.
9	Probably a lot of the same things [as student mentioned in Question 4]. The subject matter was not my strong point to begin with, so I probably required more in-depth instruction than a lot of the students who were in this class might have.
10	There was nothing.
11	Just to stay motivated. And then...some of it was hard to understand, so it was harder to get on my own, just by reading it and using the computer.
12	The most difficult part about the class itself would probably have to be the software—trying to get that to load onto your computer.

Table 4.10

Student Responses to Question 6: "What did you do when you needed help or didn't understand something in the class?"

Participant	Comments
1	I would just meet with...the instructor for the class.
2	I usually communicated through email...with the instructor.
3	Most of it...I kind of figured it out on my own. My sister...was also taking a college algebra class. She helped if I had a question. The book really helped...because it had examples. The [computer] program did a really good job of explaining the process...But if I didn't understand it, I'd look in the book.
4	I was able to go to the tutoring office.
5	I did call [the instructor] most of the time... I could ask other people who were taking math classes. I did that also. But mainly I just gave [the instructor] a call and asked him a question.
6	I would email the instructor...I think that only happened one time. And I went into the tutoring lab as often as I needed to, because I had classes on campus also.
7	It only happened twice, but I talked to the teacher in email, and he usually got back to me within a couple of days. And that was it. He answered the questions and went on from there.
8	The teacher was there [at the lab on campus] when I went...I tried to be there when he was there.
9	I did go in a couple of times during [the instructor's] office hours to get some help. I also met with the math department head...on one occasion. And then, I utilized the tutorials and the software also.
10	The instructor...let us know when he'd be available, and we could send him an email or call him, and one time I did an email, and another time I called.
11	I could contact the teacher. He had office hours and I could go into the campus and talk to him then.
12	I used the lab and talked to [the instructor] or emailed him.

Table 4.11

Student Responses to Question 7: "How would you describe your overall effort in the class?"

Participant	Comments
1	I put out a decent amount of effort. It wasn't an extremely hard thing for me to get through, but it did take some effort.
2	I felt like I worked pretty hard. It was really important to me to do well…I suppose I could have studied more.
3	I put a lot of effort into it.
4	I'm a self-motivator, so I put effort into it. It takes a little bit more effort because you're trying to figure it on your own, but not a lot.
5	The best that I could at the time. It's like I said, I had a three-month-old, so that was a little time-consuming.
6	I give probably a good 85 percent effort…Loved that B. Loved that B. In fact, I worked my butt off for that one.
7	About the same as any other. It was a pretty easy class, so I didn't have to work too hard at it. But I didn't work any less hard because it was on line or anything like that.
8	*I didn't put any effort on that.*
9	I'd probably give it a 7 out of 10. I wasn't terribly motivated, just because I was having a hard time.
10	I put a lot of effort into it to make sure that I understood what was going on, because in high school I really didn't pay attention. So I wanted to make sure that I did what I needed to do, and made sure I made the time and did the math that was needed to get the grade I got.
11	I think I probably could have put a little more effort into it and did a little bit better on the tests and that kind of thing when I went in to take them. But I put a lot of effort into it at home to do the homework and to keep up with it.
12	I think I tried harder in that class than I did in the actual classroom because it seemed to be more personal. [Student took Survey of Algebra in past using traditional instruction and earned a D]

Table 4.12

Student Responses to Question 8: "How would you compare this math class to other math classes you have had?"

Participant	Comments
1	The other math classes that I've had...they just seem to be easier.
2	I took Elementary Algebra [in the traditional format]...if you just lose [the instructor] for a second and there are 40 people in the class...sometimes you can raise your hand, but other times you just don't feel like raising your hand every time you don't understand something. And so you end up getting behind, and then you kind of feel like you're lost in the class...On the on-line class...you can just go at your own pace...If you want to back up a screen or spend 10 minutes on one screen, you can.
3	Compared to other classes, I like the fact that...I have to rely on myself to learn it instead of somebody else's way to learn it...I can interpret it and have it make sense to me instead of relying on a teacher to tell me all the answers...I really liked that. It made me rely on my own thinking.
4	It's not much different. I liked it because it took me less time.
5	I liked it better just that I didn't have to sit and listen...to a professor...I've always done better when I'm able to kind of figure it out on my own at my own pace.
6	I actually understood things that I couldn't get in the classroom...It was the easiest math class I've ever had...I think mostly because of the immediate feedback. Because I knew right away what I didn't know and what I did know, so I could concentrate immediately on what I didn't know and kind of go over what I did already. [Student took Survey of Algebra twice in past using traditional instruction and withdrew both times shortly before final exam]
7	Well, it was pretty darn easy, because I took the harder stuff in high school...I liked [the format] more.
8	It was hard...trying to understand...on your own.
9	I would say the structure of the class...was more difficult....It just didn't work for me with my learning style. I felt like I needed to have more interaction with other students and with the instructor on a daily basis, more structured assignments and homework.
10	I liked...that I could do it at home, I could go at my own pace, and there was no peer pressure or people making fun of you if you didn't understand anything...I wasn't compared to, "They're going faster," or, "They're going slower," or, "Somebody will think I'm asking a stupid question," type of thing.
11	I liked this one...much better than my high school math classes. I understood it a lot more. It explained the basics and the concepts behind the algebra instead of just the formulas.
12	This math class...seemed to be much more helpful...because it wasn't 30 other kids and competition when you didn't understand something...If you had a problem, you got a personal answer from the instructor...It seemed to be more directed to help the individual.

Note. In retrospect, Question 8 wasn't worded appropriately to elicit the type of response that the investigator had intended. The investigator had hoped students would make comparisons to other math courses with respect to instructional delivery method specifically (CAI vs. traditional instruction). Some students did not address differences in instructional delivery method in their responses.

Table 4.13

Student Responses to Question 9: "What recommendations do you have for improving the class?"

Participant	Comments
1	Have somebody…on line at the time…that was there to help you with any questions that you had, or to show it to you a different way.
2	It's just important for teachers to make sure that they somehow stress the importance of staying on track and doing the work through the book...You wouldn't have to…actually read the chapter, but it's very helpful to do that. [Comment made after tape recorder turned off: During first class session, instructor should show students how to use software program.]
3	I had a couple of…technical difficulties with the program…I couldn't enter [the answer]. It was the most frustrating thing.
4	I didn't have any problems with it. I liked the book…I liked everything that we used.
5	Maybe looking at people who make the program…about skipping ahead if you understand it.
6	I think there are some things on the software that are a little dumbed-down for college level…I remember one section of it, I think it was binomials…I just thought it was a little hokey, I guess.
7	The online stuff…a lot of it, you couldn't skip through, if stuff that you knew. So it was very time-consuming when it didn't necessarily have to be.
8	I think you should work…in groups…Because whatever one doesn't know, the other might know, or might figure it out easier.
9	I would probably have more of a schedule. Say, "On this night, do this assignment." I've taken other online classes where there were regular conference calls between the teacher and the student that were set up on a biweekly basis…More open schedule for testing—times that you have to go onto campus to do the testing.
10	I think keeping it and not changing the way it is.
11	There were a few things I had trouble with the program actually working…you couldn't put the right answers in because it didn't have the right buttons, or certain things like that…The instructor could have been a little bit more helpful at the beginning to tell us how the class was going to work, how often we needed to see him, and that kind of stuff…
12	That was frustrating sometimes…when you knew that there were certain computers [in the lab] that you needed to use because that's what the software was loaded onto, and they were taken…you couldn't tell them to move.

Table 4.14

Student Responses to Question 10: "Would you take another class (either math or a different subject) using computerized instruction?"

Participant	Comments
1	Any other class would be okay, but probably not a math…
2	Yeah. I'm taking three more classes right now on line…U.S. History 2, English Comp 2, and Philosophy. [Student also took College Algebra and Comp I using CAI]
3	Yeah, I would…psychology class was part on line. But all of it on line? I don't know.
4	Definitely. I am right now. [Child Development] [Student had taken internet class before; specific subject not mentioned]
5	Yes…I'm taking College Algebra now
6	I am taking Psych II now on line, which is a little different because it doesn't have the software that goes along with it; it's just instructor-based…And then, I took Philosophy last spring.
7	I don't think I'd want to take a new math class that way… something I wasn't familiar with.
8	Yeah…I'm taking Psychology right now. And I took Archaeology. Actually, I like it…I think it's just math [that is difficult to do online]…
9	I'm not going to do math on line anymore. I would not take math. But yes…I had a great experience with my English class…I did that on line…But no, I wouldn't do math, simply because it didn't work for me for that subject.
10	I definitely would do the math. I haven't had any experience taking any other classes on line. [Student also took course immediately preceding Survey of Algebra using CAI]
11	I think it would depend on the class, but I would.
12	I did take English 090 on line as well, and I'm taking [College Algebra] this semester on line as well.

Table 4.15

Student Responses to Question 11: "What advice would you give to another student considering taking this class using computerized instruction?"

Participant	Comments
1	Definitely make sure that you at least have the book as another resource, because the book also gives you different ways. And if you're not very good with math in the first place, I wouldn't advise taking a computer math course.
2	The first thing I told [my stepdaughter when she took the class] is, "Make sure you stay on track. Don't get behind." You really need to keep up...you don't want to get behind.
3	I can't imagine going into it not knowing anything about that math...And I'd say, "If you're not very good at teaching yourself something, then it's probably not for you."...I see a lot of people getting frustrated with math teachers, and I think...an Internet class would be good for them. Especially math.
4	I would think that if somebody didn't take an Internet class before, they might find it a little hard at first...If they're self-motivated...People who can think on your own, figure things out.
5	Make sure you have a set schedule where you can sit down and work on it...Make sure that they...followed the deadlines.
6	If you have no personal structure or motivation to do your work, it won't work for you. You have to be able to sit down at your computer as long as it takes to get the assignment done...I don't think it would work for anybody that didn't have that stick-to-it-iveness.
7	Don't procrastinate...if you don't do everything you need, it's not going to work.
8	Don't put it off...Try to keep the schedule...Use the instructor, too, as much as they can.
9	I would probably just suggest that if the hours that the professor is available work for them, and that math is a strong subject for them, I probably would suggest it...
10	Make sure that you're disciplined to where you can sit down and do it at home. Make sure you make the time to study... and just know that the teachers [are]... great, and helpful
11	Don't get behind. It's hard to get caught up if you get behind in what you're trying to do.
12	Make sure you don't turn the sound off. When the program talks to you, don't just try and look at the examples, because the voices will actually help explain it to you real good. Take it with [student named a specific instructor]. He's a really good teacher, so. . . .

Table 4.16

Student Responses to Question 12: "Is there anything else you would like to share about your experience in the class?"

Participant	Comments
1	It wasn't a horrible thing. It just would have been easier if it was the traditional way.
2	Not really. I think that about covered it.
3	I don't think people really know much about it...If you had a question or something wasn't going well, you could go in for a tutorial session... I always see them offered all the time...The [instructor] was very personal...in his emails with me, he took time to go through each email and answer questions...I could always rely on him and [he] emailed back.
4	I can't think of anything.
5	I would recommend definitely doing more online classes that transfer...Because it is a good way to get them out of the way without having to drive all the way to one of the universities...[The instructor] gave us feedback at the end-of-the-semester thing. People who kind of kept up with that syllabus...did a lot better. So I mean, I think that's a good point is, stick with the due dates.
6	I guess the only thing I can think of is that I kind of had to figure out that there were online classes...I'm not sure if other people knew that they're available. I only knew because I was looking for them, because I knew I wanted to be at home.
7	Not really.
8	When I look for help, I can find it...I did take the class in a classroom and...I got an A...It works if you have the time and you don't have kids...I think it will work for people who are just students and single.
9	That may have been part of the reason why it's hard for me, because it's been 20 years since I took math...The distance in learning between when I last took math and now may have been part of my difficulty. It might not be as hard for someone coming right in from high school...I wasn't terribly motivated, just because I was having a hard time. So I felt my motivation slipping toward the end of the semester.
10	The most top in my mind is keeping it the way it is, or keeping...the same type of computer program...And for somebody that flunked, or got really bad grades in math in high school, I ended up with an A and a B in the two classes that I took...Yeah. I really learned it this time...The only reason I got a B was because I started late and had to kind of rush through a couple of the chapters... [The instructor] was very reachable and made sure that... he'd understood my question...then made sure that I understood what he was explaining.
11	I think, overall, it was a very good program. The actual...instruction...was very detailed and very easy to follow, and...it was much better than just trying to read it out of the book.
12	[The company that owns the program is] using third-party software, so it's really hard on the computers on home to load it. I mean, you have to pretty much shut down all of your security systems...And with those unknowns, then you have to kind of leave yourself open to junk...if we could tie in just through the [college] website for it.

Note. Question 12 was included to serve as a catch-all so that students could mention other things they felt would be important or relevant.

Table 4.17

Major Themes Developed from Student Responses to Interview Question 1: "What were your reasons for choosing to take Survey of Algebra using computerized instruction?"

Theme	Number of participants who mentioned theme
Individualization:	6
Could work at own pace	
Could learn on own	
Could get ahead	
Fit with time constraints (work, family, vacation)	
Location:	5
Going to class/campus not required	
Could work at home/work	
Support:	1
Could get help from computer program	
Instructor available in lab	
Past experience:	1
Unsuccessful in classroom setting in past	
Other:	2
Curious how online class worked	
Test abilities because not much computer experience	
Cancelled section student had registered for	

Table 4.18

Major Themes Developed from Student Responses to Interview Question 2: "Did you receive any advising about taking this class, such as from an instructor or advisor at Aims?"

Theme	Number of participants who mentioned theme
No	2
Yes, met with an advisor	5
Yes, met with course instructor during first class session (face-to-face meeting)	4
Yes, met with another math instructor	2
Did not remember/specify clearly	1

Table 4.19

Major Themes Developed from Student Responses to Interview Question 3: "What did you like the most about the class?"

Theme	Number of participants who mentioned theme
Individualization:	9
Could work on own schedule	
Could work at own pace	
Could learn on own	
Could get ahead	
No specific deadlines	
Could spend more time on difficult topics	
Location:	3
Going to class/campus not required	
Could work at home/work	
Support:	2
Could get help from computer program	
Computer provided immediate feedback	
Nothing/Don't know/Did not like class	2

Table 4.20

Major Themes Developed from Student Responses to Interview Question 4: "What did you like the least about the class?"

Theme	Number of participants who mentioned theme
Computer program: Lacked multiple explanations of material Didn't allow student to skip sections s/he understood Program was corny	3
Testing: Tests covered multiple chapters; delay difficult for students with poor long-term retention Tests didn't cover same material that was on computer program/Instructors wrote tests Hours for testing limited/at inconvenient times	3
Support: Help not immediately available when student had question Delay with e-mail Instructors' office hours limited/at inconvenient times Little interaction with instructor	4
Isolation: No interaction with others Hard for student to work on his/her own	3
Cost: Book and software were expensive	1
Computer availability: All computers in lab taken	1
Technical difficulties with computers: Loading software at home Logging on	2
Time management: Difficult to find time for/keep up with homework	3
Motivation: Difficult to stay motivated	1
Nothing student didn't like	1

Table 4.21

Major Themes Developed from Student Responses to Interview Question 5: "What were the most difficult parts about the class?"

Theme	Number of participants who mentioned theme
Computer program: Lacked multiple explanations of material Student had to use other resources and then return to computer program to do work	1
Testing: Not knowing what to expect on first tests Hours for testing limited/at inconvenient times	2
Support: Help not immediately available when student had question Time delay with e-mail Instructors' office hours limited/at inconvenient times Little interaction with instructor	3
Isolation: Some information hard to understand on own Student is on her/his own if s/he has problems	3
Technical difficulties with computers: Logging in Loading software at home	2
Time management: Overestimating time available to work on course Underestimating amount of time needed to work on course	1
Motivation: Difficult to stay motivated	1
Individual aptitude: Math is not student's strength Student required more in-depth instruction than other students	1
Student found nothing difficult/Unsure	3

Table 4.22

Major Themes Developed from Student Responses to Interview Question 6: "What did you do when you needed help or didn't understand something in the class?"

Theme	Number of participants who mentioned theme
Met with the instructor in the lab or during office hours	5
Communicated with the instructor through email	5
Communicated with the instructor over the phone	2
Met with the department head	1
Used Aims' tutoring services	2
Asked students in other math classes	2
Looked in the book	1
Utilized software	1
Figured it out on his/her own	1

Table 4.23

Major Themes Developed from Student Responses to Interview Question 7: "How would you describe your overall effort in the class?"

Theme	Number of participants who mentioned theme
No effort	1
Moderate amount of effort/Some effort	4
A lot of effort	4
More effort than in other classes	1
Same effort as in other classes	1
Could have studied more/given more effort	2
Student gave the best s/he could at the time	1

Table 4.24

Major Themes Developed from Student Responses to Interview Question 8: "How would you compare this math class to other math classes you have had?"

Theme	Number of participants who mentioned theme
Positive aspect of this class: Liked the format/structure (computerized instruction)	1
Positive aspect of this class: Individualization Could work at own pace Relying on self vs. teacher to learn Not required to sit and listen to instructor Could work at home More directed to help individual student No peer pressure	5
Positive aspect of this class: Support Computer provided immediate feedback Could get a personal answer from instructor Student did not have to compete with others	2
Positive aspect of this class: Time commitment This class took less time	1
Positive aspect of this class: Learning/Comprehension Student understood (things that s/he was not able to understand when she took course in traditional format)	2
Positive aspect of this class: Difficulty Easiest math class student has ever had Easy	2
Negative aspect of this class: Isolation Difficult trying to understand on own Needed more interaction with students/instructor	2
Negative aspect of this class: Format/structure Structure didn't fit with student's learning style Needed more structured homework/assignments	2
Positive aspect of other classes: Other classes were easier	1
Negative aspects of other classes: Got behind/felt lost in classes taught in traditional format	1
Not much difference	1

Table 4.25

Major Themes Developed from Student Responses to Interview Question 9: "What recommendations do you have for improving the class?"

Theme	Number of participants who mentioned theme
Direction from instructor: More information in the beginning from the instructor about course logistics Instructor should *show* students how to use software program at first class session (face-to-face), rather than just talking about it Instructors stress importance of staying on track Instructors stress importance of using book	2
Support: Have someone available online to provide immediate help Set regular conference calls between student and instructor	2
Computer program: Address technical glitches with software program Alter so that student can skip ahead Ensure presentation appropriate for students' maturity level Ensure sufficient computers are loaded with software and available in lab	6
Testing: More flexibility/hours when students can go to campus to test	1
Other: Include group work Set a more specific schedule for assignments	2
No suggestions/problems Keep it the same	2

Table 4.26

Major Themes Developed from Student Responses to Interview Question 10: "Would you take another class (either math or a different subject) using computerized instruction?"

Theme	Number of participants who mentioned theme
Yes, has taken another math course	4
Yes, has taken a course in another subject	7
Yes, would take another math course	1
No, would not take another math course	2
Yes, would take a course in another subject	1
Yes, but it would depend on the particular course	1

Table 4.27

Major Themes Developed from Student Responses to Interview Question 11: "What advice would you give to another student considering taking this class using computerized instruction?"

Theme	Number of participants who mentioned theme
Motivation:	2
Does student have personal motivation?	
Aptitude for/knowledge of math:	3
Is student strong in vs. not good at math?	
Does student know anything about the math content?	
Independent learner:	2
Is student able to figure things out on his/her own?	
Is student good at teaching self?	
Discipline/time management:	7
Have a set schedule	
Make time to do the work at home	
Stay on track/Be disciplined	
Don't procrastinate/get behind	
Follow instructor's general deadlines	
Support:	3
Use book as resource	
Use instructor as much as possible	
Instructors are helpful	
Computer program:	1
Don't turn sound off, voices are helpful in explaining	
Other:	4
Course might be difficult for student if it is first CAI course s/he has taken	
Take the course with a specific instructor	
Might be good if student gets frustrated with math instructors	
Be sure instructor's schedule of availability works with student's schedule	

Table 4.28

Major Themes Developed from Student Responses to Interview Question 12: "Is there anything else you would like to share about your experience in the class?"

Theme	Number of participants who mentioned theme
CAI vs. traditional: Student recommended offering more CAI courses, including courses that transfer so students don't have to drive to university Traditional instruction would have been easier.	2
Marketing of CAI courses: Student felt not many other students knew about CAI option	2
Computer program: Program was detailed, easy to follow, and easier than trying to learn from book Keep the same computer program Company that owns program is using third-party software which makes students' computers vulnerable when loading software	3
Support/resources: Student was able to find help when s/he looked Tutorial sessions were readily available Instructor was accessible, reliable, helpful	3
Personal characteristics/reflections on individual experiences: Student who earned F believes CAI would work for students who are single (no kids), have time, and are just students (vs. working full-time) Student received feedback from instructor that students who kept up generally did better in class Student attributed difficulty to the fact that he hadn't taken a math class for 20 years Student felt motivation slipping toward end of semester because s/he was having a hard time Student felt s/he earned a B in class only because s/he started late and had to rush Student who earned low math grades in high school (F) felt s/he really learned the math this time Student who earned F in CAI section later earned A in traditional section	4
No additional comments	3

For the third level of coding, the investigator summarized students' responses to each question in a few sentences, referring to the themes that were generated most often. Table 4.29 shows the results of the third level of coding.

Table 4.29

Summaries of Major Themes from Students' Responses to Interview Questions

Question	Summary
1. What were your reasons for choosing to take Survey of Algebra using computerized instruction?	Most students chose to take the class in a section that used CAI because doing so allowed for more individualized learning, flexibility, and/or convenience. Having access to academic support also was a factor in some students' decisions and some chose a CAI section because they had been unsuccessful taking the course in the traditional format in the past.
2. Did you receive any advising about taking this class, such as from an instructor or advisor at Aims?	Some students met with an advisor or another math instructor prior to taking the class, although it was not always clear from students' responses during the interview whether instructional delivery method was discussed. Some students said the advising they received came during the first class meeting, a mandatory face-to-face meeting where the instructor explained how the course would work. In some cases, no advising occurred.
3. What did you like the most about the class?	Aspects of the class that students liked the most were similar to the themes generated when students explained why they took the class using CAI (Question 1). Individualized learning, flexibility, convenience, and opportunities for support were the most common themes.
4. What did you like the least about the class?	Aspects of the class that students liked the least varied. The theme mentioned most often was having insufficient or delayed support from the instructor. Others included feeling isolated, being dissatisfied with aspects of the computer program and/or testing, having difficulty with time management, and having technical difficulties with the computers/software.
5. What were the most difficult parts about the class?	Students' responses about the most difficult parts of the class often were similar to their responses about what they liked the least (Question 4). The most common themes included having insufficient or delayed support from the instructor and feeling isolated. Having technical difficulties with the computers/software and being dissatisfied with testing also were cited by more than one student. A few students said nothing about the course was difficult for them.
6. What did you do when you needed help or didn't understand something in the class?	Nearly every student used the instructor for help with the class. Most often, this meant meeting with the instructor during office hours or in the computer lab or communicating via email. Some students communicated with the instructor over the telephone, used college tutorial services, or asked other students for help.
7. How would you describe your overall effort in the class?	Most students felt they gave either a moderate amount or a lot of effort for this class. Students mentioned that they gave either the same amount or more effort than they gave to other classes. A couple of students said they could have given more effort and one said she put no effort into the class.
8. How would you compare this math class to other math classes you have had?	Most students mentioned positive aspects of the CAI class. The most frequently cited positive aspect was the individualization. Students also mentioned that, compared to other classes, the CAI class was easy, they understood it, and they received support and feedback. Negative aspects of the CAI class included that students felt isolated and/or did not like the structure/format of the class.
9. What recommendations do you have for improving the class?	Students' recommendations for improving the class varied but most often reflected the aspects of the class that students liked least (Question 4) or had difficulty with (Question 5). Dissatisfaction with the computers and various aspects of the computer program were most commonly cited. Having more direction and support from the instructor was also mentioned by several students.
10. Would you take another class (either math or a different subject) using computerized instruction?	Several students had already taken or said they would be willing to take another math class using CAI, although two students said they would not take another math class in that format. More than half of the students had already taken or said they would take another course using CAI, in a subject other than math.
11. What advice would you give to another student considering taking this class using computerized instruction?	Students most often said they would encourage/discourage others from taking the course using CAI depending upon whether they possess specific personal characteristics, including discipline/time management, aptitude for math or some knowledge about the content, motivation, and ability to learn independently. They also recommended that students taking the class using CAI use available resources, including the instructor, the book, and the audio portion of the computer program.
12. Is there anything else you would like to share about your experience in the class?	Most of the responses to the final open-ended question reflected themes that had been brought up in earlier questions, including comments about the computer program, support/resources, and personal characteristics that students attribute to success/non success in the course. However, two students mentioned that they didn't feel many other students knew about the availability of CAI courses, a topic that hadn't come up in responses to previous questions.

To increase the validity of the findings from interviews, the investigator went back to the interview transcripts and searched for contradictions or discrepancies among students' responses. Quotes that illustrate these contradictions are grouped by topic in Table 4.30. (Topics do not necessarily correlate with specific interview questions. Bracketed words are the investigator's.)

Table 4.30

Evidence of Discrepancies or Contradictions in Students' Comments During Interviews

Topic	Examples of contradictions or discrepancies
Degree to which student enjoyed this course	I loved it. I loved it.
	I actually enjoyed it.
	I didn't really like the class.
	Oh, [I really liked] nothing [about the class].
Degree of difficulty of this course compared to other math courses student had taken	It was the easiest math class I've ever had.
	It was a pretty easy, straightforward class.
	It was really easy.
	It was hard.
	The other math classes [in a traditional setting] that I've had...they just seem to be easier.
Software program that was used in this course	The program did a really good job of explaining the process.
	The instruction that the computer gave was very detailed and very easy to follow.
	The computer was just too confusing for me.
	The teachers [have] different, easy ways to do problems, to solve problems, than the way they are on the computer.
Amount of effort student put into this course	I put a lot of effort into it.
	I didn't put any effort on that.
Learning on their own in this course	I like the fact that...I have to rely on myself to learn it.
	I've always done better when I'm able to kind of figure it out on my own.
	Some of it was hard to understand, so it was harder to get on my own, just by reading it and using the computer.
	To do it on your own; it was hard to work on your own.
Implications of having children while taking this course	I have two small girls who it's hard to leave at home sometimes...So...I thought that would be a good way to still get a class out of the way, but without having to find babysitters.
	I have children, so I wanted to be at home more.
	It works if you...don't have kids... I think it will work for people who are just students and single.
Recommendations about changing this course	I think it is set up well.
	I think keeping it and not changing the way it is.
	I would probably have more of a schedule.
	I think you should work...in groups... Because whatever one doesn't know, the other might know, or might figure it out easier.

Next, the investigator took the third-level summaries and discrepant information and reduced them to three paragraphs that broadly summarize students' experiences and perceptions using asynchronous CAI to complete Survey of Algebra:

Advising from an instructor or professional staff person did not play a major role in students' decisions to take Survey of Algebra using CAI. Students typically chose to take the course using CAI because it offered them flexibility, convenience, an individualized approach to learning, and/or opportunities for academic support. These were the same aspects of the course that students most frequently cited that they liked the most.

Aspects of the course that students liked the least, found most difficult, or would recommend changing varied, but included having insufficient or delayed support from the instructor, feeling isolated, being dissatisfied with the computer program and/or testing, having difficulty with time management, and having technical difficulties with the computers/software. Nearly every student communicated with the instructor for help with the course, whether through email, meeting in person, or talking on the telephone.

Most students felt they put either a moderate amount or a lot of effort toward this course and compared it favorably to other math courses they had taken. Many students had already taken or said they would be willing to take another course using CAI, whether math or a different subject. Students said they would encourage another student to take the course using CAI if the other student possessed specific personal characteristics, including discipline/time management, aptitude for math or some knowledge about the content, motivation, and ability to learn independently.

Despite the fact that most students interviewed had positive comments about taking the course using CAI, more than one student had mostly or somewhat unfavorable opinions, including the student who earned an F as well as students who earned grades of B and C. These students did not enjoy the course, found it difficult or confusing, put little or no effort toward it, didn't like the lack of structure or independent learning that was required, and did not think the format was a good fit for students who also have children and/or work full-time. In general, students' experiences in and perceptions about taking Survey of Algebra using computerized instruction seemed to be based on the degree to which external variables (i.e., the structure and format of the course) were or were not compatible with personal characteristics, learning preferences, prior knowledge of the content, and aptitude for math.

Finally, the investigator identified three themes or aspects of CAI that were most salient across all interviews: convenience, individualization, and support. Each theme is described below and accompanied by exemplary quotes (in parentheses and italics) from students who were interviewed. Some students commented favorably and others commented unfavorably; both positive and negative comments are included below.

<u>Convenience and flexibility:</u> Most students chose to take Survey of Algebra using CAI because it offered convenience and flexibility that weren't available in a traditional classroom setting. They were able to work from home (or elsewhere) on a schedule that fit their personal time constraints. *(I liked being able to do it when I had a chance to do it instead of having to go to class at a specific time.)* They also liked that they were not bound to specific deadlines. *(I liked the flexibility of how it wasn't . . . that you had to get a certain thing done in a certain amount of time.)*

Some students, however, found that the course format included too much flexibility or too little structure. *(I felt like I needed to have... more structured assignments and homework. Sometimes it was really hard to stay motivated to get it done, to keep up with what I was supposed to have done.)* While most students found the convenience and flexibility of the CAI format worked well for them, others described it as a drawback or an impediment to their success.

Individualization and self paced instruction: Most students who were interviewed believed that taking the course using CAI allowed for more individualization. *(It seemed to be more directed to help the individual.)* On the other hand, some students did not feel that CAI was a good fit with their personal learning needs. *(It just didn't work for me with my learning style.)* Others did not like the individualized nature of the course because they felt isolated. *(It was hard to work on your own. I felt like I needed to have more interaction with other students and with the instructor on a daily basis. The bad part about doing stuff on line is you don't have any interaction with anyone else. I just kind of felt like I was left out there by myself.)*

Self-paced learning is a component of individualization that was important to many students. *(On the on-line class...you can just go at your own pace...If you want to back up a screen or spend 10 minutes on one screen, you can. There was no peer pressure or people making fun of you if you didn't understand anything...I wasn't compared to, "They're going faster," or, "They're going slower," or, "Somebody will think I'm asking a stupid question," type of thing.)* However, there was some disagreement about the extent of self-paced learning because the computer program did not allow students to move quickly through some sections and slower through others. *(I* *couldn't skip ahead when I went into a lesson that I did understand, you couldn't skip on to the next page if you got that one.)* While many students appreciated the individualized and self-paced nature of the CAI format, others felt that the isolation that came with the CAI format left them at a disadvantage.

Personalized support: A number of students felt they received personalized support in a timely manner by taking the course using CAI. Support and feedback came from the computer program and from the instructor. *(It was the easiest math class I've ever had…I think mostly because of the immediate feedback. Because I knew right away what I didn't know and what I did know. If you had a problem, you got a personal answer from the instructor. I could contact the teacher. He had office hours and I could go into the campus and talk to him then.)* Other students, however, felt that support and feedback were either insufficient and/or delayed. *(The computer gave only one explanation. If I didn't get it, I would have to go to other resources to be able to figure it out. You don't have somebody right there to ask a question if you need it. You have a little bit of a delay.)* It was clear from students' responses that having support was important to them. There was some disagreement, however, about the adequacy of the support provided by the computer program and instructor in the CAI format.

Summary – Qualitative Analysis

Using multi-level coding for data analysis creates an audit trail from the raw data to the investigator's broad interpretation and identification of three major themes. Readers have access to this audit trail in the preceding pages, which should increase trustworthiness. In another attempt to increase trustworthiness and the validity of the findings, the investigator returned to the published literature and compared her interpretations to existing research on the topic. This will be discussed in Chapter 5.

Summary

In this chapter, the results of quantitative and qualitative data analysis were presented and interpreted separately. In Chapter 5, the investigator compares the results of the quantitative and qualitative parts of this study with each other and with the results of published research, discusses the implications of these results in greater detail, and makes recommendations for future studies.

CHAPTER 5 – DISCUSSION

Chapter 5 begins with a summary of the purpose of this study. Findings of the study are discussed, including summaries of the most important quantitative and qualitative findings and a comparison of quantitative and qualitative findings. The findings of this study are then compared with results of published research. Next, the investigator discusses implications of the study. Recommendations for the participating institution and for further study also are discussed.

Summary of Study

The overall purpose of this study was to increase understanding about the impact of instructional delivery method on student success in community college remedial mathematics. The study used a mixed methods design and had two parts. First, the investigator analyzed the relationship between instructional delivery method (traditional versus asynchronous computer-assisted), students' gender, students' age, and students' final course grades in a remedial mathematics course (Survey of Algebra) and in a subsequent, college-level mathematics course (College Algebra). Second, the investigator focused specifically on asynchronous computer-assisted instruction (CAI), conducting interviews with students to explore in greater detail their experiences and perceptions using asynchronous CAI in Survey of Algebra. Specific research questions are listed in chapters 1, 3, and 4 and results for each of the research questions for parts I and II of this study are described in Chapter 4. The next section reviews only the most important findings.

Findings of Study

Summary of Important Findings from Quantitative Analysis

The main independent variable for this study was method of instruction for Survey of Algebra. Course pass rates (grade of C or higher) were 66% for students who used traditional instruction and 43% for students who used CAI. The investigator found that 16% more of the students who took Survey of Algebra using traditional instruction earned As or Bs than did the students who took the course using CAI (48% vs. 32%). However, with both methods of instruction, a high percentage of students earned Fs, Ws, or AWs: 29% for the group that used traditional instruction and 50% for the group that used CAI. In particular, 45% of students who used CAI earned Ws or AWs, compared to 24% of students who used traditional instruction. Results of the *t* test indicate that the difference in mean final grade by type of instruction was statistically significant and had a medium effect size.

Course pass rates in College Algebra for students who used traditional instruction for Survey of Algebra were 69%, compared to 59% for students who used CAI. Students who used CAI for Survey of Algebra were only slightly less likely than students who used traditional instruction to earn As or Bs (46% vs. 50%). There was a large difference between the two groups, however, in the percentage who earned Fs, Ws, or AWs (28% for the traditional group vs. 42% for the CAI group). Results of the *t* test indicate that the difference in mean final grade in College Algebra by type of instruction used in Survey of Algebra was not statistically significant and the effect size was small.

This study also found that, regardless of type of instruction, females outperformed males and non-traditional age students outperformed traditional age students. In most cases, *t* tests for those research questions showed that the differences were statistically significant, and effect sizes ranged from small to medium-large. When all three independent variables were analyzed together, however, there was no significant interaction.

The investigator drew the following major conclusions based on the results from Part I of this study:

1. Results consistently favored using traditional instruction over CAI for Survey of Algebra.
2. Regardless of type of instruction, a large proportion of students earned Fs, Ws, or AWs in Survey of Algebra.
3. Type of instruction used in Survey of Algebra had *some* impact on the percentage of students who earned As or Bs in the subsequent math course, College Algebra. However, type of instruction used in Survey of Algebra had a *large* impact on the percentage of students who earned Fs, Ws, and AWs in College Algebra. Results favored students who used traditional instruction in Survey of Algebra.
4. Results consistently showed that females earned higher final grades than males and non-traditional age students earned higher final grades than traditional age students in Survey of Algebra.
5. When all three independent variables were considered together, the mean grade for four of the eight subgroups was below a 2.00, or grade of C, which is required for students to advance to the next mathematics class.
6. When all three independent variables were considered together, the subgroup with the highest mean grade was non-traditional age females who used traditional

instruction. Their mean grade, 2.49, was only a half grade higher than what is required for students to advance to the next math class. In other words, no subgroup of students had a mean grade of A (4.00) or B (3.00), grades the investigator identified as evidence of being *highly successful* in the course.

Summary of Important Findings from Qualitative Analysis

In general, students' experiences in and perceptions about taking Survey of Algebra using computerized instruction seemed to be based on the degree to which external variables (i.e., format and logistics of the course) were or were not compatible with students' personal characteristics, learning preferences, prior knowledge of the content, and aptitude for math. Three major themes related to CAI were salient across all interviews – convenience, individualization, and support – although some students commented favorably and others commented unfavorably about those aspects of using CAI. The investigator drew the following major conclusions based on the interviews conducted in Part II of this study:

1. Only a few students recalled receiving advising from an instructor or professional staff person that included discussion specifically about CAI.
2. Most students chose to take Survey of Algebra using CAI because it offered them flexibility, convenience, an individualized approach to learning, and/or opportunities for academic support. These were the same aspects of the course that students most frequently cited that they liked the most.
3. Aspects of the course that students liked the least, found most difficult, and/or would recommend changing varied, but included having insufficient or delayed support from the instructor, feeling isolated, being dissatisfied with

the computer program and/or testing, having difficulty with time management, and/or having technical difficulties with the computers/software.

4. Nearly every student communicated with the instructor for help with the course, whether through email, meeting in person, or talking on the telephone.
5. Most students felt they put either a moderate amount or a lot of effort toward this course.
6. Most students had already taken or said they would be willing to take another course using CAI, whether in mathematics or a different subject.
7. Students said they would encourage another student to take the course using CAI if the other student possessed specific personal characteristics, including discipline/time management, aptitude for mathematics or some knowledge about the content, motivation, and ability to learn independently.
8. It may not be surprising that most students interviewed had positive comments about taking the course using CAI, because all but one student earned an A, B, or C in the course. However, a few students had mostly or somewhat unfavorable opinions about the course, including the student who earned an F as well as students who earned grades of B and C. These students did not enjoy the course, found it difficult or confusing, put little or no effort toward it, didn't like the lack of structure or independent learning that was required, and did not think the format was a good fit for students who also have children and/or work full-time.

Comparison of Quantitative and Qualitative Results

Direct comparison of results from the quantitative and qualitative portions of this study is somewhat difficult because the qualitative portion only involved students who took Survey of Algebra using CAI. Nonetheless, it is worthwhile to compare results to the degree possible as the purpose of using a mixed methods design was to use results from quantitative analysis to help inform results from qualitative analysis and vice versa.

Results from Part I consistently favored traditional instruction over CAI. During the interviews conducted in Part II, some students who took the class using CAI reported feeling isolated and having limited interaction with the instructor and peers. Support and feedback from the instructor were sometimes delayed. Students also found it difficult to stay motivated and keep up with the homework/schedule. Although not every student said so directly during the interviews, it can be inferred from these responses that advantages of traditional instruction (as opposed to CAI) include, among other things, the opportunity for interaction with peers and the instructor, and more immediate feedback and support. It is possible that in a traditional setting, the instructor helps students manage their time well and stay motivated. Also, unlike the software program, instructors might be able to provide alternative explanations to material when students do not understand it the first time.

Despite results from Part I and student comments from the interviews that favored traditional instruction, most students who participated in interviews favored their experience in Survey of Algebra using CAI over experiences in other mathematics courses taught using traditional instruction. Of the 12 students who participated in interviews, three had taken Survey of Algebra more than once, at least once with each method of instruction.

One student earned an F in the course using CAI and then went on to earn an A using traditional instruction. Another student enrolled twice in traditional sections of the course. She withdrew both times shortly before the final exam because she was failing the course and a high grade on the final exam would not have been enough to raise her grade in the course. The student then earned a C in the course using CAI. The third student earned a D in a traditional section of Survey of Algebra and went on to earn an A when he enrolled using CAI. It is possible in each of these three cases that the student's ultimate success had more to do with other factors – such as having been exposed to the content more than once – than with method of instruction. The important point is that results from Part II do not unequivocally support either method of instruction. There appear to be advantages to both.

Results from Part I of this study also indicate that females outperformed males and non-traditional age students outperformed traditional age students, regardless of type of instruction. These differences did not exist among students who were interviewed for Part II. However, students included in Part II represented only a very small portion of the total population.

Comparison of Findings of this Study with Results of Published Research

This study adds to existing research that specifically addresses the effectiveness of using asynchronous CAI versus traditional instruction in a postsecondary remedial mathematics course. This investigation differs from the majority of research in that it used a mixed methods design.

Comparison with published quantitative research. In Chapter 2, the investigator described the results of a number of published quantitative studies that measured the effectiveness of using CAI in remedial mathematics courses at the postsecondary level. In some of the studies, researchers focused specifically on comparing CAI versus traditional instruction. Seven studies described in Chapter 2 were similar to this study in that investigators measured effectiveness using course completion rates, course withdrawal rates/attrition, course pass rates, and/or pass rates in subsequent mathematics courses. Several of those studies also included other outcome measures, such as final exam scores, attitude, etc. However, addressing other outcome measures was beyond the scope of this study. Therefore, the following section will mention the results of the other studies only on the outcomes that were also included in this study. Results from those studies are mixed. The following section will briefly review each of the seven studies and the two studies that also used the Academic Systems software program will then be discussed in greater detail.

The results of one study favored traditional instruction. Summerlin's (2003) measures of effectiveness included course success rates (grade of C or higher) and grades in a subsequent college-level mathematics course. Academic Systems software was used in his study and, in addition to instructional method, other independent variables included age, gender, ethnicity, and reading ability. Results indicated students in the control group were significantly more likely to earn a passing grade in the remedial course and in the subsequent college-level mathematics course (College Algebra). Multiple regression analysis revealed that none of the other independent variables was a significant confounding or contributing factor.

Two studies led to mixed results that included no significant differences on at least one outcome and favored traditional instruction on at least one outcome. Garrett (1995) found no significant differences in the proportion of students who completed a remedial mathematics course, passed the course, or earned a C grade or better. The group that received traditional instruction had significantly higher final grades, however.

Ford and Klicka (1998) compared outcomes on several variables, including course pass rates (C or better), course completions rates, and pass rates in the subsequent mathematics course, for students in three groups: self-paced CAI, CAI with lecture, and traditional instruction. The study included two separate remedial courses and investigators found that for one course, students in the traditional sections had significantly higher course completion rates than students taught via the two CAI methods. For the other course, students taught in the traditional sections had significantly higher course pass rates and course completion rates than students in the self-paced CAI sections but not the CAI with lecture sections.

Two researchers found no differences at all. Waycaster (2001b) looked at success rates in three remedial mathematics courses and in subsequent college-level mathematics courses. No differences were found between instructional methods in terms of course pass rates or pass rates in subsequent courses. Fleming's (2003) study also revealed no significant differences between groups on course pass rates, even when taking into account students who withdrew from the course.

Two studies led to mixed results that included no significant differences on at least one outcome and favored CAI on at least one outcome. Kinney's (2001a) study involved Academic Systems software for two remedial mathematics courses. No significant differences were found in course pass rates (D or higher). However, students in traditional sections were significantly more likely to withdraw from class.

Williams (1996) conducted a study in which CAI was used as a supplement in a remedial mathematics course at a community college. Students were grouped by instructional method and age. Outcome measures included course completion rates and final course grades. Students in the CAI group earned significantly higher grades than students in the traditional group; this was true for the entire CAI group and for older students in the CAI group. There were no significant differences in grades between the CAI and traditional group for students who were younger than 21. Students in the CAI group had significantly higher course completion rates than students in the traditional group although there were no significant differences in course completion rates when students were compared by age group.

Finally, the results of one study favored CAI exclusively. Glickman and Dixon (2002) conducted a study in which they found that attrition in the experimental group (CAI) was lower (15%) than in the control group (21%). In general, results from these studies are not consistent in terms of whether CAI, traditional instruction, or some combination of the two leads to the greatest student success in remedial mathematics courses. As described in Chapter 2, each study has limitations and differs from the others in a variety of ways, making it difficult to compare results.

Despite difficulty making cross-study comparisons, the study described here is *most* similar to those conducted by Kinney (2001a) and Summerlin (2003) in that all three used Academic Systems software and outcome measures included course pass rates. Kinney's study included 668 freshmen and sophomores in Elementary Algebra and

Intermediate Algebra in the General College of the University of Minnesota (UM). Summerlin conducted a population study that included 2,035 students in Intermediate Algebra at Northwest Vista College (NVC). While it was not possible to compare the content of these courses, it is assumed that the content in the Intermediate Algebra courses at UM and NVC was similar to the content in the Survey of Algebra course at the institution described in this study. (As mentioned in Chapter 3, the Survey of Algebra course at the institution in this study was formerly called Intermediate Algebra.)

At NVC, Intermediate Algebra was offered as an offline, home study course (Summerlin, 2003). Students communicated electronically with the instructor and peers and were required to go to campus once for an introductory meeting and again for the final exam. Sections that used CAI at the institution under investigation in this study were set up in much the same way. Kinney's (2001a) study, on the other hand, was significantly different in that students in both the traditional and CAI sections were required to attend class on campus four days a week for 50 minutes.

Kinney (2001a) found that the withdrawal rate was significantly higher for students who used traditional instruction ($\chi^2 = 7.5, p < .01$), while the results of this study found the opposite: students who used CAI were more likely to withdraw from the course (45% vs. 24%). Summerlin (2003) found that students who used traditional instruction had significantly higher pass rates (73% vs. 51%). The study described here also found that students who used traditional instruction had higher pass rates (66% vs. 43%). Kinney (2001a), on the other hand, found no significant difference in course pass rates (Elementary Algebra: 81% CAI, 78% traditional; Intermediate Algebra: 88% CAI, 90% traditional). It is important to note that Kinney's pass rate data excluded students who withdrew from the course, which was not the case in this study or in Summerlin's study. It is also important to note that, in Kinney's study, grades of D were considered passing while in Summerlin's study and this study, a passing grade meant a C or higher.

Like this study, Summerlin's (2003) study also looked at grades in the next course. Results of both studies showed that students who used traditional instruction for Intermediate Algebra/Survey of Algebra passed the next course at a higher rate than students who used CAI (Summerlin: 79% traditional, 62% CAI; this study: 69% traditional, 59% CAI) . Finally, while Summerlin found that age and gender were not significant contributing factors in course pass rates at the developmental level, results of this study revealed that females and non-traditional age students outperformed males and traditional age students, respectively, regardless of method of instruction.

Combining results of the studies conducted by Kinney (2001a), Summerlin (2003), and this investigator, it is reasonable to conclude that using CAI does not lead to higher course pass rates in remedial mathematics courses or in follow-up courses, while using traditional instruction does lead to higher pass rates in follow-up courses. It remains unclear, however, whether traditional instruction leads to higher pass rates in remedial courses, whether one instructional method leads to greater course withdrawal rates, and whether gender and/or age have a significant impact on student outcomes.

Comparison with published qualitative research. In three of the studies described in Chapter 2, researchers attempted to identify specific factors related to student success using CAI in remedial mathematics courses. King and Crouse (1997) reported on the use of Academic Systems software in remedial mathematics courses at one community college. They credited the success of the program to flexible scheduling and grading formats, strong leadership from faculty and administration, a reduction in the number of topics covered in the courses, required student attendance in the computer lab, and a student recognition program that highlighted successful completers. It is not clear from the article, however, how many students utilized the software program or how King and Crouse collected the data upon which they based their findings. Nonetheless, results of this study corroborate King and Crouse's assertions that flexible scheduling is one advantage of using CAI.

Perez and Foshay (2002) reported on a study of remedial mathematics courses that were offered either as pure distance learning courses using CAI or as traditional courses in which CAI was used in a supplemental role. Data were collected from eight community colleges and the authors gathered qualitative and quantitative feedback from faculty and 185 students who participated in the courses. Neither of the instructional formats in the Perez and Foshay study is exactly the same as the CAI format investigated in the study described here. Nonetheless, the results are worth mentioning. Faculty identified the following positive aspects of using CAI: increased time for individual faculty/learner contact; flexibility with respect to time and location; self-paced, individualized instruction; privacy; appealing, cutting-edge technology; and immediate feedback. Students also identified factors that positively impacted their experience with CAI, including frequent communication with faculty through web pages and/or e-mail; formal orientation; and alignment of course objectives with online assignments. Perez and Foshay's findings about positive aspects of CAI align with many findings of this study. Specifically, both studies identified flexibility; self-paced, individualized instruction; feedback; and communication with faculty among the most beneficial features of courses that use CAI.

Kinney (2001a) included a qualitative component in his study (the quantitative portion was described above). Pre- and post-surveys were administered to 567 subjects and focus groups were conducted with 30 students enrolled in the CAI sections. Feedback from focus groups indicated students in the CAI sections appreciated being able to control the pace of their learning and valued explanations of concepts and skills as well as feedback provided by the software. They also appreciated the opportunity to receive individual assistance from the instructor.

Overall, students reported having chosen the CAI format because it increased their control over their learning, and because they did not want to enroll in a lecture course. Also, they all felt that they understood mathematics better in the CAI setting than they would have in a lecture class. This study supports Kinney's (2001a) findings that being able to control the pace of learning and receiving feedback from the software and/or instructor are important to students who take remedial mathematics courses using CAI. In Kinney's study, students in the lecture sections indicated in the survey that they preferred instruction from a human and appreciated the opportunity to ask questions and interact with peers. Students interviewed for this study who did not like the CAI format also expressed a preference for learning in a setting where they have more interaction with the instructor and peers.

Students who participated in interviews for the study described here identified many of the same issues that students and faculty identified in the other studies. In particular, some of the common themes across studies were that students liked the following aspects of CAI: flexibility with respect to time and location; self-paced, individualized instruction; individual attention from the instructor; and immediate feedback. Students interviewed in this study who preferred traditional instruction mentioned some of the same reasons as students in Kinney's (2001a) study for why they liked traditional instruction, namely that they preferred instruction from a human and the opportunity to ask questions and interact with peers.

Implications

This study involved one institution with a full-time equivalent (FTE) enrollment of approximately 3,900. Caution should be taken when generalizing results. However, published research supports many of the findings of this study and it is reasonable to believe that the results, implications, and recommendations stemming from this study would hold true for other community colleges and perhaps other universities, especially those that use the Academic Systems software program.

Results of this study suggest that method of instruction can be a factor in student success in remedial mathematics courses. In particular, traditional instruction was found through quantitative analysis to be the more effective method of instruction. This result is supported by numerous quantitative studies that analyzed final course grades as well as a variety of other student outcomes (Ford & Klicka, 1998; Garrett, 1995; Summerlin, 2003). Despite results of quantitative analysis, however, qualitative analysis in this study showed that some students had a strong preference for CAI and were successful in Survey of Algebra using CAI. Support for CAI is evident in the findings of several other qualitative – and quantitative – studies as well (Glickman & Dixon, 2002; King & Crouse, 1997; Kinney, 2001a; Perez & Foshay, 2002;Williams, 1996).

The overall implication stemming from this study is that traditional instruction should not be eliminated and nor should CAI. Instead, the participating institution should continue to offer remedial mathematics courses in a variety of instructional formats, perhaps guiding each student toward a particular method of instruction based upon his/her unique mix of personal and motivational qualities. This conclusion has support from other researchers as well. Based on data from their respective studies, both Waycaster (2001b) and Kinney (2001a) concluded that students can succeed in both traditional and computer-assisted formats. Fleming (2003) concluded that at the institution where her study took place, a variety of instructional methods should be offered to meet students' diverse needs. Hackworth (in Miles, 2000), who has taught, authored numerous textbooks, and developed internet courses – all in the area of developmental mathematics – argued, "I believe that students who have a choice of options for overcoming academic deficiencies will perform if only because they will have a vested interest in their choice. Our institutions, too, can perform better when students are offered choice because we'll learn better how to meet student needs" (p.21).

Recommendations for the Participating Institution

The community college under investigation in this study recently decided to participate in the Academic Quality Improvement Program (AQIP), which was introduced in 1999 as an alternative process through which institutions may seek to maintain accreditation (Higher Learning Commission, 2005). AQIP focuses on continuous improvement. As part of measuring student learning and institutional effectiveness, it will be important for the institution's leadership to understand the degree to which its developmental education program is effective. As a result of this study, the following specific recommendations are offered to the participating institution:

1. Continue to offer remedial mathematics courses in both the traditional and CAI formats.
2. Continue to invest institutional resources in teaching faculty by providing professional development for instructors related to both traditional instruction and CAI (and possibly other methods of instruction).
3. Examine the reasons for high rates of withdrawal (W and AW) in Survey of Algebra (in traditional and CAI sections).
4. Conduct a more in-depth investigation about why females and non-traditional age students had higher mean grades than males and traditional age students, respectively, regardless of type of instruction.
5. Examine the cumulate grade point averages of students whose data was included in this study to find out if weaker students selected sections that used CAI. This might help explain why the mean final grade for students who used CAI was significantly lower than the mean grade for students who used traditional instruction for Survey of Algebra.
6. Use the results of this study as the basis for discussion among remedial and college-level mathematics instructors about the developmental mathematics program generally and student outcomes in particular.
7. Contact other institutions that use Academic Systems for remedial mathematics courses to compare outcomes.

8. Evaluate other software programs that can be used in remedial mathematics courses.
9. Ensure all developmental mathematics students receive advising about instructional delivery options. Advisors/instructors should describe the traditional and CAI course formats and discuss student characteristics and behaviors that have been correlated with success/non success with each type of instruction.
10. Work to eliminate technical difficulties with computer hardware and software and ensure that a software demonstration is included in the mandatory face-to-face meeting/orientation at the beginning of the course.
11. Ensure that a sufficient number of campus computers are loaded with Academic Systems software and available to students in CAI sections.
12. Ensure that instructors of CAI sections are offering a sufficient number of office hours, hours they are in the computer lab to offer help, and hours when students may take tests. Ensure that those hours are at times that accommodate students' varying schedules.
13. Consider providing some hours during which students in CAI sections have immediate access (via email and/or telephone) to an instructor or tutor to answer questions.
14. Consider providing optional group study sessions for students in CAI sections who want more interaction with peers/instructor.
15. Consider offering a hybrid course format that combines traditional instruction with CAI.

16. For CAI sections, consider using tests developed by Academic Systems, or ensure that instructor-developed tests align well with content covered by the software program.
17. Increase advertising about the availability of CAI courses.

Recommendations for Further Study

This study provides a foundation for future research that will generate additional insight about which particular methods of instruction lead to the greatest student success in remedial mathematics courses. Because this was a study of a single institution, similar studies should be conducted before results can be generalized to a larger population of developmental mathematics students. In addition, researchers may want to conduct studies that are slightly different in focus.

Additional quantitative studies should be conducted at other community colleges and at baccalaureate degree granting institutions that offer remedial mathematics courses. Larger scale studies that incorporate multiple institutions also would be useful, as would meta-analyses of existing research. Compiling and analyzing existing institutional reports that include the entire population (vs. a sample) would be interesting as well.

Researchers may want to study other mathematics courses that are classified as remedial, college-level mathematics courses, or remedial courses in other subjects such as English and reading. Studies that focus on other methods of instruction (e.g. small-group learning, inquiry-based learning, hybrid courses that use a combination of face-to-face/lecture and CAI) would enhance overall knowledge as would studies of other software programs or studies that examine specific elements of the Academic Systems program. There are many approaches to on-line instruction; therefore, researchers also may want to compare students' outcomes in "pure" distance learning courses (i.e., students are never required to go to campus or meet face-to-face with the instructor) vs. courses taught using the CAI format described in this study.

This study looked at the impact of age and gender on student success. In the future, researchers should take a closer look at other student demographic and background characteristics as independent variables. Examples include ethnicity, learning style, familiarity with computers, attitude toward mathematics, aptitude for mathematics, and amount of time that has passed since student last took a mathematics course. Researchers also could look at whether or not students participate in advising sessions, whether they seek help from tutors, instructors, and/or peers, and what their attendance patterns are. Instructor characteristics and behaviors that should be incorporated into future studies as independent variables include teaching style, familiarity with computers, preference for CAI vs. traditional instruction, extent of training on technology as an instructional tool, and/or experience using the Academic Systems program in particular.

In the future, researchers should compare results when the same instructor teaches sections in both or all instructional methods. Analyzing the impact of differences in scheduling and course format (i.e., length of term, class size, attendance requirements) also would add important information, as would studies that use different outcome measures/measures of success, such as exam grades, achievement tests, attitude, self-confidence, and/or graduation/completion of academic program. Future studies also should address the cost-effectiveness of various methods of instruction since funding for higher education has been reduced in recent years.

For researchers interested in qualitative analysis, future studies that use interviews should include students who use traditional instruction. Interviews also could focus primarily on students who earned Ds or Fs or withdrew from the remedial course. Researchers may want to focus specifically on students who were unsuccessful in a remedial mathematics course using traditional instruction but were later successful in the course using CAI and vice versa. Interviewing instructors also would add valuable information and new perspectives as would using other methods for data collection such as surveys, focus groups, and observation.

Clearly, future investigators could go in a number of directions in designing research that would use the study described here as a foundation. Of the many options mentioned in the preceding paragraphs, the investigator of this study recommends the following as those areas that would be most valuable as follow-up to this study:

1. Conduct interviews similar to those conducted in this study but focusing on students who enrolled in a remedial mathematics course using traditional instruction. The study described here interviewed only students who used CAI.
2. Focus specifically on investigating and comparing factors that impact students' non-success (e.g., grades of D, F, or withdrawal) in a remedial mathematics course using traditional instruction and CAI. Results of this study revealed high rates of non-success for both types of instruction.
3. Focus specifically on students who were unsuccessful in a remedial mathematics course using one method of instruction but then switched to the other method and were successful. Three students interviewed for this study were unsuccessful

using one instructional method but were later successful when they switched methods of instruction.

4. Investigate the role of advising in student success in a remedial mathematics course using CAI and traditional instruction (i.e., are there differences in outcomes between students who receive no advising and students who receive advising that includes a discussion of the traditional and CAI course formats as well as student characteristics and behaviors that have been correlated with success/non success with each type of instruction). Students interviewed for this study did not all receive advising, and of those who did, the content and source of the advising differed from one student to the next.
5. Compare the short-term and long-term cost-effectiveness of using traditional instruction vs. CAI for a remedial mathematics course. Addressing cost-effectiveness was beyond the scope of the study described here but is important in the current economic climate.

Two frameworks for evaluation that have been described in the literature could be used at the participating institution or other institutions for future studies. Confrey, Sabelli, and Sheingold (2002) endorse an evaluation model that can be used with any program that utilizes educational technology. This model, developed by the U.S. Department of Education's Expert Panel on Educational Technology, takes into account three programmatic components – learning, equity, and organizational change. The framework includes measuring tools, criteria, and rubrics designed to guide the field of educational technology.

Nagarkatte (1988) explained that the design of a successful systems approach to individualized instruction in remedial mathematics involves consideration of four parameters – content, learner, instruction, and teacher. Content includes sequence of topics, scope of topics, and rate of content. Learner parameters include intellectual, emotional, social, and physical factors. Instruction involves communication styles, degree of automation, and instructional materials, and teacher parameters include roles, knowledge and skills, and personality. As foundations for future studies about developmental mathematics instruction, both models could lead to new and valuable insights.

Conclusion

Many students today enter higher education with poor mathematics skills and it is unlikely that the need for remediation at the postsecondary level will ever disappear entirely. Therefore, it is important to learn as much as possible about the factors that contribute to student success in remedial courses, because those courses are often the gatekeepers that determine whether or not students may participate fully in postsecondary education. Learning as much as possible is especially critical for community college leaders because remedial courses are more and more often being restricted to two-year institutions.

Johnson (1996) found that performance in remedial mathematics courses was a significant and positive discriminator of success in college-level mathematics courses, more powerful even than many demographic and other factors. In a recent study of community college students, the U.S. Department of Education (Evelyn, 2005) found that students who earned four or more credits in college-level mathematics were more likely to earn an associate degree or transfer to a four-year institution. The Massachusetts Community College Developmental Education Committee (1998) argued that the economic benefits of having an educated, skilled workforce are important at the local, national, and international levels.

If having a skilled workforce is related to individuals' level of educational attainment, level of educational attainment is related to successful completion of college-level mathematics courses, and successful completion of college-level mathematics courses is related to performance in remedial mathematics courses, then the need for effective remedial mathematics instruction cannot be overstated. If developmental mathematics education is to prove *not* to be an insurmountable obstacle for underprepared students, then it is imperative that researchers, practitioners, and policy makers join forces to design and implement highly effective, research-based instructional strategies and developmental programs. Hopefully, this study will be a significant contribution to a growing body of important research about the role computer-assisted instruction can play in such programs.

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APPENDIX A – INTERVIEW PROTOCOL

Interview Protocol

Student's Name: Date:

All information will be kept confidential and will not be associated with a particular student's name for purposes of this study.

1. What were your reasons for choosing to take Survey of Algebra using computerized instruction?

2. Did you receive any advising about taking this class, such as from an instructor or advisor at Aims? If so, from whom and what was discussed?

3. What did you like the most about the class?

4. What did you like the least about the class?

5. What were the most difficult parts about the class?

6. What did you do when you needed help or didn't understand something in the class?

7. How would you describe your overall effort in the class? (You may decide for yourself how to define the term *effort*.)

8. How would you compare this math class to other math classes you have had?

9. What recommendations do you have for improving the class?

10. Would you take another class (either math or a different subject) using computerized instruction? Why or why not?

11. What advice would you give to another student considering taking this class using computerized instruction?

12. Is there anything else you would like to share about your experience in the class?

13. During which term did you complete Survey of Algebra? Win. Spr. Sum. Fall

14. Are you male or female? Male Female

15. Are you 25 years of age or older? Yes No

16. Do you remember your final grade in Survey of Algebra? No Yes A B C D F

If No, "One of the purposes of this study is to compare students' experiences and perceptions about the class based on final grade. Would it be OK with you if I accessed your final grade from College records?" Yes No

If Yes, "What is your full name and SS#/Aims ID #?

17. Would you like to have your name entered into a drawing for a $50 gift certificate that may be used at a local business of your choice, such as a department store, music store, grocery store, movie theater, restaurant, spa, etc.? Yes No

If Yes, "Please give me your name and a phone number and/or e-mail address where I may contact you if you are the winner."

18. Would you like to receive a copy of the results of this study? Yes No

If Yes, "Please tell me your name and your mailing address and/or e-mail address so I can send you a report of the results when the study is complete."

Thank you for your participation in this study!

APPENDIX B – RECRUITING LETTER

February 7, 2005

Dear Aims Community College Student:

You have received this letter because your name was included on a list of students who took Survey of Algebra (MAT 106) sometime in 2004. Aims' records indicate you were in a class that used Academic Systems computer-assisted instruction.

We are conducting a study on behalf of Colorado State University to learn more about students' experiences using computers in math classes. Part of the study involves interviewing students. Results of this study will help instructors at Aims learn about the most effective ways to teach math.

We are requesting your participation in a one-on-one interview that will last approximately fifteen minutes. The interview will be conducted at Aims Community College (Greeley, Loveland, or Fort Lupton) or at another public place such as a library. In special cases, the interview may be conducted over the telephone. The interview will take place at a date and time that are convenient for you. Stacey Hogan will be the interviewer. Your participation is voluntary and your responses will remain confidential.

As a token of our appreciation for your time, we will enter your name into a drawing for a $50 gift certificate that may be used at a local business of your choice, such as a department store, music store, grocery store, movie theater, restaurant, spa, etc. At the end of the interview, we will ask for your contact information to notify you if you are the winner of the drawing. We also will send you a report of the results of the study if you are interested.

If you are willing to participate in an interview or have any questions about the study, please contact Stacey Hogan at 970-339-6644 or by email at stacey.hogan@aims.edu no later than Friday, February 18, 2005.

Your participation in this project is very important and your assistance is greatly appreciated. Thank you for your time.

Sincerely,

William Timpson
Principal Investigator

Stacey Hogan
Co-Principal Investigator

APPENDIX C – CONSENT FORM

PROJECT TITLE: Asynchronous computer-assisted instruction in a community college remedial mathematics course: A mixed methods study of student success and perceptions

PRINCIPAL INVESTIGATOR: William Timpson, (970) 491-7630

CO-PRINCIPAL INVESTIGATOR: Stacey Hogan, (970) 339-6644

WHY AM I BEING INVITED TO TAKE PART IN THIS RESEARCH? We are asking you to participate in this research because your name was included on a list of students who took Survey of Algebra (MAT 106) at Aims Community College sometime in 2004. Aims' records indicate you were in a class that used Academic Systems computer-assisted instruction.

WHO IS DOING THE STUDY? This study is being conducted by the two people whose names and phone numbers are listed above. William Timpson is a faculty member at Colorado State University. Stacey Hogan is a student at Colorado State University and works at Aims Community College.

WHAT IS THE PURPOSE OF THIS STUDY? We want to find out more about students' experiences in math courses that use computer-assisted instruction at Aims Community College. Your participation will help us learn about the most effective ways to teach math.

WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST? This study will take place at Aims Community College and will last approximately four months (January – April, 2005). Your participation will consist of one 10 to 15 minute interview.

WHAT WILL I BE ASKED TO DO? After reading and signing this consent form, you will participate in a one-on-one interview with Stacey Hogan, the co-principal investigator. The majority of the questions will ask about your experience using computer-assisted instruction for Survey of Algebra (MAT 106). A few questions will ask for information about you such as your gender and age. The interviewer will either audiotape the interview or take handwritten notes. You may indicate your preference on page 3 of this consent form.

It should take about 10 to 15 minutes to complete the interview. The interview will be conducted at Aims Community College or at another public place such as a library. In special cases, the interview may be conducted over the telephone. The interview will take place at a date and time that are convenient for you.

(see back side)

Participant's Initials __________ Date __________

ARE THERE REASONS WHY I SHOULD NOT TAKE PART IN THIS STUDY? The investigators do not know of any reasons why you should not participate in this study. You might be concerned about whether your grades in future math classes at Aims could be affected by your choice to participate in this study. Instructors at Aims will not know which students have agreed to participate.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS? There are no known risks associated with this procedure. It is not possible to identify all potential risks in research procedures, but the researchers have taken reasonable safeguards to minimize any known and potential, but unknown, risks.

WILL I BENEFIT FROM TAKING PART IN THIS STUDY? This study should help improve teaching methods used in math classes at Aims. Additionally, the information gained may assist the College in more effectively advising students who are planning to take a math course and are considering a section that uses computer-assisted instruction. There are no known direct benefits for participants in this study.

DO I HAVE TO TAKE PART IN THE STUDY? Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.

WHAT WILL IT COST ME TO PARTICIPATE? There are no costs for participation in this study.

WHO WILL SEE THE INFORMATION THAT I GIVE? We will keep private all research records that identify you, to the extent allowed by law. Your information will be combined with information from other people taking part in the study. When we write about the study to share it with other researchers, we will write about the combined information we have gathered. You will not be identified in these written materials. We may publish the results of this study; however we will keep your name and other identifying information private. We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is.

WILL I RECEIVE ANY COMPENSATION FOR TAKING PART IN THIS STUDY? After all interviews have been conducted, we will enter participants' names into a drawing for a $50 gift certificate that may be used at a local business of the winner's choice, such as a department store, music store, grocery store, movie theater, restaurant, spa, etc. We will contact you if you are the winner. If anyone asks who the winner is, the winner's name may be disclosed, therefore changing confidentiality.

(see next page)

Page 2 of 3

Participant's Initials __________ Date __________

WHAT HAPPENS IF I AM INJURED BECAUSE OF THE RESEARCH? The Colorado Governmental Immunity Act determines and may limit Colorado State University's legal responsibility if an injury happens because of this study. Claims against the University must be filed within 180 days of the injury.

WHAT IF I HAVE QUESTIONS? Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind. You may contact the investigator, William Timpson, at (970) 491-7630, or the co-investigator, Stacey Hogan, at (970) 339-6644. You also may contact us later, if you have questions about the study. If you have any questions about your rights as a volunteer in this research, contact Celia Walker, Director of Regulatory Compliance, at (970) 491-1553.

Please indicate your preference:

___ I prefer to have my interview audiotaped.

___ I prefer to have the interviewer take handwritten notes.

___ I have no preference.

Your signature below acknowledges that you have read the information stated and willingly sign this consent form. Your signature also acknowledges that you have received, on the date signed, a copy of this document containing three pages.

_______________________________________ _______________

Signature of person agreeing to take part in the study **Date**

____

Printed name of person agreeing to take part in the study

_______________________________________ _______________

Name of person providing information to participant **Date**

____

Signature of research staff

****

Obtain your parent's permission ONLY if you are under 18 years of age.

PARENTAL SIGNATURE FOR MINOR

As parent or guardian I authorize ______________________________ (print name) to become a participant for the described research. The nature and general purpose of the project have been satisfactorily explained in this consent form and I am satisfied that proper precautions will be observed.

_____________ _____________________

Minor's date of birth Parent/Guardian name (printed)

_____________________ _______________

Parent/Guardian signature Date

****

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Participant's Initials _________ Date _________