THE EFFECTIVENESS OF COMPUTER-ASSISTED INSTRUCTION IN DEVELOPMENTAL MATHEMATICS

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The Effectiveness of Computer-Assisted Instruction in Developmental Mathematics

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Abstract

Kathy Spradlin. THE EFFECTIVENESS OF COMPUTER-ASSISTED INSTRUCTION IN DEVELOPMENTAL MATHEMATICS. (Under the direction of Dr. Beth Ackerman) School of Education, July, 2009.

Colleges and universities are trying alternative instructional approaches to improve the teaching of developmental mathematics with the goal of increasing the number of students who have the skills and knowledge required for college-level math courses and for the twenty-first century workforce. Computers and the internet make possible new methods of delivering instruction so students will have choices of when, where, and how they learn math. The purpose of this study was to compare academic performance of students enrolled in a developmental mathematics course using traditional instruction, traditional instruction supplemented with computer-assisted instruction, and online distance learning. In addition, gender differences in mathematical performance were also investigated. The quasi-experimental study was conducted in Intermediate Algebra classes at a large, private, eastern university. An analysis of covariance was used to adjust the mean posttest scores for any initial difference in the groups on the pretest. There was no statistically significant difference in the posttest scores of students receiving traditional instruction and traditional instruction supplemented with computer-assisted instruction. There was a significant difference in the posttest scores of females and males, with females outperforming males in both modes of instruction. Although the original intent of this study was to include a group of students who took the course online, pretest scores for this group excluded them from the analysis. Institutions should offer

developmental mathematics courses in a variety of formats, assist students in selecting the mode of instruction that best suits their learning style, and provide professional development in computer-assisted instruction.

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CHAPTER 1: INTRODUCTION

Many students entering college need further preparation in mathematics to successfully meet their educational and career goals. Many colleges and universities offer developmental mathematics courses and other services to prepare these students for college-level math courses. Traditional teaching strategies have produced low passing rates in developmental mathematics courses. Colleges and universities are trying alternative instructional approaches to improve the teaching of developmental mathematics with the goal of increasing the number of students who have the skills and knowledge required for college-level math courses and for the twenty-first century workforce. Computers and the internet make possible new methods of delivering instruction so students will have choices of when, where, and how they learn math. This study will investigate whether there are differences in the academic achievement of students enrolled in a developmental mathematics course using traditional instruction, traditional instruction supplemented with computer-assisted instruction, or an online distance learning course. It will also investigate gender differences in mathematics achievement. The study will be conducted in Intermediate Algebra classes at a large, private, eastern university.

Statement of the Problem

The use of computer technology to supplement traditional instruction and to deliver instruction online to developmental mathematics students is a recent development. Although considerable research indicates that computer-assisted instruction can have a positive impact on learning for students of all ages and in a variety of content areas, the research is limited and inconclusive for students in developmental mathematics. Some researchers think that computer-assisted instruction has great potential for improving developmental education. Others contend, however, that developmental students need personal interaction with an instructor and other students. Does computer-assisted instruction enhance the learning of developmental mathematics or is traditional instruction more effective for these students? Can developmental mathematics students who are studying in an online distance learning course with no face-to-face contact with the instructor learn at least as well as their on-campus counterparts? Is there any difference in the mathematical performance of males and females in developmental mathematics courses?

Null Hypotheses

1. There is no significant difference in the mathematics performance of students in a developmental mathematics course using the following instructional modes:
    i. traditional lecture
    ii. lecture with computer-assisted instruction
    iii. online distance learning
2. There is no significant difference in the mathematical performance of developmental mathematics students by gender.

Significance of the Study

A significant number of students start college unprepared for a college-level mathematics course (National Center for Educational Statistics, 2003b). Without intervention, only 10% will graduate, and with appropriate assistance, up to 40% of those beginning college in developmental programs will earn a bachelor’s degree (Brittenham, et al., 2003). Success or failure in a mathematics course determines students' choice of major and whether they graduate and qualify for meaningful jobs (Hall and Pontoon, 2005; McCabe, 2000). Some four year colleges and universities and most community colleges offer courses equivalent to basic arithmetic and high school algebra in an attempt to prepare these students for courses such as college algebra and statistics (NCES, 2003b).

Typically developmental mathematics courses have been taught with the traditional lecture method used for years in college-level courses (Armington, 2003; Kinney and Kinney, 2003; Maxwell, 1979; Miles, 2000; Roueche and Kirk, 1974). University educators across the country are concerned that the pass rate in developmental mathematics courses varies considerably, being as low as 24% at some colleges (Boylan, Bonham, and White, 1999; Trenholm, 2006; Waycaster, 2001; Wright, Wright, and Lamb, 2002). Consequently, educators are implementing new programs designed to increase the number of students who stay in school, pass a college-level mathematics course, and graduate. Instructors are supplementing the traditional lecture with teaching strategies that emphasize understanding of concepts, active learning, and relevant applications (Armington, 2003; Felder and Brent, 1996; Kinney, 2001; Perez, 1998; Roueche, 1974). It is widely accepted that solely addressing the math skills of these students is not sufficient (Hall and Pontoon, 2005; Higbee and Thomas, 1999; Perez, 1998). Math anxiety, negative attitudes, poor study skills, and lack of responsibility for learning are also being addressed.

Universities that accept students who are not prepared for college-level work have the responsibility to offer courses and support services to prepare these students (Boylan, Bonham, and White, 1999). Through research and experience, educators at both two and four year colleges are becoming aware that developmental mathematics students must be offered a learning experience that is different than their previous unsuccessful experiences in order to have a chance at success. Increased availability of computers and students' increased interest in using computers for communication and socialization has led educators to explore ways to use computers as tools to enhance student learning (National Center for Educational Statistics, 2003b; Pew Internet and American Life Project, 2002). Standards developed by the American Mathematical Association of Two-Year Colleges (AMATYC, 1995) and also by the National Council of Teachers of Mathematics (NCTM, 2000) call for the use of technology to enhance student learning. In the fall of 2000, 31% of the 3230 colleges surveyed by the National Center for Educational Statistics (2003b) reported that computers were frequently used by students as an instructional tool for on-campus remedial mathematics, and 13% offered remedial courses through distance education, an increase from 3% in 1995.

The computer-assisted instruction of the 1960s was used to drill, tutor, and test students (Kulik and Kulik, 1991). With the rapidly changing capabilities of computer hardware and software, computers have the potential to enhance learning in a greater variety of ways. Most of the software currently being used in developmental mathematics was developed by textbook publishers and either supplements classroom instruction with tutorials and algorithmically generated problems or provides a thorough presentation of concepts with interactive multimedia (Kinney and Robertson, 2003). When traditional instruction is supplemented with computer-assisted instruction, students receive traditional instruction in the classroom, but the computer changes how they study outside the classroom. Computer-assisted instruction allows students to work at their own pace at a time and place of their choosing from any computer with internet access. Students receive immediate feedback on assignments and can revisit topics until they have mastered the content (Cotton, 2001; Hannafin and Foshay, 2008). They may have access to videos, guided practice problems, and online tutoring. The software can provide each student with an individualized study plan. Teachers can create quizzes and tests to be delivered and graded by the software. It also provides the instructor with data to show how students are progressing in the course (Ford and Klicka, 1998).

According to the National Center for Educational Statistics (NCES, 2003a), the number of higher education institutions offering distance education courses and the number of students enrolled in distance education courses has increased dramatically from 1994 to 2001. Distance education courses are appealing to students with work and family responsibilities. The delivery of instruction in an online distance learning course is usually described by the term *computer-mediated instruction*, which provides a thorough explanation of the concepts by interactive multimedia software (Kinney and Robertson, 2003; Trenholm, 2006). Chat rooms, discussion boards, and email build community and facilitate communication. Students can control the pace of their learning, although there is a schedule for completion of lessons. Students take responsibility for their learning, deciding when, where, and how long to work. The instructor has the role of facilitator and coach (Brown, 2003).

Numerous studies indicate that computer use has a positive impact on student achievement, attitudes, learning rates, and other variables. A meta-analysis of 254 studies comparing outcomes in computer instructed and traditional classes found small positive changes in student attitudes toward computers and learning, a reduction in the amount of time needed for instruction, and an increase in exam scores of 0.3 standard deviations (Kulik and Kulik, 1991). The study included students of all ages, kindergarten through adult, who used computer-based instruction (CBI) in mathematics, social studies, science, reading and language, and vocational training. The computers were used for drill and practice, tutoring, and programming. In 81% of the studies, the CBI classes had the higher end-of-course exam scores, and in 19% the traditional classes had the higher average. The changes in mathematics were higher for precollege (0.37) than postsecondary (0.14). These findings were consistent with three previous meta-analyses by Kulik and his associates comparing the achievement levels of students receiving computer-based instruction to students who received traditional instruction in elementary, secondary, and college courses (Bangert-Drowns, Kulik, and Kulik, 1985; Kulik and Kulik, 1986; Kulik, Kulik, and Bangert-Drowns, 1985).

A report based on 176 literature reviews and individual studies found that educational technology had a positive impact on achievement for all subject areas from preschool through higher education (Bialo and Sivin-Kachala, 1996). The achievement of students using computer-based instruction was significantly related to the amount of technology-related training the teachers had received and whether the technology was being used appropriately. A review of 59 research reports on computer-based learning and student outcomes concluded that computer-assisted instruction as a supplement to traditional instruction produced higher achievement than traditional instruction alone, but when computer-assisted instruction alone was compared to traditional instruction alone, the results were too mixed to lead to any conclusion (Cotton, 1991).

The research on the effects of computer-assisted instruction on the mathematical learning of students of various ages and ability levels suggests that computer-assisted instruction as a supplement to traditional classroom instruction is more effective than traditional instruction alone (Boers, 1990; Brothen and Wambach, 2000; Butzin, 2000; Dalton and Hannafin, 1988; Fletcher, Hawley, and Piele, 1990; McSweeney, 2003; Nguyen, 2002; Olusi, 2008; Raghavan, Sartoris, and Glaser, 1997; Wenglinsky, 1998). The test scores of low-achieving students were higher with computer-assisted instruction combined with traditional instruction than with traditional instruction alone (Hannafin and Foshay, 2008; Mevarech and Rich, 1985). A review of studies from 1988 to 1995 in K-12 classrooms found that students with mild and moderate cognitive learning disabilities learned as well or better with computer-assisted instruction than without it (Fitzgerald and Koury, 1996).

There is no meta-analysis or conclusive research on computer-assisted instruction in developmental mathematics, according to Barbara Bonham, the senior researcher at the National Center for Developmental Education (Trenholm, 2006). The existing research is limited to isolated studies, and the results are mixed.

Stillson and Alsup (2003) studied the effectiveness of teaching Basic Algebra using the interactive learning system ALEKS to supplement traditional instruction. Higher test scores were associated with more time spent using ALEKS. However, a high number of students either dropped the course or received failing grades because they did not use the learning system. Interviews indicated that students liked the immediate feedback, the repetition, and the convenience of working at their own pace. Those who used the software thought they learned more than in previous math courses. They did not like that ALEKS did not correspond with the textbook, making them feel like they were taking two math courses.

A study at a historically black community college in Texas concluded that traditional instruction supplemented with computer-assisted instruction resulted in higher mathematical performance than traditional instruction alone (Mahmood, 2006). The study used a pretest-posttest quasi-experimental design. Two classes received traditional instruction and two received traditional instruction supplemented with computer-assisted instruction. The practice test for the Texas Higher Education Assessment test was used for the pretest and posttest. Success in mathematics was measured by gain scores, the difference in students’ pretest and posttest scores. An analysis of variance was conducted on the gain scores. Students who received traditional instruction supplemented with computer-assisted instruction had significantly higher scores than those who received only traditional instruction in both Fundamental Mathematics classes and Analytical Mathematics classes.

A quasi-experimental study with a design similar to the current study found no significant difference in the test scores of pre-algebra students who received computer-assisted instruction (CAI) and traditional lecture (TL) (Teal, 2008). The study was conducted at a suburban community college in the mid-Atlantic region and included 152 students. The CAI group received mini-lectures using online lecture notes and used the remainder of the class time to ask questions and work on computer assignments. Online homework, tutorials, and quizzes were completed during or outside of class. The TL students received instruction primarily through lecture and were expected to take notes as the professor provided explanations and examples. Three professors each taught a CAI class and a TL class. Students self-registered for the course, effectively choosing their mode of instruction. This study used ACCUPLACER as the pre-test, a 16-question multiple choice test after six weeks of instruction, and the department final exam after 16 weeks of instruction. Other studies comparing traditional instruction to traditional instruction supplemented by computer-assisted instruction for developmental mathematics students also concluded that there was no significant difference in the learning outcomes of the two groups (Jacobson, 2006; Kinney, 2001; Owens and Waxman, 1994; Reagan, 2004; Waycaster, 2001).

The research on the success of distance learning courses delivered entirely online is limited, which is not surprising given that using the internet to deliver instruction is a recent addition to distance education. In a study of the effectiveness of distance learning in higher education, the Institute for Higher Education Policy (1999) stated that only a small percentage of the articles written on distance learning contained original, quantitative research. Most of these quantitative studies found no significant difference in the learning outcomes of online and traditional classes. The quality of most of these studies was questionable, making their findings flawed or misleading. A study of a management information systems course offered online and face-to-face found no significant difference in the gain score (difference between pretest and posttest scores), course grade, and student satisfaction, but the study found a significantly higher drop rate in the online course (Carey, 2001). Glenn (2001) found similar results comparing traditional and internet distance learning government courses at a community college in Texas. In contrast, Koury (2003) reported better learning outcomes for an online version of an Introduction to Shakespeare course than the equivalent on-campus version of the course taught by the same instructor.

Engelbrecht and Harding (2005) wrote in *Teaching Undergraduate Mathematics on the Internet* that research on this new mode of instruction is very limited because using online instruction for undergraduate mathematics courses is very new. In addition, teachers and students must address the challenges of communicating on the internet with mathematical symbols. Both teachers and students must adapt to new roles in the online environment.

Some educators are asking whether developmental students can learn mathematics in the distance learning environment without face-to-face contact with an instructor. In 2002, Hunter Boylan, the Director of the National Center for Developmental Education, wrote, “Computer-based distance learning has yet to be proven effective with developmental students. Distance learning often requires independent learning skills, study discipline, time management skills, and a high degree of motivation. These characteristics are not plentiful among developmental students” (Boylan, 2002, p. 82).

In 1999, the League for Innovation in the Community College, PLATO Learning Inc., and eight community colleges from six states collaborated in an action research project called “Adding Up the Distance: Critical Success Factors for Internet-Based Learning in Developmental Mathematics” (Perez and Foshay, 2002). Six colleges used the PLATO Web Learning Network in a complete online course, and two colleges used PLATO as a supplement to a traditional course. Each college implemented PLATO in a different way. The study identified factors critical to success in an online developmental mathematics course: courseware that is easy to access and navigate; technical support for students and faculty; courseware aligned to course objectives; self-paced, individualized, anytime/anywhere features; learners with motivation, time management, and academic goals; learners who attended an orientation session; frequent contact from faculty and help desk; professional development for faculty; faculty who were experienced with distance learning or showed great interest in learning how to teach with technology; and administrative support.

At Onondaga Community College in New York, the pass rate of students in beginning and intermediate algebra using the publisher's resources in an online course was 20% higher than the pass rate of students in residential classes who had access to the electronic resources but were not required to use them (Testone, 2005). The students had access to computer-assisted homework, guided practice problems, videos, and a multi-media textbook. A required orientation session introduced students to the technology. Faculty and tutors attended workshops to learn how to use the resources. Residential and online students took the department final exam on campus in a proctored setting. Residential students who used the resources had higher success rates than those who did not. As a result of this study, the faculty is introducing several web-enhanced sections and hybrid sections of developmental mathematics.

A study examining the effectiveness of computer-assisted instruction in two developmental mathematics courses at a Pennsylvania community college had mixed results (Ford and Klicka, 1998). Classes were offered in four settings: traditional lecture, computer-assisted instruction (CAI) with non-lecture, computer-assisted instruction with lecture, and distance learning. Students chose their own class to fit their schedules and may not have considered whether computers were involved. In the Fundamentals course, no significant differences were found between traditional instruction and the other delivery methods in passing the course, passing the final exam, achieving an A or B on the exam, remaining in college, and passing the next math course. In Basic Algebra, no significant differences were found between traditional instruction and the other methods in passing the next math course, remaining in college, or passing the exam with an A or B. However, traditional sections had significantly higher pass rates and course retention rates, and computer-assisted sections and distance learning sections had significantly higher final exam pass rates. The authors suggest that the CAI non-lecture classes are best suited for self-motivated, self-disciplined, and independent learners. As a result of this study, faculty decided to continue offering students choices of instructional methods and to improve the students' course selection process.

Although previous research indicates that computer-assisted instruction has positive effects on learning for students in a wide range of ages and subject areas and publishers provide testimonials about the advantages of their learning systems, research comparing the academic performance of developmental mathematics students enrolled in online courses, traditional courses, and traditional courses supplemented with computer-assisted instruction is limited and inconclusive. Educators are asking if distance education has positive results for all academic areas and if it works better for some students than for others. Some contend that developmental mathematics students need the face-to-face interaction with the instructor and other students.

Gender differences in mathematics are a concern of educators who are attempting to prepare all students for fulfilling careers. Stereotypes that females lack mathematical ability, perform poorly in math courses, and have limited experience with computers persist in society. There is evidence that over the past several decades, the gender gap between men and women in mathematical performance has narrowed but may not be eliminated. An analysis of state assessment test scores produced effect sizes for gender differences consistently less than 0.10, indicating no gender differences (Hyde, Lindberg, Linn, Ellis, and Williams, 2008). The National Center for Education Statistics (2005) reported that females are now performing as well or better than males on many indicators of achievement. The National Assessment of Educational Progress mathematics scores for 1990 through 2003 had very small gaps between males and females. However, a higher proportion of males took the AP exams in science and calculus in 2002, and males had higher average scores on these exams than females. Gender differences in college majors still persist. Males tend to outperform females on standardized tests (Bridgeman and Wendler, 1991; Odell and Schumacher, 1998), while females outperform males in classroom assessments (Bridgeman and Wendler; Ding, Song, and Richardson, 2006; Gallaher, 1998). It appears that females and males have equal access to computers (NCES, 2005; Price, 2006; Wallace and Clariana, 2005) and perform equally well on computer assessments (Mevarech and Rich, 1985; Nguyen, 2002; Wallace and Clariana). Few studies on the performance of developmental mathematics students receiving computer-assisted instruction also investigated gender differences and those have mixed results (Mahood, 2006; Owens and Waxman, 1994).

Results of this study may initiate changes in one or more of the instructional modes in order to enhance mathematical achievement for all students. With information about the potential impact of computer-assisted instruction, institutions can invest their resources wisely. It may suggest future research into ways to transfer what is successful in residential developmental mathematics courses to improve learning in online courses. In addition, it may lead to investigation into what student characteristics are associated with the highest achievement in the various delivery formats.

Methodology

This was a quasi-experimental study that used the non-randomized pretest-posttest design. Established classes of Intermediate Algebra students were used in order to not disrupt students' schedules. Two of the classes received traditional instruction, two received traditional instruction supplemented with the computer learning system coordinated with the textbook, and two received instruction in the distance learning format using the same computer learning system. The first null hypothesis was: There is no difference in the mathematics performance of students in developmental mathematics courses using a traditional lecture, lecture with computer-assisted instruction, and online distance learning. The independent variable was the mode of instruction and the dependent variable was mathematical performance as measured by the final exam. All students completed a questionnaire and a pretest the first week of class. Instruction was delivered for a sixteen-week semester. The last week of the semester, all students took a comprehensive final exam. Descriptive data was compiled from the questionnaires. An analysis of covariance was conducted with the pretest scores as the covariate, the method of instruction as the independent variable, and the posttest as the dependent variable. This adjusted the mean posttest scores for any initial differences between the three groups. The second null hypothesis was: There is no significant difference in the mathematical performance of developmental mathematics students by gender. An analysis of covariance was conducted with the pretest as the covariate, gender as the independent variable, and the posttest as the dependent variable. The interaction of method and gender was also analyzed.

Definitions

ANCOVA: Analysis of covariance, which is a statistical procedure used to evaluate the difference between means by adjusting the mean posttest scores for initial differences between the groups on the pretest.

Computer-assisted instruction (CAI): Refers to tutorials, drill-and-practice, graded assignments, and other activities delivered by computer as a supplement to traditional teacher-directed instruction; also referred to as computer-based instruction (CBI) and computer-mediated instruction.

Computer learning systems: Software provided by textbook publishers to complement a textbook. The software includes features such as homework, quizzes, tests, tutorials, videos, and online tutoring.

Computer-mediated instruction: Refers to a thorough explanation of concepts using interactive multimedia software, which usually includes activities requiring student interaction imbedded in the instruction, online assessment with immediate feedback, and course management features to track student progress. The software uses text, graphics, sound, animation, video, and pictures to present information.

Covariate: A variable known to be related to the dependent variable and included in the experiment to adjust the results for differences existing among the subjects prior to the experiment. In this study, the covariate will be the pretest.

Developmental Mathematics: The courses and programs designed to provide the skills and knowledge for underprepared students to succeed in college-level mathematics courses.

Intermediate algebra: A developmental mathematics course offered by most community colleges and some four-year colleges and universities that presents the concepts and skills necessary for college-level mathematics courses such as statistics, college algebra, and liberal arts mathematics. It typically includes factoring, systems of equations, rational expressions, absolute value, radicals and roots.

Mathematics achievement: For the purpose of this study, mathematics achievement will be defined as the score on the posttest, which is the final exam.

NCDE: National Center for Developmental Education whose purpose is to improve the quality of practice in developmental education.

NCES: National Center for Educational Statistics.

SPSS: The Statistical Package for Social Science is a software application for performing statistical calculations.

Traditional instruction: Face-to-face instruction delivered by a teacher dispensing knowledge and demonstrating skills using lectures sometimes integrated with discussion and group work.

CHAPTER 2: REVIEW OF THE LITERATURE

Many students who are otherwise well-qualified to attend colleges and universities need further preparation in mathematics to successfully meet their educational and career goals. According to two well-respected researchers and practitioners in developmental education, there always have been and always will be college students who are academically weak and poorly prepared but very capable of succeeding with additional assistance (Casazza, 1999; Maxwell, 1979). Developmental mathematics offers the courses and other services to help underprepared students become prepared for college-level courses. Seventy-one percent of higher education institutions and ninety-nine percent of two-year colleges offered at least one developmental mathematics course in the fall of 2000 (National Center for Educational Statistics, 2003b). Educators are concerned about the wide range of pass rates in developmental courses and how best to meet the diverse needs of the students. Considerable research in the last four decades has established some best practices and policies in developmental education, but research on the effects of computer-assisted instruction, particularly in the distance learning environment, on the academic achievement of developmental mathematics students is limited and inconclusive.

This review of literature begins with defining developmental mathematics in the context of developmental education, including a brief historical overview. In addition, the review of literature examines the need for developmental mathematics and the characteristics of students in developmental mathematics. The three modes of instruction relevant to this study are discussed. Finally, research on the effectiveness of each instructional method is reviewed. The researcher examined scholarly journals and books, websites of professional organizations, dissertations, the World Wide Web, Google Scholar, reference lists of other articles, and the *Annotated Research Bibliographies in Developmental Education* (2007) published by the National Center for Developmental Education. The literature was examined for developmental education, remedial education, developmental mathematics, underprepared students, computer-based instruction, computer-assisted instruction, computer-mediated instruction, online instruction, distance learning, e-learning, and gender differences.

Definition of Developmental Mathematics

Developmental mathematics is one component of the broader field of developmental education, which is defined as courses and services provided to help underprepared college students attain their educational goals (Boylan and Bonham, 2007). The terms *college prep* and *basic skills* are also used (Merisotis and Phipps, 2000). As the motto of the National Association for Developmental Education states, developmental education helps “underprepared students prepare, prepared students advance, and advanced students excel” (Boylan, 2002, p.3). Developmental education includes a wide range of interventions to help unprepared students succeed in higher education. The most common remedial courses are in reading, English, and mathematics (NCES, 2003b). In addition to academic courses, developmental education may include a variety of support services, such as tutoring, workshops, learning laboratories, counseling, advising, and assessment (Boylan and Bonham, 2007). Study skills and learning strategies may be stand alone courses or integrated into the academic courses. Courses may be offered in freshman orientation, writing skills, and test preparation for graduate school. What constitutes remedial or developmental education varies from institution to institution.

There is some confusion about the terms *remedial* and *developmental*. Some educators use them interchangeably and others have replaced the term *remedial* with *developmental* to emphasize building on what students know instead of emphasizing what they do not know. However, Boylan, Bonham, and White (1999) of the National Center of Developmental Education differentiate between the two terms, saying that remedial courses teach content typically offered in high school and developmental courses are college-level courses with a focus on academic development such as study strategies, critical thinking, and writing. Remedial students are unprepared students who did not master the content in their previous exposure to the material. They attempt to redo their first experience, often with the same delivery method, in hopes of a better outcome. Developmental students differ from remedial students in that they have not been exposed to the course content. Although remedial and developmental students are fundamentally different and should receive different instruction, they are in the same classes. Casazza (1999) adds that *remedial* is a term used to describe weaknesses or deficiencies. It implies something needs to be fixed, usually by taking a course over and over until the student passes or gives up. In contrast, the term *developmental* implies a more holistic approach which focuses on the intellectual, social, and emotional growth of the student.

The main goal of developmental mathematics is to remediate deficiencies in mathematical skills required for success in college-level mathematics courses as well as science, business, and other courses that require mathematical skills (Armington, 2003). In addition, developmental mathematics may also strengthen students' learning skills that will improve their performance in a variety of college courses. A third purpose, that is sometimes not acknowledged, is that colleges use developmental mathematics courses to eliminate students who are not qualified for further college study.

Need for Developmental Mathematics

For nearly 200 years, colleges and universities have accepted students who have not met their admissions standards and have provided services for these underprepared students (Casazza, 1999; Merisotis and Phipps, 2000). In the 17th century, Harvard University provided tutors in Greek and Latin for underprepared students. Land-grant colleges established in the 1800s had programs for students below average in reading, writing, and arithmetic. At the beginning of the 20th century over half of the students enrolled at Harvard, Princeton, Yale, and Columbia were placed in remedial programs. The vast numbers of veterans taking advantage of the G.I. Bill after World War II and the more open admissions policies following the passage of the Civil Rights Act of 1964 greatly increased the numbers of college students needing remediation. This assistance began to take on a formal organizational structure with the establishment of learning centers in the 1960s, about the same time that community colleges were established (Trenholm, 2006). By the 1970s, many of the students entering college were first-generation college students and there was an increase in the number of women, older students, students with learning or physical disabilities, and students from poor families (Casazza). At the same time colleges were adopting calculus as the entry level mathematics course (Maxwell, 1979). In order to survive, colleges have accepted large numbers of unprepared students and offered remedial programs and courses to prepare them for college-level work.

Thirty years ago little attention was given to developmental education at the national level (Boylan and Bonham, 2007). There was only one professional organization and one journal dedicated to developmental education. There was little effort to determine the most effective practices. Educators began to realize that simply offering developmental courses was not sufficient to prepare students for college-level courses. In 1980, the Kellogg Institute was established to train and certify developmental educators. Five universities now offer graduate degrees in developmental education: Appalachian State University, Grambling State University, National – Louis University, University of Missouri – Kansas City, and Texas State University (Armington, 2003). Numerous journals, national and regional conferences, and professional organizations focusing on developmental education have been established within the last 30 years (Boylan and Bonham).

Developmental or remedial education began to be recognized as a field of study in the late 1960s. John Roueche and his associates at the University of Texas – Austin conducted much of the early research in remedial education. They observed that most of the remedial courses of the 1960s were watered-down versions of college-level courses, poorly planned and implemented, ineffective at correcting deficiencies, and rarely evaluated (Roueche and Kirk, 1974). Since then, considerable research has been conducted on all facets of developmental education. The National Center for Developmental Education has conducted two national studies, one between 1990 and 1996 including 6000 randomly selected students from 160 colleges and universities (Boylan, H. R., Bliss, L. B., & Bonham, B. 1997), and a second begun in 2004 focusing on community colleges (Gerlaugh, Thompson, Boylan, and Davis, 2007).

The need for developmental education has remained fairly consistent over the past 30 years. As postsecondary enrollments have increased, the number of underprepared students has grown proportionately. The National Center for Educational Statistics (NCES) first collected statistics on developmental education in 1984 and has published three reports since then. Boylan and Bonham's study (2007) of the four reports showed that consistently 30% of entering college and university students needed one or more developmental courses. The most recent survey of 3230 institutions of higher education by the NCES (2003b) revealed that 71% of higher education institutions and 99% of two-year institutions offered at least one remedial mathematics course in the fall of 2000. Nearly 22% of incoming freshman enrolled in a remedial mathematics course at these institutions. In 2005, 59% of high school graduates who took the ACT scored lower than the college readiness benchmark of 22, indicating they were candidates for developmental mathematics (ACT, 2005). According to Robert McCabe, former president of the League for Innovation in the Community College (2000), only 42% of students leave high school with skills adequate for college work. Perez and Foshay (2002) agree, stating that almost half of the students entering community colleges need remediation.

Each year about two million students participate in developmental education (Boylan, 1999). Four-year institutions serve about one-third of developmental students. Most of the rest attend community colleges, and a small number are in developmental programs provided by business and industry. Without intervention only 10% will graduate, and with appropriate assistance, up to 40% of those beginning college in developmental programs will complete a bachelor's degree (Brittenham, et al., 2003). In a study at a large four-year public university, Lesik (2006) found that participation in the developmental mathematics program significantly increased the chances a student would successfully complete a college-level mathematics course on the first try. Nationally, 22% of students who enroll at a community college complete an associate's degree at that college, while 24% of those who participate in developmental education complete an associate's degree (Boylan, 1999). For universities, 45.6% of all students earn a bachelor's degree compared to 40% of those participating in developmental education. This suggests that underprepared students can be just as successful in higher education as fully prepared students.

As stated in the Principles and Standards of the National Council of Teachers of Mathematics (2000),

> The need to understand and be able to use mathematics in everyday life and in the workplace has never been greater and will continue to increase. In this changing world, those who understand and can do mathematics will have significantly enhanced opportunities and options for shaping their futures. Mathematical competence opens doors to productive futures. (p.1)

Students who do not complete developmental mathematics and an undergraduate degree limit their career choices. Success or failure in a mathematics course determines students' choices of major and whether they graduate (Hall and Ponton, 2005). There is a high cost to society to not develop the nation's work force to its highest potential (Merisotis and Phipps, 2000). Today's economy requires highly skilled, knowledgeable workers. More than 80% of the new jobs in the 21st century will require a college education (McCabe, 2000). These jobs will require higher levels of productivity, problem solving skills, and competence than existing jobs. According to McCabe, an essential goal of higher education is to offer effective developmental education that provides the opportunity for underprepared students to fulfill their educational goals and qualify for meaningful jobs. If only one-third of students taking a remedial course earn a bachelor's degree, they would produce more than $13 billion in state and local taxes and $74 billion in federal taxes, while costing about $1 billion to remediate (Spann, 2000).

National studies of developmental education indicate success rates close to 70%. A study by the National Center for Developmental Education reported that 72% of students still on the roster at the end of developmental courses earned a C or better (Gerlaugh, Thompson, Boylan, and Davis, 2007). Seventy-six percent of reading students, 73% of writing students, and 68% of math students were successful. Fifty-eight percent of developmental math students passed a college-level math course with a C or better. These results were consistent with the most recent National Center for Educational Statistics study on developmental education (2003b). However, the pass rate in developmental mathematics courses varies greatly across the country, being as low as 24% at some colleges (Wright, Wright, and Lamb, 2002). A study of developmental education in Texas revealed that pass rates on a statewide assessment test varied from below 25% to over 90% in community colleges and from 30% to nearly 100% in universities (Boylan, Bonham, and White, 1999). Waycaster's study (2001) of community colleges in Virginia reported pass rates from 29% to 64%. McCabe's work also showed that less than half of community college students enrolled in remedial courses successfully complete those courses (2000). In New York, between 40% and 60% of incoming community college freshman must take a developmental math course and 50-60% of those fail on their first attempt (Trenholm, 2006). According to Boylan, Bonham, and White, this wide variation in success rates can at least partially be attributed to educators failing to be guided by the best practices and policies that thirty years of research provides. According to the National Study of Developmental Education, developmental students are most successful in programs that have centralized organization, tutoring with tutor training, program evaluation, mandatory assessment, mandatory placement, and advising (Boylan, 2002).

Developmental education programs vary considerably in their policies and practices. Students are typically identified as being underprepared by scores on SAT, ACT, or local assessment tests (Boylan, 1999). There are differences in placement instruments and cut-off scores, content of the courses, instructional methods, grading standards, number of credits awarded, use of technology, and other aspects (Armington, 2003). A study of four-year colleges in a Midwestern state illustrates some of these differences. There was no consensus among the fourteen colleges on what constituted developmental mathematics. Some defined it as any course below College Algebra (45%) and others as any course below Intermediate Algebra (37%). Sixty percent of the institutions in this study taught developmental mathematics courses through the traditional mathematics department and the rest taught developmental mathematics in learning centers. There were wide variations in the ACT scores used for placement into college-level mathematics courses. Only 31% had mandatory placement testing. The majority (78%) awarded institutional credit (counts toward financial aid and housing but not toward degree completion). Most had no restrictions on the number of times a student may take a developmental course and most allowed students to enroll in college-level courses in another subject area at the same time. The National Center of Educational Statistics survey of over 3,000 colleges provides a national perspective (2003b). The most common method for determining which students needed remedial work was to give placement tests. Seventy-five percent had mandatory placement policies, 82% had restrictions on college courses students could take while enrolled in remedial courses, and 73% gave institutional credit. About one-fourth reported that there was a limit on the number of times students could take remedial courses. At the institutions surveyed, traditional academic departments provided the remedial instruction in mathematics (72%), writing (70%), and reading (57%).

Characteristics of Developmental Mathematics Students

There are numerous reasons why so many college students lack the basic mathematical skills that are taught in middle and high schools. According to Hammerman and Goldberg (2003), some students are filled with rules and not understanding in elementary school because those teaching math too often do not understand math themselves. Students are sometimes presented with material for which they are not intellectually ready. Other contributing factors include the math courses offered at a student’s high school and the highest math course the student completed (Hall and Ponton, 2005). Students who take the minimum math requirements in high school and delay taking a math course in college often need remedial work (Johnson and Kuennen, 2004). The poor reading skills of some college students are compounded by the high reading level of many math textbooks (Maxwell, 1979). Many adult students coming to college years after graduating from high school need developmental mathematics to review their skills (Merisotis and Phipps, 2000). According to researchers at the National

Center for Developmental Education, often there is not a connection between what high schools teach and what colleges expect incoming students to know (Boylan, Bonham, and White, 1999).

Students in developmental mathematics courses are very diverse in learning styles and math experiences. Some have gaps in their knowledge due to frequent moves or illness resulting in them getting behind and never catching up (Hammerman and Goldberg, 2003). In addition to lacking academic knowledge, many developmental students have deficiencies in study skills and organizational skills that are important for success in college (Armington, 2003). Some have the ability to learn math but lack motivation or confidence (Higbee and Thomas, 1999; Armington). Some students are not self-regulated learners and lack the ability to identify why they are not succeeding or what they can do to improve their learning (Hall and Ponton, 2005). Some do not feel that they are in control of their successes and failures, crediting external factors instead of their own behavior (Armington). Some have been humiliated by a teacher or parent (Hammerman and Goldberg). Repeated negative comments discourage some students from asking questions and lower their confidence in their ability to succeed in math. In a study of 652 students at Ohio State University, Betz (1978) found high levels of math anxiety in students with inadequate high school math backgrounds and higher levels of math anxiety associated with lower math achievement test scores.

In *Best Practices in Developmental Mathematics*, Thomas Armington (2003) identifies five types of developmental mathematics students. The first are capable students who have fallen behind but not for a lack of ability. If they apply themselves, they will succeed. Second are the students who perform well in other college courses but have a weakness in mathematics. A third category is students who are motivated to attend college but lack both learning skills and math skills. With appropriate assistance in learning skills as well as mathematical content, many of them will succeed in college. A fourth category is students with learning disabilities. Many of these students can succeed with the appropriate accommodations. The final category is students with a broad range of deficiencies including mathematical abilities, learning strategies, motivation, and organizational skills. These students have difficulty succeeding even with strong support.

Saxon and Boylan examined 18 studies and summarized the demographic, social, and personal characteristics of community college students (1999). Their research indicated that remedial students at community colleges are female (55%), about 24 years old, white (67%), single (75%), attend college full-time (68%), are motivated for college work, have low self-efficacy, and provide for themselves financially. They concluded that, although the research does indicate some similarities in community college students, there is no typical remedial student. The ages range from 16 to 55. Although most are white, a large percentage is African-American (23%) and Hispanic (6%). The majority of students in developmental education are United States citizens (over 80%), and the others are likely to be taking developmental reading and writing courses. Some are married and some are single. Most have low high school grades and SAT scores, but some are above average. The most significant factor that separates them from other community college students is lower scores on a college assessment test.

According to Hunter Boylan (1999), Director of the National Center for Developmental Education, it is not surprising that nearly one-third of students entering college are underprepared when nearly two-thirds of high school graduates enter college, a large number of college dropouts return to attempt to earn their degrees, and a number of adults who graduated from high school ten or more years ago are attending college. According to Martha Casazza, former president of the National Association of Developmental Education, college students have become increasingly diverse in ethnic background (1999). More students have diagnosed learning disabilities. The number from homes where English is the second language has increased. More adults are returning to college after being away from education for a number of years. These students are capable of succeeding but need additional assistance (Boylan; Casazza). Developmental educators contend that these students deserve an opportunity to be successful in college and that developmental education can provide that opportunity.

Developmental education students who choose distance learning courses may differ demographically from developmental students in general. Perez and Foshay (2002) collected demographic data on the 185 students in their study of success factors in distance education and compared them to national statistics. Their data indicated that distance education students may be older, more often female, and more likely high school graduates than on-campus students. Carr agreed that distance education students are more often older and have more job and family obligations than residential students (2000). Distance education is well-suited to students who have work-related travel or who do not live close to a college or university. In Heubeck’s discussion of the advantages and disadvantages of internet college education, she asserts that the most obvious benefit is convenience (2008). Online courses are particularly appealing to active-duty military personnel. The students in Smith and Ferguson’s case study of online calculus and college algebra courses tended to be mature women with full-time jobs who were returning to college to finish a degree (2004). They were nervous to be taking college courses again, initially insecure about the online environment and the lack of face-to-face contact with the instructor, but very motivated. Students in an online Introduction to Shakespeare course at the University of Berkeley were mostly college-educated working adults, including teachers continuing their professional development and lifelong learners interested in Shakespeare (Koury, 2003). Students in an online statistics course were older, worked more hours, and were enrolled in fewer credit hours than the students in the equivalent traditional course (Estes, 2002). In a study of 231 students in an online health education course, Diaz (2002) found that the students were older and had completed more credit hours. Successful students, those earning a C or better, had a higher average GPA prior to enrolling in the online course than unsuccessful students. In addition, successful students had a strong independent learning style. Online students had higher course grades and grades on exams than traditional students but their drop rate was higher (13.5% v. 7.2%).

Success in a college course is not dependent solely on exposure to the course content, but also the motivation of the student and the use of learning strategies that result in meaningful learning. This is especially true for developmental students who have been exposed to the content previously and did not retain it perhaps because they did not use appropriate learning strategies. Wadsworth and his associates observed that students who have used effective learning strategies in traditional courses may not be able to transfer those strategies to the online environment (Wadsworth, Husman, Duggan, and Pennington, 2007). Their research suggested that success in online developmental mathematics courses is dependent on self-efficacy, motivation, concentration, information processing, and self-testing skills of the student. Although more research needs to be done on which students are more likely to be successful in the online environment, implications of this study are that colleges and universities should screen students to determine which learning environment is best suited for their needs and that educators should integrate learning strategy instruction in online developmental courses. Koury's work revealed that students who complete an online course are self-directed and task-oriented (2003). Heubeck (2008) agrees that maturity and discipline are required to regularly participate in discussion groups, complete learning activities, and take tests on time and not all students have the required self-motivation to be successful.

Students choose to enroll in online computer-mediated courses for a variety of reasons including (a) they prefer to learn through multimedia rather than lecture, (b) they think multimedia is more visual than what the teacher writes on the board, (c) they prefer to learn independently rather than have the teacher show them, (d) they can control the pace of the learning, (e) they like the immediate feedback, (f) the multimedia holds their attention better than a lecture, and (g) they want to avoid the possibility of another negative classroom experience (Kinney, 2001). However, few students enrolled in traditional college classes are interested in taking courses online based on a survey of students at 27 colleges and universities, both public and private, two-year and four-year (Pew Internet and American Life Project, 2002). Only six percent of the students took an online course and of those only 52% thought the course was worth their time and 50% thought they learned less than they would have in an on-campus course.

Instructional Strategies

Traditional Instruction

Traditional instruction is teacher-centered and characterized by direct instruction. Direct instruction usually includes the presentation of material, thinking aloud by the teacher, guided practice, correction and feedback, and modeling by the teacher (Kinney and Robertson, 2003). The teacher plays the role of the expert imparting knowledge. The teacher decides what, when, and how students should learn (Brown, 2003; Kinney and Robertson). All students study the same topic at the same time. A teaching style inventory administered to 381 faculty members at 200 U.S. public and private colleges and universities revealed that 60% taught using the teacher-centered mode of instruction assuming the role of expert, authority, and model (Grasha, 1994). The facilitator and delegator teaching styles, which are student-centered, were used less in mathematics and computer science classes than in any other discipline.

The tendency is for teachers to use the same instructional methods with which they were taught and with which they feel comfortable. This often means that developmental mathematics students have been and still are receiving instruction by the traditional lecture (Armington, 2003; Kinney and Kinney, 2003; Maxwell, 1979; Miles, 2000; Roueche and Kirk, 1974). In colleges and universities, the predominant mode of instruction has been the presentation of material through lecture and demonstration using whiteboard, chalkboard, overhead, PowerPoint, or graphing calculator (Armington, 2003). The teacher talks and students listen and write. The teacher demonstrates step by step procedures which are reinforced with drill and practice. Interaction is limited to students responding to the teacher’s questions.

Some educators have a very negative view of the traditional lecture. According to Brown (2003), the teacher is responsible for thinking and the students memorize and recite. Teachers are focused on content, schedules, and standards, not needs of the students. Felder and Brent (1996) describe the traditional lecture as stenography with the teacher reciting the course notes, the students transcribing the notes, and “the information not passing through anyone’s brain” (p.3). Professors that teach by lecturing operate under the assumption that if they do not lecture they will lose control of the class. Students are viewed as empty pails waiting to be filled and the teacher as the “sage on the stage” (Mahmood, 2006, p.25). According to Brothen and Wambach (2000), faculty, students, and administrators think that teaching means “speaking aloud from the front of the room” (p.64). Based on their research on a developmental psychology course, they concluded that lectures are an inefficient means of delivering instruction.

Traditional instruction that is purely lecture has not been effective for developmental mathematics students. As early as 1974, Roueche and Kirk concluded that traditional approaches have not been successful with developmental students. They have already received instruction at least once on the same material. Most likely it was presented by the traditional lecture mode of instruction (Trenholm, 2006). If the traditional lecture had been successful, then they would not be in developmental classes. Teaching developmental mathematics in the traditional large lecture classes has produced low pass rates and high dropout rates (Wright, Wright, and Lamb, 2002). At Southwest Texas State University, over 50% of students receiving traditional instruction in Intermediate Algebra received a D or F in the subsequent math course, but 60% of the students receiving non-traditional instruction received a C or better in their next mathematics course (Armington, 2003).

Educators have implemented various strategies to make classroom instruction more active and less passive. Some enhancements to the traditional lecture that are associated with higher pass rates are lectures supplemented with collaborative work (Kinney, 2001; Perez, 1998), peer tutoring (Kinney; Perez; Roueche and Kirk, 1974), computer labs (Kinney; Miles, 2000), group learning activities (Felder and Brent, 1996; Wright, Wright, and Lamb, 2002), class discussions, peer study groups and Supplemental Instruction (Perez). Some instructors have found increased learning by limiting presentation of the material to the first 10 or 15 minutes followed by individual instruction and student work (Armington, 2003). Cooperative learning techniques encourage students to take responsibility for their own learning and solve problems with their peers (Armington; Felder and Brent). Some instructors use graphing calculators and spread sheets to enhance the teaching of real-life problems (MacDonald et al., 2002). Most community colleges in Virginia limit class size to 20 or 25 students (Waycaster, 2001). Some universities have established mentoring programs and learning communities (Perez). Providing support services outside the classroom, such as tutoring, academic advising, study skills workshops, freshman orientation, and Supplemental Instruction are important to the success of developmental students (Gerlaugh, Thompson, Boylan, and Davis, 2007). Strategies that encourage students to become responsible for their own learning, build their confidence, teach study skills, encourage persistence, and decrease math anxiety have been shown to contribute to higher success rates (Perez; Hall and Pontoon, 2005; Higbee and Thomas, 1999; Roueche and Kirk).

Student surveys, focus groups, and questionnaires have shown that students choose lecture style classes because they prefer to learn by observing an instructor present the material, asking questions in class, listening to questions from other students and the instructor's response, and having the opportunity for more human interaction (Kinney, 2001). In addition, they were not interested in learning math with a computer.

Computer-Assisted Instruction: An Overview

According to numerous researchers, colleges should offer developmental students choices of instructional approaches. Since developmental students are very diverse in mathematical background and have a variety of learning styles, no one instructional style will meet the needs of all students (Boylan, 2002; Boylan, Bonham, and White, 1999; Felder and Brent, 1996; Higbee and Thomas, 1999; Kinney and Robertson, 2003; Miles, 2000; Perez, 1998; Roueche and Kirk, 1974; Waycaster, 2001). Computers and the internet make possible new methods of delivering instruction to developmental mathematics students so that they will have choices about when, where, and how they learn mathematics.

Standards developed by the American Mathematical Association of Two-Year Colleges call for a greater use of technology in the classroom (AMATYC, 1995). Emphasis should be on high-quality technology that enhances student learning but does not become the main focus of instruction. AMATYC emphasizes that just the presence of computers or other technology does not improve learning. In 2000, the National Council of Teachers of Mathematics published *Principles and Standards* for the purpose of improving student learning. The Technology Principle states that "Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning" (p.3). Computers, when used effectively, can support fundamental characteristics of learning: active engagement, participation in groups, frequent interaction and feedback, and connections to real-world contexts (Roschelle, Pea, Hoadley, Gordin, and Means, 2000).

Technological advances have made computers more powerful and less expensive, which have resulted in more students having access to computers at home and at school (Rapaport and Savard, 1980). The internet has the potential to provide a learning environment that is stimulating and engaging. Educators are able to design a wide array of courses that appeal to the inclination of current college students to use technology and potentially increase learning and retention (Trenholm, 2006). According to a 2002 Pew Internet and American Life Project, 20% of today's college students began using the computer between five and eight years of age, 85% have their own computer, and 79% say that the internet has had a positive impact on their college academic experience. College students frequently use the internet to check email, download music files, instant message, browse for fun, and communicate with family, friends, and professors.

Computer-assisted instruction is an alternative to traditional instruction used both for on-campus and distance learning courses, providing individualized, self-paced instruction. Computer-assisted instruction, according to some researchers, has great potential for developmental education because it allows a student to work at his or her own pace, provides immediate feedback, guided practice problems, and 24-hour access (Kinney, 2001; MacDonald et al., 2002; Merisotis and Phipps, 2000; Miles 2000). In 1976, only ten percent of the institutions surveyed used computer-assisted instruction to teach mathematics (Maxwell, 1979). According to the National Center for Educational

Statistics (2003b), in the fall of 2000, 31% of the 3230 colleges surveyed reported that computers were frequently used by students as a hands-on instructional tool for on-campus remedial mathematics, and 13% offered remedial courses through distance education, an increase from 3% in 1995.

Computer-assisted instruction is supported by the early work of Roueche and Kirk (1974). One of their eleven recommendations for effectively serving remedial students is to accommodate individual differences and permit students to learn at their own pace. According to Roueche and Kirk, “Individualized instruction is critical to the effectiveness of developmental programs” (p.88). They did not advocate any particular methodology but asserted that lectures are not appropriate for remedial students. Teachers should not stand in front of the class and talk at the students. Developmental students typically do not have the reading and listening skills to succeed in traditional instruction. They learn best by being active learners, by seeing and doing instead of listening. Computer-assisted instruction requires seeing and doing as students use the interactive tutorials and other multi-media.

Beginning in the early 1960s computer-assisted instruction was used almost exclusively to drill, tutor, and test students (Kulik and Kulik, 1991). With the rapidly changing capabilities of computer software and hardware in recent years, computer-based instruction now has a greater variety of possible uses. Textbook publishers have developed much of the software currently being used in developmental mathematics (Kinney and Robertson, 2003). It typically is one of two models: (1) software designed to support a traditional course with the instructor providing the content and the software providing videos and algorithmically-generated problems and (2) software designed to provide a thorough presentation of concepts with interactive multimedia and the instructor as facilitator. In the selection of software it is critical to first determine whether the learning is teacher-entered or student-centered. Software can be used in a variety of instructional formats: a supplement to direct instruction, a component of a hybrid course that combines teacher-centered and student-centered instruction, independent learning in an open computer lab with tutors available, computer-mediated learning that is student-centered and meets in a classroom with the same students and same instructor, and distance learning with no face-to-face contact between student and instructor. The current study focuses on computer-assisted instruction as a supplement to traditional instruction and computer-assisted instruction in distance learning courses.

Traditional Instruction Supplemented with Computer-Assisted Instruction

Computer-assisted instruction, also referred to as computer-based instruction and computer-enriched instruction, can support traditional classroom instruction. The software typically includes problems generated algorithmically, videos of each lesson, online tutoring, and a website with additional resources (Kinney and Robertson, 2003). It is designed to supplement but not replace the instructor. In this instructional model, students receive instruction in traditional classrooms, but the computer changes how they study outside the classroom. The computer component is available 24 hours a day from any computer with internet capability, so each student can choose when, where and how long he works outside the classroom. Instructors may create electronic homework, quizzes, and exams that are graded and recorded by the software. Drill and practice software leads the student through exercises designed to build accuracy and speed, assuming the student has received prior instruction (Kulik and Kulik, 1991; Olusi, 2008).

Interactive tutorials include guided practice problems, which encourage students to be actively engaged with the learning process (Mahmood, 2006; Merisotis and Phipps, 2000). Software can provide a student with an individualized study plan based on his scores on homework and quizzes (Cotton, 2001; Hannafin and Foshay, 2008). There is an element of competition as the student competes against his own previous score. Software can be programmed for mastery learning so a student does not proceed to the next lesson before mastering the current one. Computer-assisted instruction permits the student to work at his own pace and to receive immediate non-judgmental feedback on assignments (Cotton; Hannafin and Foshay; Merisotis and Phipps). Frequent testing and feedback has been identified by the National Association of Developmental Education as one of the best practices of developmental education (Boylan, 2002). Instructional management features store, organize, and process scores, response times, and other data that inform instructors and students how students are progressing in the course (Ford and Klicka, 1998).

Computers as instructors have several advantages over human instructors. The computer has infinite patience but a human does not (Kulik and Kulik, 1991; Mahmood, 2006). The student can revisit the same topic numerous times until he has mastered the concept and developed confidence (Brothen and Wambach, 2000). Computers do not get tired, frustrated, angry, or bored (Cotton, 1991; Kulik and Kulik). They keep accurate records and are always available. If they are programmed to do so, computers always remember to praise the student's work (Cotton; Mahmood). A student can take risks to try a solution, get instant feedback, and try again without being embarrassed when he makes a mistake. Unlike a human instructor, computers are impartial to gender, race, and ethnicity. In addition, students report they like working with computers because they teach in small increments, individualize instruction, build proficiency in computer use, reduce the drudgery of doing certain activities by hand, and allow teachers to be available for more meaningful interactions (Cotton). Computer-assisted instruction encourages a student to take responsibility for his or her learning, acquire effective study habits, and persist until he has mastered the content (Brothen and Wambach). He can control when he works and how much time he spends on each lesson (Reagan, 2004).

By supplementing traditional classroom instruction with computer-assisted instruction, students receive the benefits of both instructional modes. According to Maxwell, developmental mathematics students need to see the instructor work problems (1979). Instructors are able to observe individual students work, identify their misconceptions, and attempt to change their attitudes and study habits. By providing short lectures, the instructor is preparing developmental students for the lecture approach that is used in other college mathematics courses.

Computer-Assisted Instruction in the Distance Learning Format

Online distance learning is a new and rapidly growing mode of delivering instruction. As colleges and universities try to reach more students, they offer distance learning courses to serve students who otherwise may not be able to earn a college degree. The percentage of higher education institutions offering distance education courses has increased (33% to 55%) and the number of students enrolled in distance education courses has increased dramatically (753,640 to 2,876,000) from 1994 to 2001 according to studies by the National Center for Educational Statistics (NCES, 2003a). Among institutions offering distance education courses, 90% reported that they offered internet courses using asynchronous (not simultaneous) computer-based instruction, which was a 30% increase from three years earlier. In the early distance learning courses, students watched lectures on video tape, read the textbook, worked exercises, and took paper and pencil tests which were mailed to the instructor for grading (Armington, 2003). The instructor was often available to answer questions by phone or email. Distance learning courses are also offered using live interactive television and compressed video (Coggins, 1999). However, in 2001, more colleges and universities that offered distance education courses offered online courses than pre-recorded videos to deliver instruction (NCES, 2003a). The first online mathematics courses were attempts to replicate traditional classroom courses (Englebrecht and Harding, 2005).

Delivery of instruction in an online computer-assisted course is best described by the term *computer-mediated instruction*, which is a student-centered model that delivers individualized instruction. Thorough explanation of concepts is provided by interactive multimedia software, which usually includes activities requiring student interaction imbedded in the instruction, immediate feedback with detailed solutions, opportunities to develop skills, online assessments, and course management features to track students' progress (Kinney and Robertson, 2003; Trenholm, 2006). Multimedia uses text, graphics, sound, animation, video, and pictures to present information. The animation, color, and sound of the interactive tutorials and multimedia encourage students to be actively engaged with the learning process (Mahmood, 2006). In addition, chat rooms, discussion boards, and email build community and facilitate communication. Online courses provide flexibility for students with families and jobs, giving them the choice to work any time of day from any computer with internet access (Brothen and Wambach, 2000). Students can control the pace of their learning, although there is a schedule for completion of lessons (Kinney and Robertson). Students who need a review of the material can move quickly through the lessons, and others can spend as much time as needed and even return to previous material. Some colleges and universities require some personal contact for orientation and testing (Armington, 2003). Some require proctors for testing. To take an online course, students must have the necessary computer equipment and internet access and know how to use them. Students taking online courses should be self-motivated and disciplined in order to meet deadlines and complete the course (Armington; Coggins, 1999).

Computer-mediated instruction is a student-centered mode of instruction, where more responsibility is placed on the students for their own learning and the instructor takes on the role of facilitator and coach (Brothen and Wambach, 2000; Brown, 2003; Kinney and Robertson, 2003). The instructor's role is not to deliver instruction, but to provide students with the necessary resources, structure, communication, and feedback to complete the course. The instructor may monitor student progress toward course completion, encourage students to persist, counsel students on effective study strategies, and answer questions about course content. Student-centered approaches accommodate for the differences in what students need to learn, how they learn, the pace at which they learn, and the support they need in the learning process. Computer-mediated instruction can address these needs whether offered in distance-learning or in an on-campus computer lab. Student-centered approaches have been associated with greater mastery of concepts, motivation to learn, depth of understanding, appreciation of the subject, and satisfaction with the course and with less tardiness and absenteeism (Felder and Brent, 1996; Grasha, 1994).

Research on Traditional Instruction Compared to Computer-Assisted Instruction

Numerous studies have been conducted on the effects of computer use on student achievement, attitudes, learning rates, and other variables. Meta-analyses, reviews of literature, and individual studies generally indicate that computer-assisted instruction has a positive effect on student learning. A meta-analysis combines the results of numerous studies that were conducted in different settings, at different times, and under different conditions and therefore can give a better indication of the effects of a treatment than an individual study can. A series of meta-analyses by James Kulik and his associates at the University of Michigan compared the achievement levels of students using computer-based instruction with students who received traditional instruction. They reported significant effect sizes in elementary (0.47), secondary (0.26), and college instruction (0.36) in a variety of courses (Bangert-Drowns, Kulik, and Kulik, 1985; Kulik and Kulik, 1986; Kulik, Kulik, and Bangert-Drowns, 1985). In a study of 123 colleges and universities, the use of the computer as a tutor to supplement traditional instruction was associated with more learning in less time, slightly higher grades on post-tests, and improved attitudes toward learning (Kulik and Kulik, 1986).

An updated meta-analysis of 254 studies comparing outcomes in computer instructed and traditional instructed classes was consistent with the earlier studies (Kulik and Kulik, 1991). The study included students of all ages, kindergarten through adult, who used computer-based instruction (CBI) in mathematics, social studies, science, reading and language, and vocational training. The computers were used for drill and practice, tutoring, and programming. Overall there were small positive changes in student attitudes toward computers and learning, a reduction in the amount of time needed for instruction, and an increase in exam scores of 0.3 standard deviations. It should be noted that the results were not consistently and overwhelmingly in favor of CBI. In 81% of the studies, the CBI classes had the higher average on end-of-course examinations, and in 19% the traditionally taught classes had the higher average. The effect sizes in mathematics were higher for precollege (0.37) than postsecondary (0.14). This suggests that developers of CBI programs may be more successful at creating programs to teach elementary skills and basic knowledge than higher order skills. All the studies included in this meta-analysis were published before 1984.

Computer software has changed rapidly in recent years so it is important to examine more recent studies on the effectiveness of computer-assisted instruction to determine if the positive effects indicated by earlier studies have persisted. A review of 16 studies published since 1990 on the impact of computer-assisted instruction in mathematics in elementary and middle schools found that all had at least slightly higher test scores and for nine of the studies the increase was statistically significant (Kulik, 2002). The median effect size was 0.38 which is consistent with the studies from the 1960s through 1990. Evaluation of computer tutorials in science courses had even stronger positive results. A more recent meta-analysis of 52 studies of 5000 subjects in Taiwan from first grade through college in English, physics, chemistry, statistics, mathematics, and business found that computer-assisted instruction had moderately positive effects on students’ achievement over traditional instruction (Liao, 2007). The overall grand mean effect size was 0.552, the mean effect size for math was 0.291, and the mean effect size for college was 0.823.

Results of literature reviews have been consistent with these meta-analyses in concluding that computer-assisted instruction (CAI) does produce higher achievement for students of different ages and in different subject areas, especially when CAI is combined with traditional instruction. In a review of research on computers used for drill-and-practice, problem solving, simulation, and tutorials, all studies showed that computer-assisted instruction as a supplement to traditional instruction was more effective than traditional instruction alone (Edwards, Norton, Taylor, Weiss, and Dusseldorp, 1975). CAI as a substitute for traditional instruction had mixed results. Students learned more quickly with CAI, but students who received traditional instruction exclusively retained more of what they learned. Thomas (1979) reported that computer-assisted instruction was associated with achievement levels equal to or higher than traditional instruction. In addition, he reported improved attitudes toward computers and the subject matter, a reduction in time to master content, and comparable levels of retention. In a review of research by the Northwest Regional Educational Laboratory, traditional instruction supplemented by CAI resulted in higher achievement than traditional instruction alone but CAI as a replacement for traditional instruction had mixed results (Rapaport and Savard, 1980). Low-ability students were found to benefit more than high-ability students. CAI students completed the same material in less time than traditional students. There were no consistent results on retention rates of the two groups.

A more recent review of 59 research reports on computer-based learning and student outcomes concluded that computer-assisted instruction as a supplement to traditional teacher-directed instruction produced higher achievement than traditional instruction alone (Cotton, 1991). In addition, the findings reported that when computer-assisted instruction alone was compared with traditional instruction alone the results were too mixed to lead to any conclusion. Other conclusions were that students retained more material, they learned at a faster rate, their attitudes towards computers and course content improved, their attendance was better, CAI benefitted younger students more than older ones and lower-achieving students more than higher achieving ones, CAI was more beneficial for teaching lower-cognitive material than higher-cognitive material, handicapped students had higher achievement with CAI than with traditional instruction, and there were no significant differences in achievement of male and female students. A 1996 report based on 176 research reviews and individual studies found that educational technology had a positive impact on achievement for all subject areas from preschool through higher education (Bialo and Sivin-Kachala, 1996). The achievement of students using CBI was significantly related to the amount of technology-related training the teachers had received and whether the technology was being used appropriately. Software that gave immediate feedback and that allowed students to control the pace and sequence of instruction was associated with higher success rates.

Considerable research has been conducted on the effects of computer-assisted instruction on the mathematical learning of students of various ages and ability levels. Most studies show computer-assisted instruction has a positive effect on mathematical achievement, but how computers were used in these studies varied greatly. In one of the few national studies of the effect of technology in the classroom, some uses of computers increased fourth and eighth graders’ mathematical achievement and others were less effective (Wenglinsky, 1998). Students who used computers for higher-order thinking skills had higher levels of achievement than those who used them for drill-and-practice. The frequency of use was unrelated or had a negative effect. However, students of teachers who had received professional development in computer use had higher levels of achievement. Students in kindergarten through fifth grade in Project CHILD classrooms, which integrate computer stations with hands-on exploratory projects and direct instruction, had higher test scores in reading, language arts, and mathematics than students in traditional classrooms at the same schools (Butzin, 2000). In addition, the study reported better discipline, more positive attitudes toward school and learning, and positive feedback from parents of children in the program. Third and fifth graders in Canada who used the computer to supplement classroom instruction scored significantly higher on a standard test of mathematics achievement than those receiving conventional instruction (Fletcher, Hawley, and Piele, 1990). Sixth graders who received computer-based instruction in addition to traditional instruction on the concepts of area and volume scored higher than eighth grade students who received traditional instruction only (Raghavan, Sartoris, and Glaser, 1997).

Studies of middle and high school mathematics students have also shown positive results. Ninety-five seventh and eighth grade students from two classrooms were randomly assigned to either computer assessment or paper-and-pencil assessment for two weeks while studying fractions and decimals (Nguyen, 2002). There were statistically significant differences between the groups' performance on homework and the posttest with the computer group outperforming the paper-and-pencil group. The attitude toward mathematics of the computer group improved significantly, but the attitude of the traditional group remained the same. Interviews revealed that students liked the immediate feedback and the opportunity to retake homework. In a study to examine the effects of various mastery learning teaching methods involving five combinations of traditional and computer-based instruction, students in an eighth grade mathematics course had the highest achievement when initial instruction and remedial instruction were delivered by different methods (Dalton and Hannafin, 1988). This suggested that computer-based instruction and traditional instruction are most effective when they complement one another. Ninth grade algebra students receiving computer-assisted instruction on the conceptual knowledge of variables had more flexible approaches to problem solving and were better at using variables to model problem situations, at reading and interpreting graphs and tables of values, and at relating graphs to their equations than students receiving traditional instruction (Boers, 1990). A study of the mathematic achievement of high school students in Nigeria revealed a significantly higher mean for the group receiving CAI (Olusi, 2008). Two-hundred seventy students were randomly assigned to computer-assisted instruction and traditional instruction and given a pretest and posttest.

The learning of low-achieving students is higher when computer-assisted instruction is combined with traditional instruction than with traditional instruction alone. Low-achieving, disadvantaged Israeli children in third, fourth, and fifth grades in classes with computer-assisted instruction supplementing traditional instruction scored significantly higher on a national arithmetic test than those receiving only traditional instruction (Mevarech and Rich, 1985). Both groups received equal instructional time each week, which sets this study apart from prior studies in which instructional time for the CAI group is greater because the CAI is added onto the traditional instruction instead of replacing some of the traditional instruction. The computer delivered drill and practice tailored to the individual student and provided immediate feedback. The results also revealed that attitudes toward mathematics and toward school in general was higher for students using computer-assisted instruction combined with traditional instruction than for students exposed to traditional instruction alone. The arithmetic achievement and attitude scales of males and females did not differ significantly.

A more recent study of low-achieving high school students also found positive effects for computer-assisted instruction. Computer-based instruction (CBI) was associated with improved passing rates on a state competency exam (Hannafin and Foshay, 2008). A Massachusetts high school designed a remediation strategy that assigned 10^{th} grade students at risk for failing the exam to a computer-based math course. Students worked independently at their own pace through 34 instructional modules. They could seek help from the teacher, who also taught study strategies and test taking skills once a week. Both CBI and non-CBI groups had a significant increase in state test scores with the CBI group outperforming the non-CBI group in terms of their gain in scores (20.4 vs. 11.2). In 1990, only 40% of the 10^{th} graders at the school passed the state exam. The pass rate increased to 62% in 2000 and 84% in 2001 when CBI was added for at-risk students. Since other strategies were implemented at the same time, it is unknown how much of the success can be attributed to the use of computer-based instruction. However, the researchers concluded that CBI in combination with other efforts gave many under-achieving students an opportunity to succeed when they previously had failed with traditional instruction.

Computer-assisted instruction has positive effects on the learning of students with mild and moderate cognitive learning disabilities (Fitzgerald and Koury, 1996). A review of empirical studies from 1988 to 1995 in K-12 classrooms found that the students learned as well or better with CAI than without it in reading, writing, mathematics, science, and social studies. Students preferred CAI over other forms of instruction. Students with cognitive disabilities benefited the most from CAI when the software gave immediate feedback, interspersed mastered items with new items, and limited the use of extra graphics. The positive results in mathematics instruction were attributed to the software providing large amounts of practice that students need in order to master a skill. The software provided drill and practice to increase accuracy and speed.

Computer-assisted instruction has significantly positive results for college students. The average improvement in post-test scores over pre-test scores in an introductory calculus course using online tutorials and quizzes to review algebra and improve computational skills was significantly higher than the group that did not use these resources (McSweeney, 2003). Students in a computer-assisted developmental psychology course showed significantly higher pass rates and final exam scores than those receiving traditional instruction (Brothen and Wambach, 2000). A comparison of students receiving A grades and F grades revealed that A students persisted until they succeeded and F students failed to work hard, which in most cases was related to nonacademic factors such as health, family, or personality variables.

On the other hand, some studies indicate that computer-assisted instruction does not positively affect the learning of mathematics. Diem (1982) conducted a study at Florida Atlantic University to determine the extent to which microcomputer instruction affects the learning of mathematics in College Algebra. Students were randomly assigned to four different methods of instruction: traditional lecture followed by textbook homework, computer tutorial program followed by textbook homework, lecture followed by a computer drill and practice program, and computer tutorial followed by computer drill and practice programs. A pretest and posttest were given. The results of an analysis of variance indicated that there was no significant difference in the achievement in learning between any of the four groups. Diem also calculated growth quotient values, which showed that significant learning gains did occur in all groups.

Colleges and universities are also using computer software in a variety of ways in an attempt to improve pass rates and retention rates in developmental mathematics courses. According to Barbara Bonham, the senior researcher at the National Center for Developmental Education, there is no meta-analysis or conclusive research, only isolated studies, on computer-assisted instruction for developmental mathematics (Trenholm, 2006). The existing research indicates mixed results which may possibly be attributed to the choice of software used in the study, if it was used effectively, and if students were required to use the software. Stillson and Alsup (2003) studied the effectiveness of teaching Basic Algebra using the interactive learning system ALEKS to supplement traditional instruction. The students who took the time to use the software thought they learned more than they had in previous math courses, but a high number of students either dropped the course or received failing grades because they did not use the learning system. Higher test scores were associated with greater mastery and more time spent on ALEKS assignments. Interviews at the conclusion of the course indicated that students liked the immediate feedback, the repetition, and the convenience of working at their own pace. They did not like that ALEKS and the textbook did not correspond making them feel like they were taking two math courses. Platforms such as Blackboard provide an instructional tool for educators to design developmental math courses in a mastery learning format (Boggs, Shore, and Shore, 2004). Multiple versions of tests can be created by random selection from a test bank, grading is automatic, feedback is immediate, teaching students working on different objectives is manageable, and multiple methods of communication between students and instructor are possible. The Allegheny College of Maryland reported a 66% success rate (40 students) compared to a 55 % success rate (220 students) in classes not using Blackboard. A study of the effect of a multimedia, interactive mathematics program on the mathematical achievement of students enrolled in Intermediate Algebra at a community college in Texas suggested that the program was not effective (Bump, 2004). The mean final exam score of students in lecture classes (20.65) was significantly higher than the mean final exam score (15.61) of students in the computer-assisted classes that met in a lab with no lecture. Bump acknowledged that there were numerous problems with the computer-assisted classes, including slow servers, software flaws, confusing feedback, problems with the videos, and internet problems, that may have influenced the outcome of the study.

A number of studies on the impact of computer-assisted instruction on the learning of developmental mathematics indicate that students using computer-assisted instruction are learning at least as well as those receiving traditional instruction. A study comparing the effectiveness of computer-assisted instruction and traditional instruction for teaching geometry and algebra to African American students enrolled in a developmental mathematics course suggested that CAI is effective for teaching geometry but had no significant effect in teaching algebra (Owens and Waxman, 1994). In addition, students in the CAI group had significantly higher attitudes towards mathematics at the end of the course than the traditional group. There were no differences in the algebra test and math attitude test results for males and females.

Waycaster's (2001) study of 15 developmental mathematics classes at five Virginia community colleges showed no significant difference in pass rates among three modes of instruction: lecture, individualized instruction with tutoring, and computer-assisted instruction. However, developmental mathematics students had higher retention rates than non-developmental students and the same or higher pass rates as non-developmental students in college-level mathematics courses.

In a study at the University of Minnesota, students were allowed to select a computer-mediated or lecture class (Kinney, 2001; Kinney and Robertson, 2003). A placement exam written by the mathematics faculty and an inventory related to computer-mediated or traditional learning environments helped students select a course. In the lecture classes, the instructor presented the content, gave students time to work collaboratively, and provided feedback as they worked. All students worked on the same concepts at the same time and took tests at the same time. In the computer-mediated classes, instruction was delivered by the interactive multimedia from Academic Systems Corporation. Computer-mediated instruction is often used in an open lab or in an online course. However, in this study students met at the same time in the same room with the same instructor. This permitted students to interact with each other and with the instructor who provided individual and small group assistance. Students worked at their own pace but were required to attend class and complete exams by a scheduled date. All students in both the lecture and computer-mediated classes had access to the software. This allowed students who missed class an opportunity to study the lesson. Students in the lecture classes who did not fully understand the instructor's presentation could use the software for an additional presentation or for additional practice with immediate feedback. There was no significant difference on common final exams in Elementary Algebra in the computer-mediated classes ($M=70.12$, $SD=14.47$) and lecture classes ($M=70.82$, $SD=16.61$), $t(233)=0.30$, $p=0.76$. In addition, there was no significant difference on common final exams in Intermediate Algebra in computer-mediated classes ($M=67.19$, $SD=12.26$) and lecture classes ($M=68.47$, $SD=11.61$), $t(336)=1.02$, $p=0.31$. The study also found that there was no significant difference in pass rates and students in lecture classes were significantly more likely to withdraw than students in computer-mediated classes.

In a 2006 study at a public four-year college, computer homework did not help pre-algebra students perform better on an exam than students who did not use computer homework, although students believe it helped them learn (Jacobson, 2006). The students used the computer learning system that accompanied the textbook to complete homework exercises for ten lessons. The students could use the tutorial features of the program to practice exercises before completing problems for a grade. An analysis of covariance was conducted on the second exam scores using the first exam scores as the covariate. No significant difference was found between the classes with computer homework and those without. However, there was a significant difference in sections taught by different instructors. Students reported that all components of the program helped them learn with the exception of the videos. Almost 25% of the students strongly disagreed that the computer was helpful and expressed frustration with learning to use the equation editor to enter answers. It is important to note that the computer tutorials and homework in this study were added to an already existing course and that students only used the computer for ten lessons. Computer use may have had a positive impact on exam scores if students had more instruction in the use of the equation editor, if the format of the exams were similar to the computer homework format, if the computer program was demonstrated in class, and if the computer component had been an integral part of the course for the entire semester. This study suggests that how well or poorly computers are integrated into the curriculum may have an impact on whether computer-assisted instruction benefits student learning.

A quasi-experimental study with a design similar to the proposed study found no significant differences in the test scores of pre-algebra students who received computer-assisted instruction (CAI) and traditional lecture (TL) (Teal, 2008). The study was conducted at a suburban community college in the mid-Atlantic region in fall semester of 2006. The CAI group met in a computer classroom, received mini-lectures using online lecture notes, and used the remainder of the class time to ask questions and work on computer assignments using Educo Learning System. Online homework, tutorials, and quizzes were completed during or after class. The TL students received instruction primarily through lecture and were expected to take notes as the professor provided explanations and examples. In addition, they worked in groups, turned in homework, and took quizzes and tests. Three professors each taught a CAI class and a TL class. Students self-registered for the course, in effect choosing their own mode of instruction. This study used ACCUPLACER for the pretest to establish the mathematical knowledge prior to treatment. Two posttests, a 16-question multiple choice test after six weeks of instruction and the department final exam after 16 weeks of instruction, were administered to the 152 students.

These results were consistent with the prior work of Reagan comparing student learning in traditional classrooms and computer-assisted classrooms in Beginning and Intermediate Algebra at a rural community college in Texas (2004). This study was also a quasi-experimental design with ACCUPLACER used for the pretest and posttest and a total sample size of 112. Students were also administered a computer attitude scale, reading placement test, and demographic questionnaire. Although the study found no significant differences in the mathematics test scores, there was a significant positive correlation between math performance and reading placement scores. These studies suggest that computer-assisted instruction is at least as effective as traditional instruction and that both instructional methods should be offered to give students a choice.

A study at a historically black community college in Texas revealed higher mathematical performance in classes with traditional instruction supplemented with computer-assisted instruction than traditional instruction alone (Mahmood, 2006). The study used a pretest-posttest quasi-experimental design, which is the design of this present research. The pretest and posttest was the practice test for the state-required Texas Higher Education Assessment test (THEA). Failure to pass THEA places students into developmental mathematics courses. Two classes received traditional instruction and two received traditional instruction supplemented with computer-assisted instruction. Success in mathematics was measured by the gain scores, the difference in students' pretest and posttest scores. An analysis of variance was conducted on the gain scores.

Students who received traditional instruction combined with computer-assisted instruction had significantly higher scores than those who received only traditional instruction in Fundamental Mathematics classes $F(1,57) = 4.560$ $p<.05$ and Analytical Mathematics classes $F(1,62) = 3.99$ $p<.05$. In addition, the study found no significant difference in the mathematical achievement of males and females.

The developmental mathematics program at the University of Texas at Brownsville had higher final exam grades and higher course pass rates with computer-assisted instruction combined with classroom instruction compared to computer-directed instruction. The university had disappointing results with Introductory Algebra and Intermediate Algebra courses offered by computer-directed instruction, in which the instruction was primarily by computer in a campus computer laboratory with the instructor available as facilitator (Villarreal, 2003). The delivery was similar to an online distance learning course but the students worked at a time of their choosing in a campus computer lab staffed with tutors. Most students lacked the motivation and self-discipline to complete the course. Some students relied on a tutor to explain the material and did not read the textbook or use the computer tutorials. The courses were redesigned as computer-assisted instruction with three hours of classroom instruction and three hours of laboratory per week. The percentage of students passing the courses increased an average of 12% within two years. An additional alternative was classroom instruction with pencil/paper laboratory for students who preferred greater interaction with the instructor. These results were consistent with the conclusion of the National Center for Developmental Education that computer-based instruction is most effective with developmental students when used as a supplement to traditional classroom instruction (Boylan, 2002).

Textbook publishers provide testimonials from colleges and universities on the positive effects of their computer learning systems. For example, Pearson Education published descriptive data from an assortment of two-year and four-year colleges indicating an increase in success rates (A, B, C), the amount of homework completed, homework grades, and final exam grades and a decrease in withdrawals and failures in courses using MyMathLab compared to those not using MyMathLab (Pearson Education, 2005). Cengage Learning, the company that provides the learning system used in this proposed research, claims that CengageNOW delivers better student outcomes, engages students in course materials, and saves instructors time (Cengage Learning, 2008). According to a survey of CengageNOW users, nearly 90% of students agreed that it helped them understand key concepts, nearly 80% said it helped them better prepare for exams, and more than 80% said it helped them earn a higher grade.

Research on Computer-Assisted Instruction in Distance Learning Courses Compared to Other Modes of Instruction

The research on the success of distance learning courses delivered entirely online compared to other modes of instruction is limited and inconclusive. This is not surprising given that using the internet to deliver instruction is a recent development in distance education although other forms of distance education have been used for many years. In his annotated bibliography *The No Significant Difference Phenomenon,* Thomas Russell (2001) of the International Distance Education Certification Center cites 355 research reports, summaries and papers from as early as 1928 on student outcomes in alternate modes of educational delivery. Some educators use Russell's work to support the contention that distance learning outcomes of students using technology are similar to outcomes of students in traditional classrooms. However, the Institute for Higher Education Policy advocates more careful scrutiny and more cautious conclusions (IHEP, 1999). In a study on the effectiveness of distance learning in higher education commissioned by the American Federation of Teachers and the National Education Association, the IHEP stated that (1) only a small percentage of the articles written on distance learning contained original, quantitative research, (2) most of these quantitative studies found no significant difference in the learning outcomes of online and traditional classes, and (3) the quality of most of these studies was questionable making their findings erroneous or misleading.

Carey attempted to address the flaws cited by the IHEP report in a study of a management information systems course offered in a web-based, online, asynchronous format and in a face-to-face, synchronous format (2001). Both formats had the same instructor and same assignments. Her study found no significant differences in gain scores (difference between pretest and posttest), course grade, and student satisfaction. An additional finding was the dropout rate of the online course (7.4%) was significantly higher than the traditional course (2.8%), which may have skewed the results because the students who dropped out of the course most likely had low grades. Carey claimed that much of the research is conducted by the instructors who are teaching the courses themselves and that they may have a strong interest in showing positive outcomes for the online delivery.

Glenn (2001) conducted a study at a community college in Texas to determine whether there were differences in achievement and perceptions between students who complete a Texas government course in two different learning environments, the traditional classroom and distance learning. Both courses were taught by the same instructor and had the same assignments. The on-campus classes were taught primarily by lecture with some films and class discussion. The distance learning course was taught entirely on the internet with the same lectures, films, and outline. An objective pretest and objective posttest measured student achievement before and after instruction. A survey was used to collect data about student demographics and perceptions of the course. An independent samples t-test revealed no significant difference in the pretest scores ($t=-1.827$, $p=.069$), no significant differences existed on the posttest ($t=-.969$, $p=.334$), and no significant difference in student perceptions of the course ($t=1.775$, $p=.077$) between students in the distance learning course and students in the on-campus course. A Pearson-product moment correlation coefficient was calculated to determine if there was a relationship between student performance and student perceptions. No statistically significant relationship existed for either the on-campus group or the online group.

Other studies have suggested positive results for online distance learning courses. The online version of an Introduction to Shakespeare course had better learning outcomes than the equivalent on-campus version taught by the same instructor (Koury, 2003). One outcome was that student projects in the online class were of higher quality than those in the face-to-face course. A study conducted by James Detwiler of the Department of Geography at Pennsylvania State University compared the performance and study habits of two groups of students in a course in Geographic Information Systems software programming (2008). A group of adult professionals received instruction asynchronously online and a second group of undergraduates received instruction in a blended online/face-to-face format. The totally online group performed higher than the blended group in spite of the second group having face-to-face lecture and lab time in addition to the online components of the course. Evaluation of the students' diaries of time devoted to the course suggested that a student's success may be dependent on the student's motivation, maturity, and time management skills more than on the delivery method of the course.

Engelbrecht and Harding (2005), in their article, *Teaching Undergraduate Mathematics on the Internet*, claim that it is not surprising that research is very limited because e-learning in undergraduate mathematics is such a new phenomenon. They stated, "Research on this new mode of instruction is sparse and open research questions are temptingly plentiful" (p.235). One challenge is using mathematical symbols in the language commonly used on the internet, HyperText Markup Language. Some of the newer software has addressed this problem by using Mathematical Markup Language or Java applets. Another challenge discussed by Engelbrecht and Harding is the assumption by both students and faculty that face-to-face contact is necessary to teach mathematical concepts. Both teachers and students must learn new roles in the online environment.

Other researchers including Testone (1999) and Smith and Ferguson (2004) discovered a high degree of frustration among students and teachers in attempting to communicate with mathematical symbols over the internet. Smith and Ferguson contend that online math instruction has been difficult and frustrating for both teachers and students mainly due to the inability to communicate in the web environment with math notation and diagrams. Supported by a National Science Foundation grant, they conducted a needs assessment of online math instructors, established criteria for an ideal math-friendly online environment, compared new math-friendly tools, and conducted calculus and algebra pilot courses using one of these tools. The results of their case study were that the online courses using NetTutor were as effective for math learning as the face-to-face courses. Students and instructors could communicate two-way asynchronously and in real-time chats using math notation and diagrams. They felt more connected to their classmates and the instructor and learned difficult concepts as well as students in traditional courses.

A study comparing the learning outcomes of statistics students found that the final exam scores and course grades of those in the traditional classes were higher than those in the online classes (Estes, 2002). In addition, the withdrawal rates for online classes was higher (39.4%) than the traditional classes (13.2%), and the success rate, defined as A, B, or C, was lower for online classes (44.4%) than traditional classes (77.0%). Several improvements were made to the online course including a daily presence by the instructor through online office hours and email, more structure in the form of weekly quizzes and a course calendar, an online tutor, and focus groups. Success rates over five semesters improved nearly 30% in the online course.

Another example of college instructors learning to create courses using the computer to deliver instruction is the work of Barabash, Guberman-Glebov, and Baruch in designing courses for mathematics teacher training (2003). They attempted to match the needs of the instructor, students, and course content with a blending of online and traditional instruction. A psychology of teaching and learning course was offered completely online, an assessment course combined classroom lectures with online library and discussions, and a plane geometry course was delivered primarily by classroom instruction supplemented with online hints and solutions to exercises. Their results indicated that these combinations of classroom and computer instruction had been effective and students were very satisfied with their progress. The researchers asserted that technology itself was not what improved learning but its wise use may have resulted in more meaningful learning. They stated that the instructor is indispensible in any mode of instruction.

Colleges and universities are concerned about the low retention rates of students in distance learning programs. Course completion rates are often ten to twenty percent higher in traditional courses than in distance courses (Carr, 2000). There are no national statistics on how many students complete distance learning courses, but individual institutions have reported completion rates from less than 50% to more than 80%.The two reasons given most often by students for dropping a distance course were busy schedules and teachers inexperienced with managing distance courses. Taylor and Mohr agree, stating that the most frequent reason given by students for not completing a distance learning developmental mathematics course from the University of Southern Queensland, Australia, were personal problems or not sufficient time due to work and family commitments (2001). In addition, the researchers stated that students often use developmental courses to test their suitability for college and some may conclude that they are not and drop the course. According to Carr, frequent contacts with students and clear expectations have been linked with keeping students engaged with the course.

Before the course begins, professors should inform students how much time and computer skill will be required to successfully complete the course. Students who can work independently and are computer literate may have better chances for success in a distance learning course than those who are not.

Some preliminary research has been conducted on learning strategies that affect success in online developmental courses, but more is needed to determine how these strategies can be taught in the online environment and how students can transfer successful strategies from the traditional classroom to the on-line classroom (Wadsworth et al., 2007). Some educators have examined factors critical to the success of online courses and found that frequent feedback from faculty, students being comfortable with computer technology, a comprehensive syllabus, faculty who are trained to teach in the distance learning format, instructors who engage the students in the class, enrollment counseling and advising, and students who are self-disciplined and self-directed are among these factors (Coggins, 1999; National Center for Academic Transformation, 2005; Testone, 1999). Another factor is that the best instructors in the traditional classroom may not be the best instructors for distance education courses.

Some educators are asking whether developmental students can learn mathematics in the distance learning environment or whether they need a traditional classroom with the assistance of an instructor. The National Study on Developmental Education conducted between 1990 and 1996 found an inverse relationship between amount of computer technology used in a developmental course and pass rates (Boylan, Bliss, and Bonham, 1997). There were higher failure rates in classes that used computers to deliver most of the instruction than in classes where computers were used to supplement instruction. In a collaborative study between the Continuous Quality Improvement Network and the National Center for Developmental Education, the best-practice institutions used technology only to provide tutoring, drill and practice, and supplemental assistance (Boylan, 2002). Boylan asserted that “Computer-based distance learning has yet to be proven effective with developmental students. Distance learning often requires independent learning skills, study discipline, time management skills, and a high degree of motivation. These characteristics are not plentiful among developmental students” (p.82). According to the *National Study of Developmental Education II: Baseline Data for Community Colleges*, the number of developmental courses offered completely online has increased only slightly since 1996 when the first National Study of Developmental Education reported that three percent of developmental courses were taught totally online (Gerlaugh, Thompson, Boylan, and Davis, 2007).

Since these studies were conducted there have been changes in how computers deliver instruction and how instructors have adapted to the online environment. Educators have gained more experience in managing online courses (Wadsworth, et al., 2007). Taylor and Mohr (2001) studied the effectiveness of a distance learning developmental mathematics course from the University of Southern Queensland, Australia. The focus of the course was to alleviate math anxiety while increasing the confidence and mathematical skills of the students. The average age was 35 years. Sixty-five percent were female and thirty-five percent were male. To provide the support that developmental students need, the course included phone support at no cost, electronic discussion groups, videos and tutorials. Diary entries and essays were integrated in the course assignments to create a similar experience to the student-teacher interaction that takes place in the traditional classroom. Analysis of course grades, essays, surveys, and phone interviews revealed that 51% reported a decrease in math anxiety, 90% reported increases in confidence in their ability to do mathematics in their future studies, 90% of the students still enrolled in the course passed with a C or better, and 50% of the number originally enrolled did not complete the course.

In 1999, the League for Innovation in the Community College, PLATO Learning Inc., and community colleges collaborated in an action research project “Adding Up the Distance: Critical Success Factors for Internet-Based Learning in Developmental Mathematics” (Perez and Foshay, 2002). A total of 185 students from eight community colleges from Florida, Michigan, Illinois, Hawaii, Iowa, and Ohio participated in the project. Some colleges had been using internet-based learning for more than 20 years and for others this was their first attempt at using technology with developmental learners. Six colleges used the PLATO Web Learning Network in a complete online course and two used it as a supplement to a traditional course. Each college implemented PLATO in a different way. The study identified factors critical to success in an online developmental mathematics course: courseware that is easy to access and navigate; technical support for learners and faculty; courseware aligned with course objectives (in contrast to drill-and-practice); self-paced, individualized, anytime/anywhere features; learners with motivation, time management, and academic goals; learners who attended orientation sessions; frequent contact from faculty and help desk; professional development for faculty; faculty who were experienced with distance learning or showed great interest in learning how to teach with technology; and administrative support.

Faculty in this study identified six positive outcomes of online distance courses for developmental education learners (Perez and Foshay, 2002):

- Tutorials: Learners are able to study and review basic math concepts freeing up more time for individual assistance from faculty.
- Flexibility: Adult learners who have work and family time constraints can work anytime, anywhere.
- Self-paced: Learners are not held to pre-determined course schedules and may complete assignments in as little or as much time as they need.
- Privacy: Learners can work in a private environment and focus on the concepts they need.
- Cutting edge: Developmental learners, who have often been offered second-rate services, are offered an attractive state-of-the-art learning option.
- Interactive feedback: Learners receive immediate feedback after each response rather than having to wait for homework and tests results.

At Onondaga Community College in Syracuse, NY, the pass rate of students in beginning and intermediate algebra using the publisher’s resources in an online course was 20% higher than the pass rate of students in residential classes who had access to the electronic resources but were not required to use them (Testone, 2005). The students had access to computer-assisted homework, guided practice problems, videos, and multi-media textbook. A required orientation session was held to introduce the students and tutors to the technology. Residential and online students took the department final exam on campus in a proctored setting. Residential students were also given access to the online resources and those who did use the resources had higher success rates than those who did not. As a result of this study, the faculty is introducing several web-enhanced sections and hybrid sections of developmental mathematics. The National Center for Academic Transformation reported a similar improvement in a redesign of an Intermediate Algebra course at the University of Alabama into a computer-based, self-paced tutorial (2005). The D/F rate decreased from 43% to 27%. A strong correlation was found between students' time-on-task and success in the course.

A study examining the effectiveness of computer-assisted instruction in two developmental mathematics courses at a Pennsylvania community college had mixed results (Ford and Klicka, 1998). Classes were offered in four settings: traditional lecture, computer-assisted instruction non-lecture, computer-assisted instruction with lecture, and distance learning. In the Fundamentals course, no significant differences were found between traditional instruction and the other delivery methods in passing the course, passing the final exam, achieving an A or B on the exam, remaining in college, and passing the next math course. In Basic Algebra, no significant differences were found between traditional and the other methods in passing the next math course, remaining in college, or passing the exam with an A or B. However, traditional sections had significantly higher pass rates and course retention rates, and computer-assisted sections and distance learning sections had significantly higher final exam pass rates. The authors acknowledged that one factor affecting the results was that students chose a class that fit their schedule and did not consider whether computers were involved. They concluded that the CAI non-lecture classes are best suited for self-motivated, self-disciplined, and independent learners. As a result of this study, faculty decided to continue offering students choices of instructional methods and to improve the students' course selection process.

Gender Differences in Mathematical Performance

There is concern that the gender gap in mathematics, if it still exists, will limit females' access to college and to careers that require skills in mathematics (Ding, Song, and Richardson, 2006; NCES, 2005). Stereotypes that females lack mathematical ability and have poor math skills continue to persist in society, particularly among parents and teachers (Hyde, Lindberg, Linn, Ellis, and Williams, 2008). A basic principle of the *Crossroads in Mathematics: Standards for Introductory College Mathematics Before Calculus* adopted by the American Mathematical Association of Two-Year Colleges (1995) is to increase participation in mathematics and careers using mathematics by all students, including women, minorities, and others who have traditionally been underrepresented in the field. There is evidence that over the past several decades, the gender gap between men and women in mathematical performance has narrowed but may not be eliminated. Researchers have investigated gender differences in course grades, standardized test scores, attitudes, motivation, interest, college majors, and the reasons for the differences.

An analysis of data from state assessments on seven million students in grades two through eleven in ten states suggests that there may no longer be a gender difference in math skills (Hyde, Lindberg, Linn, Ellis, and Williams, 2008). Effect sizes for gender differences were consistently less than 0.10. Twenty-one were positive indicating a better performance by males, 36 were negative indicating a better performance by females, and nine were zero. The weighted mean was so small (0.0065) that it indicated no gender differences. This study differs from an earlier study by Hyde, Fennema, and Lamon (1990) that found that males outperformed females in problem solving in high school (d=0.29) and college (d=0.31), which may have influenced the number of females pursuing careers in science, technology, engineering and mathematics. Over time the magnitude of the difference declined. For studies published in 1973 or earlier the effect size was 0.31, but for studies published after 1973 the effect size was 0.14.

A 2004 report by the National Center for Education Statistics on the educational status of girls and women in elementary through postsecondary education in the United States concluded that females are now performing as well or better than males on many indicators of achievement (2005). The data suggest that large gaps that once existed between males and females have been reduced or eliminated. In kindergarten through third grade, males and females had similar overall mathematics performance with the exception of third grade where males scored slightly higher. The National Assessment of Educational Progress mathematics scores for 1990 through 2003 for grades 4, 8, and 12 had very small gaps between males and females, which changed only slightly over time.

The NCES study (2005) also found that a higher proportion of males took the AP exams in science and calculus in 2002 and males had higher average scores on these exams compared to females. It appears that female high school students are taking mathematics and science courses that are at least as challenging as male high school students. In 2000, female high school graduates were more likely to have taken biology, chemistry, AP/honors biology, geometry, and algebra II than male students. However, males were more likely than females to have taken physics. Gender differences in college majors still persist. NCES reports that although females have made sizable gains in the past 30 years, males are still more likely than females to earn degrees in engineering, physics, and computer science, and females are more likely than males to earn degrees in education and health related majors. In other majors, the gender differences are negligible.

There is evidence that males outperform females on standardized tests and females outperform males on high school course grades. Males had significantly higher SAT-M scores than females in first-year mathematics courses at nine universities (Bridgeman and Wendler, 1991) and in a four-year business college (Odell and Schumacher, 1998). Ding, Song, and Richardson (2006) attempted to document the timing of gender differences in mathematics using standardized tests and mathematics course grades by examining four years of data for students in grades three, seven, and nine from two school districts. Females had a significantly higher mathematics grade point average that emerged in middle school and persisted through high school. Earlier studies also found that females received equal or better grades in math courses than males (Gallagher, 1998), had higher high school grade point averages (Bridgeman and Wendler), and higher high school class rank (Odell and Schumacher).

If females have less access to computers at home or school, they may feel less comfortable using the computer as a tool in a mathematics course. Based on the available data, the NCES study concluded that males and females have equal access to computers (2005). Similar percentages of males and females reported using computers at school and at home for general use and educational purposes. However, there is evidence that males are more likely to complete high school with greater interest in and knowledge of computers. Eighty-six percent of the students who took the AP computer science exam were male in 2002. Males had higher average scores on the exam than females.

There is evidence that any differences in access to computers or experience with computers may be diminished by a course with extensive computer exposure. Wallace and Clariana (2005) examined student performance in an introductory computer skills course. Students were randomly assigned to either paper or computer tests. Females scored lower than males on both paper and computer tests given early in the semester, but females scored higher on the computer administered final exam. Overall performance on the computer-administered tests was higher than the paper tests.

Price examined gender differences in online courses by comparing three years of data from students in an online undergraduate social science course and comparable non-online course at the Open University (2006). The results indicated that women's access to computers and the internet is lower than men's but the difference is too small to be significant. This suggests that computers and the internet do not hinder women who want to study online. Women were more likely than men to complete the online course and twice as likely to pass the course. There were no significant differences found in the non-online course. Additional findings were that females studying online were more self-confident, more academically engaged with the course, and more willing to learn from other students than males. This study challenges the stereotype that females are disadvantaged by technology when studying online.

A 1988 meta-analysis of 82 studies on the impact of computer-based instruction (CBI) at all grade levels did not find sufficient evidence to link effectiveness of CBI to gender (Roblyer, Castine, and King, 1988). More recent studies concur. A study of seventh and eighth graders comparing attitudes and achievement on fraction and decimal tasks found no significant differences in genders or ethnic groups (Nguyen, 2002). Similarly, Mevarech and Rich (1985) found no significant gender differences in low achieving, disadvantaged Israeli third, fourth, and fifth graders in a study comparing the attitude and arithmetic achievement of students receiving traditional instruction and traditional supplemented with computer-assisted instruction.

Few studies on the performance of developmental mathematics students receiving traditional instruction compared to those receiving traditional instruction supplemented with computer-assisted instruction have also investigated gender differences. Mahmood (2006) found no significant gender differences and no significant interaction of gender and method of instruction for students enrolled in two developmental mathematics courses at a historically black community college in Texas. In contrast, a study comparing the effectiveness of computer-assisted instruction and traditional instruction for teaching geometry and algebra to African-American students enrolled in a developmental course found significantly higher posttest scores for males than females (Owens and Waxman, 1994). Females had significantly higher attitudes toward mathematics at the beginning of the course; however, males had significantly higher attitudes toward mathematics at the end of the course. There was no significant interaction between treatment and gender.

Summary

Computer technology provides the building blocks for faculty to design courses that improve the learning experience. Although considerable research indicates that computer-assisted instruction has positive effects on learning for students in a wide range of grades and subject matter, it is essential that research be ongoing to determine if the effectiveness has changed with the development of more sophisticated computers and software and with educators learning how to design courses that use computer-assisted instruction. Although some educators think that the benefits of computer-assisted instruction have been well-established by the research, this review shows that much of the research was conducted in the 1970s and 1980s when software was limited to drill and practice and much of it focused on elementary and secondary students rather than college students. This early research may not generalize to college students and specifically developmental mathematics students who need assistance with learning strategies and attitudes as well as learning mathematics. There is a need for more research to establish best practices in the use of computers to improve learning and retention (Trenholm, 2006).

The research on the effectiveness of computer-assisted instruction in developmental mathematics is limited to isolated studies, and most of those were conducted at community colleges. Some studies comparing traditional instruction and traditional instruction supplemented with computer-assisted instruction show no significant difference in the students' mathematical achievement. Studies comparing online developmental mathematics courses to other modes of instruction are scarce and inconclusive. Few studies also examine gender differences in the mathematical performance of developmental mathematics students using computer-assisted instruction. The lack of conclusive research on computer-assisted instruction in developmental mathematics may be due to the relative newness of the field of developmental education, the newness of online developmental courses, rapid changes in technology, variation among schools in hardware and software and how it is used, and reforms in other areas occurring at the same time. The proposed study will add to the existing knowledge as it examines the mathematics achievement of developmental mathematics students in three modes of instruction at a large, four-year university.

CHAPTER 3: METHODOLOGY

Overview of the Study

Colleges and universities are searching for programs and strategies to increase the number of underprepared students who pass developmental mathematics courses, succeed in a college-level mathematics course, and graduate. The traditional lecture has not been effective with developmental students. With the increased use and availability of computers, educators are exploring how best to use computers to improve learning. This study will explore whether there is a difference in the mathematics performance of developmental mathematics students using traditional instruction, traditional instruction supplemented with computer-assisted instruction, or computer-assisted instruction in the distance learning format.

Design of the Study

The non-randomized control group pretest-posttest design was used for this quasi-experimental study. Intact groups of established classes were used. Students registered themselves for the courses and could not be randomly assigned to the control or treatment groups without disrupting their schedules. The independent variable was the mode of instruction, and the dependent variable was mathematics performance as measured by the posttest. The null hypotheses were:

1. There is no significant difference in the mathematics performance of students in a developmental mathematics course using the following instructional modes:
   i. Traditional lecture
   ii. Lecture with computer-assisted instruction

iii. Online distance education

2. There is no significant difference in the mathematical performance of developmental mathematics students by gender.

In this study the subjects were the students enrolled in six sections of Intermediate Algebra at a large, private, eastern university. The spring 2009 enrollments are 11,704 residential students and 36,652 distance learning students from 50 states and 80 countries. This included 10,668 residential undergraduates and 17,853 online undergraduates. Forty-seven percent of the residential enrollment is male, and 49% of the distance learning enrollment is male. There are 17 computer labs on campus for student use, and 95% of the campus has wireless access. The university offered three developmental mathematics courses with Intermediate Algebra being the last in the sequence and the pre-requisite for college algebra, statistics, and math for liberal arts.

The control group was two classes receiving instruction in the traditional lecture format with written homework. Students listened to lectures, took notes, observed the instructor working examples on the board, and asked and answered questions. At times, the students worked individually or in small groups as the instructor observed their work. Students turned in daily homework from the textbook, and it was graded and returned the following class. All quizzes, tests, and the final exam were taken in class on paper and graded by the instructor. Outside of class students could seek assistance from the instructor during office hours and from tutors in the developmental mathematics tutoring center, which offered free tutoring without an appointment.

The first experimental group consisted of two classes receiving instruction by traditional lecture supplemented with computer-assisted instruction. The classroom instruction was the same as the control group. The difference was how students learned outside the classroom. Students used the computer learning system that accompanied the textbook and included homework and tutorials. Tutorials provided practice problems similar to homework problems, examples worked step by step with explanations, and links to the appropriate textbook pages. Tutorials were not graded. Each lesson had a computer homework assignment of 10 to 15 problems. Problems were free-response, multiple choice, and matching. Each question could be attempted three times during a session. The student received immediate grading of the problem when he clicked "submit." Each assignment could be attempted 10 times. This encouraged students to immediately identify and correct their errors, attempting to earn a perfect score on each assignment. The management functions of the software allowed the instructor to see the number of attempts for each assignment, the grade, the time spent, and the answers to individual problems for each student. The computer learning system was available 24 hours from any computer that has internet access. Students could seek assistance from the instructor during office hours or from tutors in the developmental mathematics tutoring center which was available five days a week.

The second experimental group was two classes in the online distance learning format. These classes used the same computer learning system. Learning activities included reading the textbook, viewing video lessons, working tutorials, and completing homework, quizzes, and tests. With the exception of reading the textbook, all other activities were available on the computer. The learning activities were divided into eight two-week modules to provide deadlines and structure to the course so students would complete the course within 16 weeks. Although students and instructors had no face-to-face time, instructors were available by email and phone. Instructors of distance learning courses were expected to post weekly announcements, check email daily, encourage students to work persistently, and answer questions about algebra and about the learning system. Students who lived close to campus could use the developmental mathematics tutoring center.

All three groups were taught by full-time instructors who had demonstrated competence in teaching developmental mathematics students and had experience teaching in all three delivery formats. There were two instructors, each taught one class of each mode of instruction. Each class had 25 to 30 students enrolled. Students registered themselves for the courses and could not be randomly assigned to the control or treatment groups without disrupting their schedules. Students did not know they were participating in a research study so that they would not deliberately or subtly influence the outcome of the study. This was approved by the university's Institutional Review Board.

Data Gathering Methods

The first class meeting of the semester, all students completed a questionnaire to provide descriptive data of the classes and to determine similarity of the three groups. A pretest was given the first week of class consisting of five questions from the final exam, which was the posttest. Residential classes completed all three instruments on paper, and the online classes completed the questionnaire in Blackboard and the pretest and posttest in the computer learning system. Instructors graded the pretest and posttest for residential students, and the computer graded the pretest and posttest for online students. Instructors assigned a counting number to each student for the purpose of matching the questionnaire, pretest and posttest scores, and then removed the students' names from the questionnaire, pretest score, and posttest score before submitting them to the researcher. The researcher recorded the number, responses to the questionnaire, the pretest score, posttest score, and instructional method in SPSS.

Instrumentation

The questionnaire (Appendix A) asked for the student's gender, age, ethnicity, whether he or she was an international student, how many years since last math class, was this the student's first online course, how many semesters the student had been in college, number of credit hours he or she was taking the current semester, how the student had used computers in the past, and attitude toward mathematics and computers. The purpose of the questionnaire was to gather descriptive data to establish similarity of the groups. Students were placed in Intermediate Algebra based on SAT, ACT, and assessment test scores, so all students were expected to have mathematics achievement within the same range of scores. They registered themselves for the classes and were not placed by the university in a particular mode of instruction. Students had access to information about which sections used computer-assisted instruction and which used traditional instruction from their Beginning Algebra instructors, their advisors, the Developmental Math website, and the tutoring center. Gender data from the questionnaire was also used to test null hypothesis 2: There will be no significant difference in the mathematical performance of developmental mathematics students by gender.

The construct of mathematics achievement was operationally defined as scores on the Intermediate Algebra final exam (Appendix D), which was the posttest. This was a departmental final exam given to all students in Intermediate Algebra. Validity of the exam was the extent to which it measured mathematics achievement. The exam was a collection of test items created by the developmental mathematics faculty and matched to the Intermediate Algebra course objectives in proportion to the emphasis given to each topic during the semester. This provided face validity. The test questions were critiqued by a team of Department of Mathematics faculty members. This provided content validity. Reliability of the final exam is the extent to which scores were free of random error, that is, the extent to which the exam yielded consistent results. Ideally, the reliability coefficient should be close to one. Cronbach's Alpha, or coefficient alpha, for the final exam was 0.915 as calculated using SPSS, based on scores from a sample of 80 final exams from eight instructors from a previous semester. Cronbach's alpha calculates the mean of all possible split-half correlations and is preferred by many researchers when the questions have different point values, such as a Likert scale or essay test (Ary, Jacobs, Razavieh, and Sorensen, 2006).

The pretest (Appendix C) consisted of five questions from the final exam, representing five major course objectives of Intermediate Algebra. Residential classes met for 50 minutes three times a week making it logistically impossible to give the entire final exam as a pretest. The final exam was given during the last week of the semester with 120-minute exam periods. The pretest served to inform the students that they did indeed need to take the course and gave them a preview of topics that are studied in Intermediate Algebra. Cronbach's alpha for the pretest was calculated and found to be 0.714, compared to 0.915 for the posttest. Shorter tests generally have lower reliability than longer tests.

The nonrandomized control group, pretest-posttest design does not provide the control that a randomized experimental design does because subjects are not randomly assigned to groups (Ary et al., 2002). The more similar the control and experimental groups are at the beginning of the experiment, as determined by the questionnaire and similar means on the pretest, the more credible are the results of the study. Threats to internal validity must be controlled where possible. An analysis of covariance was conducted on the pretest and posttest scores, and the questionnaire data established the similarity of the groups before treatment. One group was not likely to mature at a more rapid rate than the others in the same 16 weeks of instruction. Students selected their classes and were not placed by the university. Volunteers were not used in the study. Attitudes of the subjects toward mathematics or technology may affect the outcome of an experiment (Ary et al.). In this study the affect of attitudes were controlled by not telling the subjects they were participating in a study. Many Intermediate Algebra students, whether they were participating in the study or not, completed a questionnaire and pretest, and all took the posttest. Extraneous variables were controlled where possible. All three groups had the same course objectives, same schedule, same tests, same class size, and the same 16 week semester. Each instructor taught in all three modes of instruction. Attrition may be a threat if more students with low scores withdrew from one group than the others. This research design provided partial control of threats to internal validity and gave this researcher confidence that the results were due to the different modes of instruction and not to chance alone.

External validity is concerned with whether the results of the study will generalize to other subjects and settings. A careful examination of the similarities and differences between the setting of this experiment and other developmental mathematics settings will assist in determining whether the results would generalize to another population. The subjects in this study were a sample of the students enrolled in developmental mathematics courses at a large, liberal arts university in the east that offered residential and distance learning courses. The results would likely generalize to community colleges because the academic preparation of the students at this university was diverse like a community college. The community college population would differ however because they draw students from within an hour or two of the campus, and this university had students from 50 states and 80 countries. Results would likely generalize to another university that values technology as a learning tool by having support such as computer labs, a help desk, quick response to technical problems, and administrative support for alternatives to improve student learning and to settings using publisher online resources correlated with the textbook.

Procedures

From all sections of Intermediate Algebra taught by experienced instructors, six were randomly chosen, two from each mode of instruction. No class taught by an instructor new to the university or an instructor using computer-assisted instruction for the first time was included. The independent variable was the mode of instruction. The control group was the classes that received instruction in the traditional lecture format with written homework (C). The two experimental groups were: a traditional lecture with computer-assisted instruction (E_1) and online distance learning (E_2).

The written questionnaire that asked for gender, age, ethnicity, international student or not, how many years since last math class, was this the student’s first online course (E_2), how many semesters the student had been in college, how the student had used computers in the past, and attitude toward math and computers was completed the first day of class in groups C and E_1. Group E_2 completed the same questionnaire in Blackboard.

The pretest was given the first week of class. For groups C and E_1 the pretest was on paper, in class, and graded by the instructor. For group E_2 the pretest was given and graded in iLrn. Instruction proceeded as previously described throughout the 16 week semester. The final week of the semester all students took the departmental final exam. Groups C and E_1 took the exam on paper in class for up to 120 minutes. Group E_2 had the same exam in iLrn. Students obtained a password from the instructor to open the exam and were allowed to take the exam one time. The exam was available for three days and could not be printed.

Data Analysis Procedures

Pretest and posttest scores for each participant were collected. SPSS was used to run descriptive statistics on the data. The sample size, mean, and standard deviation were tabulated by method of instruction and gender. Scores were omitted for students who did not complete either the pretest or posttest and for any outliers.

One hundred fifty-five students took the pretest (58 from the traditional, 55 from the traditional + CAI, and 42 from the online). Of these 155 students, 132 took the posttest with 51 enrolled in traditional, 48 in traditional + CAI, and 33 in online intermediate algebra. Fifty-eight were male and 74 were female. Seven of 58 (12.1%) in the traditional classes, 7 of 55 (12.4%) in the traditional + CAI classes, and 9 of 42

(21.4%) in the online classes did not complete the course. Table 1 shows the distribution of the 132 participants among the methods of instruction and gender.

Table 1

Distribution of Sample

	Male	Female	Total
Traditional	21	30	51
Traditional + CAI	23	25	48
Online	14	19	33
Total	58	74	132

An analysis of covariance (ANCOVA) was conducted to determine if there were significant differences in mathematical performance among the three methods of instruction. ANCOVA provides statistical control of variability when randomization is not possible by adjusting the scores on the dependent variable in order to reflect initial differences on a covariate (Mertler and Vannatta, 2005). ANCOVA increases the sensitivity of the F test by removing the unwanted variance associated with the covariate from the error term thereby producing a larger F-statistic. The covariate is an independent variable whose effect is removed or partialed out of the results. Using a covariate that is related to the dependent variable reduces the likelihood of error. The subjects' math performance before the study would be related to their math performance after the study. The initial math performance was measured by the pretest, which served as the covariate for this study. The dependent variable was the posttest. ANCOVA imitates the analysis of variance where main effects and interactions are analyzed but only after the effects of an unwanted variable have been removed (Mertler and Vannatta). ANCOVA is subject to six assumptions: observations are randomly sampled and independent, the distribution of scores on the dependent variable are normal, the distribution of scores on the dependent variable have equal variances, a linear relationship exists between the covariate and the dependent variable, the slope of the regression line for each group is the equal, and the covariate is reliable and measured without error.

An analysis of covariance was conducted to determine if there was a significant difference in mathematics performance by gender. The covariate was the pretest, the independent variable was gender, and the dependent variable was the posttest. The interaction of method and gender was analyzed by including method as an independent variable.

Data from the questionnaire were tabulated by group listing frequency and percent for gender, ethnicity, age, part-time or full-time status, semesters in college, years since last math course, math attitude, computer attitude, international students, and how students use computers.

CHAPTER 4: ANALYSIS OF THE DATA

The purpose of this study was to compare the learning of developmental mathematics students who received instruction in three different environments to determine whether computer-assisted instruction enhanced their learning. Specifically, the study investigated whether there was a significant difference in mathematics performance as measured by the posttest of students enrolled in Intermediate Algebra classes receiving traditional instruction, traditional instruction supplemented with computer-assisted instruction, and online instruction. In addition, the study investigated whether a difference existed in the mathematics performance of males and females enrolled in Intermediate Algebra.

Testing of the Hypotheses

The non-randomized control group pretest-posttest design was used for this study since students enrolled themselves in classes and could not be randomly assigned to groups. An analysis of covariance (ANCOVA) was conducted to determine whether differences existed in mathematics performance among the three different methods of instruction. ANCOVA provides statistical control of variability when randomization is not possible by adjusting the effect of a variable that is related to the dependent variable (Mertler and Vannatta, 2005). Students' mathematics performance before treatment was measured with the pretest, which was the covariate in the ANCOVA. Students' mathematics performance after treatment, defined to be scores on the posttest, was the dependent variable. Students completed a questionnaire to provide descriptive information of the classes and to determine similarity of the three groups. The pretest was administered at the beginning of the spring 2009 semester and the posttest was administered the last week of the semester in six classes of Intermediate Algebra, two in each of the three methods of instruction. One hundred fifty-five students took the pretest, and 133 took the posttest. Pretest and posttest data were recorded and applied to the following null hypotheses:

1. There is no significant difference in the mathematics performance of students in a developmental mathematics course using the following instructional modes:
    i. Traditional lecture
    ii. Lecture with computer-assisted instruction
    iii. Online distance education
2. There is no significant difference in the mathematical performance of developmental mathematics students by gender.

Hypothesis 1

For Hypothesis 1, the independent variable was the method of instruction. The dependent variable was mathematics performance defined as scores on the posttest. Mathematics performance before treatment was defined as scores on the pretest, which served as the covariate in the analysis of covariance. After ANCOVA adjusted the mean posttest score for any initial differences among the groups on the pretest, the posttest scores were used to compare mathematics performance of the three methods of instruction.

Before conducting the analysis of covariance, data were first screened for missing data and outliers. Box plots and stem-and-leaf plots of the posttest by gender and by method revealed one outlier. This extreme value was a posttest score of 25, which was more than three standard deviations below the mean. This subject was eliminated from the analysis. Of the 132 students in the study, 51 were traditional students, 48 were traditional + CAI students, and 33 were online students.

Table 2

Descriptive Statistics by Method including Online Group

		Pretest		Posttest	
Method	N	Mean	SD	Mean	SD
Traditional	51	29.44	15.00	73.88	14.83
Traditional + CAI	48	32.31	14.44	78.23	13.81
Online	33	67.27	23.88	72.42	16.25
Total	132	39.86	23.56	75.10	14.93

As seen in Table 2, the mean and standard deviation of the pretest for the online group were very different from the traditional and traditional + CAI groups, and statistical comparisons may possibly lead to faulty conclusions. An investigation of the pretest for the online group revealed that three of the five problems on the pretest were only available in the computer learning system as multiple-choice, not free-response. Therefore, the online students were likely to have higher scores than the other two groups because they would likely guess at the correct answer instead of leaving it blank when they did not know how to work the problem. The pretest for the traditional and traditional + CAI groups were on paper, all free-response, and graded by the instructor giving partial credit. The online pretest was delivered and graded by the computer learning system. There are many factors that make students studying online different from students attending class. There is no control over who is taking the tests and what resources they may be using like there is in a residential class where instructors supervise students during tests. In this study, the percent of students not completing the course was much higher in the online group (21.4%) than in either the traditional (12.1%) or traditional + CAI group (12.4%), resulting in only 33 students completing the online course. Since the online group appears so different from the other two, the ANCOVA was conducted excluding the online students.

Table 3 provides the descriptive statistics of the 99 students remaining in the study. The mean posttest score for traditional students was 73.88 with a standard deviation of 14.83. The mean posttest score for traditional + CAI students was reported as 78.23 with a standard deviation of 13.81. For all participants, the mean posttest score was found to be 75.99 with a standard deviation of 14.43.

Table 3

Descriptive Statistics by Method

		Pretest		Posttest	
Method	N	Mean	SD	Mean	SD
Traditional	51	29.44	15.00	73.88	14.83
Traditional + CAI	48	32.31	14.44	78.23	13.81
Total	99	30.69	14.75	75.99	14.43

After verifying that the six assumptions of analysis of covariance were met, an ANCOVA was conducted to determine if the difference in the posttest scores, after controlling for pretest scores, was statistically significant and did not occur by chance alone. Ninety-nine students completed the pretest and posttest, 51 in the traditional group and 48 in the traditional + CAI group. The independent variable was the method of instruction, the dependent variable was the mathematics performance as measured by the posttest, and the covariate was the pretest. The Statistical Package for the Social Sciences (SPSS) was used for the analysis with an alpha = .05 level of significance. The results as reported in Table 4 indicated there was no statistically significant difference for method of instruction, $F(1,94)=2.35$, $p=.128$. Therefore, Null Hypothesis 1 was not rejected. There was no statistically significant difference in mathematics performance as measured by the posttest of Intermediate Algebra students receiving traditional instruction and those receiving traditional instruction supplemented with computer-assisted instruction. The posttest mean for traditional + CAI was higher, but not significantly higher, than the posttest mean for traditional instruction. In addition, the covariate of pretest significantly influenced the dependent variable of posttest, $F(1, 99)=10.52$, $p=.002$. Table 5 shows the adjusted posttest scores after accounting for differences using the pretest scores.

Table 4

ANCOVA Summary

Source	df	MS	F	p
Between Treatments	4	1114.79	6.57	<.001
Pretest	1	1785.29	10.52*	.002
Method	1	399.66	2.35	.128
Gender	1	1773.55	10.45*	.002
Method X Gender	1	11.84	0.07	.792
Error	94	169.76		
Total	99			

*p < .05

Table 5

Adjusted Posttest Means for Method

Method	Adjusted Posttest Means
Traditional	73.51
Traditional + CAI	77.59

Hypothesis 2

Table 6 presents the descriptive statistics by gender. Forty-four males and 55 females completed both the pretest and posttest. The mean posttest score for males was 70.93 with a standard deviation of 14.89. The mean posttest score for females was 80.04 with a standard deviation of 12.81. For all 99 participants, the mean posttest score was 75.99 with a standard deviation of 14.43.

Table 6

Descriptive Statistics by Gender

		Pretest		Posttest	
Gender	N	Mean	SD	Mean	SD
Male	44	29.20	16.24	70.93	14.89
Female	55	31.89	13.48	80.04	12.81
Total	99	30.70	14.75	75.99	14.43

The ANCOVA results for Hypothesis 2 are reported in Table 4 with gender being the independent variable, posttest the dependent variable, and pretest the covariate. The results indicate a significant difference for gender, $F(1,94)=10.45$, $p=.002$. Therefore, Null Hypothesis 2 was rejected. There was a statistically significant difference in posttest scores of male and female Intermediate Algebra students, when adjusting for the effect of pretest scores. Table 7 shows the adjusted posttest scores after adjusting for differences using the pretest. The results reveal that females ($M=79.84$) scored higher on the posttest than males ($M=71.26$).

Table 7

Adjusted Posttest Means by Gender

Method	Adjusted Posttest Means
Male	71.26
Female	79.84

The ANCOVA Summary in Table 4 indicates no significant interaction between method and gender, $F(1,94)=.07$, $p=.792$. Table 8 shows that females outperformed males in both traditional instruction and traditional instruction supplemented with computer-assisted instruction.

Table 8

Adjusted Posttest Means by Method and Gender

Method	Gender	
	Male	Female
Traditional	68.87	78.15
Traditional + CAI	73.65	81.53

Questionnaire

The questionnaire (Appendix A) was used to gather information about the participants in the study. Students completed the questionnaire the first week of the semester. Information included gender, age, part-time or full-time student, years since last math course, use of computers, math attitude, and computer attitude. The purpose of the questionnaire was to describe the subjects in the study and to observe similarities or differences among the groups. Data were entered in SPSS, and frequencies and percents were calculated for each of the eleven questions and recorded (Appendix B).

The responses to the questionnaire revealed some noticeable differences in students in the online classes compared to the residential classes (traditional and traditional with computer assisted instruction). Online students were more likely to be older, white, and U. S. citizens, to have more years since their last math course, and to have positive attitudes toward math and computers. Ninety percent of the 132 students had taken their last math class one or two years ago, whereas 25% of the 33 online students had taken their last math class more than four years prior to the current semester. Overall most students had been in college two to four semesters. All of the residential students were full-time students, taking at least 12 credit hours. Online students, however, were nearly equally split between part-time (51.4%) and full-time (48.6%).

Thirty-five percent of the traditional students, 28% of the traditional + CAI students, and 9% of the online students reported having a negative or very negative attitude toward math. Nearly all students (128 of the 132) used computers for both academic purposes and other reasons, such as email, social networking, and shopping. Very few students had a negative attitude toward using the computer for educational purposes. Seventy-one percent of the traditional students, 59% of the traditional + CAI students, and 97% of the online students reported feeling positive or very positive toward using computers for educational purposes.

Overall, 44% of the students were male and 56% were female, which is fairly similar to the overall percentages for the university (53% female residential students and 51% female online students). This is also consistent with national studies that reported 56% of undergraduate students in 2000 were female (NCES, 2005), and 55% of community college remedial students were female (Saxon and Boylan, 1999). In the traditional classes there were 7% more females than males, in the traditional + CAI classes there were 4% more females than males, and in the online classes there were 14% more females than males. Ninety-five percent of the residential students were of traditional college age (≤23). However, 74% of online students were of traditional college age, with the oldest being 57. Overall, 74% of the students were white, 14% were African American, 4% were Hispanic, and 8% were other ethnicities. Seventy percent of residential students were white and 85% of online students were white. Eleven percent of the residential students and none of the online students were international students. Only three of the online students reported that this math course was their first online course.

Summary

The purpose of this study was to compare the mathematics performance of developmental mathematics students receiving traditional instruction, traditional instruction supplemented with computer-assisted instruction, and online instruction. Data were collected using a questionnaire, pretest, and posttest. Pretest scores for the online group were very different than the pretest scores for the traditional and traditional + CAI groups. Therefore the analysis was conducted on the traditional and traditional + CAI groups only. Posttest scores were analyzed using ANCOVA with the pretest as the covariate. At a .05 level of significance, there was no significant difference in the mathematics performance between the two methods of instruction. The null hypothesis was not rejected.

The study also investigated whether differences existed in male and female mathematics performance. At a .05 level of significance, there was a significant difference in the mathematics performance of males and females with females performing better than males. The null hypothesis was rejected.

CHAPTER 5: SUMMARY AND DISCUSSION

Summary

Many students enter college without the mathematics skills and knowledge to successfully meet their educational and career goals (National Center for Educational Statistics, 2003b). Most colleges and universities offer developmental mathematics courses and other services to prepare these students for college-level mathematics courses. Developmental mathematics courses have been taught with the traditional lecture method used for years in most college-level courses (Armington, 2003; Kinney and Kinney, 2003; Maxwell, 1979; Miles, 2000; Roueche and Kirk, 1974). Educators are concerned about the low pass rates (Boylan, Bonham, and White, 1999; Trenholm, 2006; Waycaster, 2001; Wright, Wright, and Lamb, 2002) and are exploring alternative instructional approaches in order to increase the number of students who stay in school, pass a college-level math course, and graduate. Computers make possible a variety of new teaching strategies, allowing students to have choices about when, where, and how they learn math. The review of literature indicated a need for further studies on the impact of computer-assisted instruction on the learning of developmental mathematics students. The purpose of this study was to investigate differences in the academic performance of students enrolled in a developmental mathematics course using traditional instruction, traditional instruction supplemented with computer-assisted instruction, and online distance learning. Gender differences in mathematics performance were also examined.

This quasi-experimental study was conducted in Intermediate Algebra classes at a large, private, eastern university. Intact groups of established classes were used because students had registered themselves for the classes and could not be randomly assigned without disrupting their schedules. The control group received traditional lecture instruction. The first experimental group received instruction by traditional lecture supplemented with computer-assisted instruction (CAI), and the second experimental group studied in the online distance learning format. The same two instructors taught in each of the three modes of instruction.

The first week of class students completed a questionnaire and a pretest. The purpose of the questionnaire was to establish similarities and differences among the three groups and to describe the sample. The pretest measured students' mathematical performance before treatment. After 16 weeks of instruction, students completed the posttest, which was the department final exam. For the purpose of this study, mathematics performance was defined as the score on the final exam. One hundred fifty-five students completed the pretest, and 133 of these completed the posttest. One outlier was eliminated. Of the 132 students in the study, 51 were traditional students, 48 were traditional + CAI students, and 33 were online students. Descriptive data for the pretest revealed a large disparity between the means of the online group (M=67.27), the control group (M=29.44), and the first experimental group (M=32.31). Concern that the analysis may possibly result in misleading or faulty conclusions led the researcher to eliminate the online group from the analysis.

An analysis of covariance was used to analyze the data because it provides statistical control of variability when randomization is not possible (Ary, et al., 2002).

Students' mathematics performance at the end of the course may be related to their mathematics performance at the beginning of the course. Therefore, the pretest, which measured mathematical performance at the beginning of the course, was used as the covariate in the analysis. ANCOVA adjusted the means of the posttest by removing any initial differences among the groups on the pretest.

Null Hypothesis 1 stated there was no significance difference in the mathematics performance of students in a developmental mathematics course using traditional lecture and lecture with computer-assisted instruction. The independent variable was method of instruction, and the dependent variable was the posttest. At the .05 level of significance, there was no significant difference between the posttest scores of students who completed a traditional developmental math course and the posttest scores of those who completed a computer-assisted developmental math course. Although the difference was not significant between the two groups, the mean of the traditional + CAI group was higher. Null Hypothesis 1 was not rejected.

Null Hypothesis 2 stated there was no significant difference in the mathematics performance of developmental mathematics students by gender. The independent variable was gender, and the dependent variable was the posttest. At the .05 level of significance, there was a significant difference between the posttest scores of males and the posttest scores of females. The posttest mean of females (M=79.84) was significantly higher than the posttest mean of males (M=71.26). Null Hypothesis 2 was rejected.

Discussion

Numerous studies have been conducted on the effects of computer use on student achievement, attitudes, learning rates, and other variables. Generally, the conclusion is that computer-assisted instruction has a positive effect on student learning. Across all 254 studies reviewed by Kulik and Kulik (1991), there was a modest advantage for computer instruction over traditional instruction (effect size=.3), but for postsecondary math students the advantage was slight (effect size=.14). Several other meta-analyses and literature reviews across all ages and subject areas also concluded that computer-assisted instruction produced higher achievement, especially when combined with and not replacing traditional instruction (Bialo and Sivin-Kachala, 1996; Cotton, 1991; Edwards, Norton, Taylor, Weiss, and Dusseldorp, 1975; Kulik, 2002; Liao, 2007; Rapaport and Savard, 1980; Thomas, 1979). The conclusion of the current study disagrees with these previous results as it found no significant difference in the mathematical performance of Intermediate Algebra students as measured by the final exam score, although the mean score of the computer-assisted group was higher.

Direct comparisons of the current study with other studies cannot be made for many reasons, including the wide variation in ages in the related studies, the various ways CAI was implemented, the different variables being studied, and the different sample sizes. This study does not concur with some of the research on the effects of computer-assisted instruction (CAI) on the mathematical learning of students of various ages and ability levels. For example, students in kindergarten through fifth grade in Project CHILD classrooms, which integrate computer stations with hands-on exploratory projects and direct instruction, had higher test scores than students in traditional classrooms (Butzin, 2000). Third and fifth graders in Canada who used the computer to supplement classroom instruction scored significantly higher on a standard test of mathematics achievement than those receiving conventional instruction (Fletcher, Hawley, and Piele, 1990). A study of the mathematical achievement of high school students in Nigeria who were randomly assigned to computer-assisted instruction or traditional instruction revealed a significantly higher mean for the computer-assisted group (Olusi, 2008). CAI has also had positive effects for calculus students (McSweeney, 2003), psychology students (Brothen and Wambach, 2000), and low-ability students (Hannafin and Foshay, 2008; Mevarch and Rich, 1985). Unlike these studies, the current study found no significant difference in final exam scores of Intermediate Algebra students receiving traditional instruction and those receiving traditional instruction + CAI.

A study at Florida Atlantic University randomly assigned students in College Algebra to one of four methods of instruction: traditional lecture followed by textbook homework, computer tutorial program followed by textbook homework, lecture followed by a computer drill and practice program, and computer tutorial followed by computer drill and practice (Diem, 1982). Students were given a pretest and posttest. The results indicated no significant difference in the achievement between any of the four groups, although significant learning gains did occur in each group. The current study concurs with Diem's study in finding no significant difference in final exam scores of Intermediate Algebra students receiving traditional instruction with textbook homework and traditional instruction with computer homework.

Although the research on computer-assisted instruction has indicated positive effects on student learning in a wide range of grades and subject matter, the research on computer-assisted instruction in developmental mathematics is limited to isolated studies according to Barbara Bonham, the senior researcher at the National Center for Developmental Education (Trenholm, 2006). Most of the studies have been conducted at community colleges, and the results are mixed. Few studies have examined gender differences along with differences in mathematical performance of developmental students. There are research studies that agree with, as well as studies that differ with, the findings of the current study.

The results of the present study confirm the findings of several other studies in developmental mathematics. Each used a different computer learning system and used it in a different way but some elements of each of the four studies are the same as the current study. In a study at the University of Minnesota, students selected a lecture class or computer-mediated class after completing an inventory related to traditional and computer-mediated environments (Kinney and Robertson, 2003). In the computer-mediated class, instruction was learner-centered with the software providing a thorough presentation of the material and the instructor providing assistance as students worked at their own pace. All students in both the lecture and computer-mediated classes had access to the software. There was no significant difference in the common final exam in Elementary Algebra in the computer-mediated classes and lecture classes. The same results were found in Intermediate Algebra. The present study also found no significant difference in final exam scores of Intermediate Algebra students in traditional lecture and computer-assisted classes. Unlike Kinney and Robertson's study where students used the computers in class with the instructor as facilitator, in the current study the computer-assisted instruction supplemented traditional classroom instruction and occurred outside the classroom. Instructors reported that students most often selected a math class based on what fit their schedule, not on whether computers were used or not.

In a more recent study, Jacobson (2006) found that computer homework did not help pre-algebra students perform better on an exam than students who did not complete the computer homework. Like the present study, students used the computer learning system that accompanied the textbook and could use tutorial features of the program to practice exercises before completing the graded homework. Jacobson conducted an analysis of covariance with the first exam as the covariate and the second exam as the dependent variable. A limitation of his study is that the computer homework was added to an already existing course for only ten lessons. Jacobson concluded that computer use may have had a more positive impact on exam scores if the computer component had been integrated into the course for the entire semester, if students received more instruction in how to use the equation editor, if the features of the computer learning system were demonstrated in class, and if the format of the exams was similar to the computer homework. The students in the current study used the computer tutorials and homework for the entire semester, and instructors told the researcher they demonstrated the equation editor and tutorial features of the software in class. However, few students reported using the tutorials; most went directly to the graded homework. This likely occurred because the link to the tutorials was separate from the homework, whereas, in some software the tutorials are imbedded in the homework exercises.

A quasi-experimental study similar to the current study also found no significant differences in the test scores of pre-algebra students who received computer-assisted instruction and traditional lecture at a suburban community college in the Middle Atlantic region (Teal, 2008). Students self-registered for the course in effect selecting their own mode of instruction. Three professors each taught a computer-assisted class and lecture class. Students in traditional classes received instruction through lecture and group work and completed homework, quizzes, and tests on paper. Unlike the current study where students used the computer outside the classroom, the students in Teal's study met in a computer classroom for mini-lectures and computer assignments. The pretest was the student's score on the ACCUPLACER test and the posttest was the department final exam.

The findings of the current study are also consistent with a study at a rural community college in Texas comparing student learning in traditional classrooms and computer-assisted classrooms in Beginning and Intermediate Algebra (Reagan, 2004). This study was a quasi-experimental design with ACCUPLACER for the pretest and posttest. Students in the computer-assisted classes received a mini-lecture at the beginning of class then worked on lessons in the computer. The results found no significant difference in the posttest scores but did find a significant positive correlation between math performance and reading scores.

The findings from the current study did not concur with other previous research results in developmental mathematics as indicated by studies by Bump (2004), Mahmood, (2006), and Villarreal (2003). Bump studied the effect of a multimedia, interactive mathematics program on the mathematical achievement of students enrolled in Intermediate Algebra at a Texas community college and found the program was not effective (2004). The mean final exam score of students in lecture classes was significantly higher than the mean final exam score of students in the computer-assisted classes that met in a lab with no lecture. Bump acknowledged that there were numerous problems with the computer-assisted classes, including slow servers, software flaws, confusing feedback, problems with the videos, and internet problems, that may have influenced the outcome of the study. In contrast, the current study of Intermediate Algebra students in a large eastern university found the mean final exam score of students in a traditional class supplemented with computer-assisted instruction was higher, but not statistically significantly higher, than the mean final exam score of students in a traditional lecture class.

Villarreal (2003) reported the results of a study at the University of Texas at Brownsville comparing outcomes before and after developmental mathematics courses were redesigned. Introductory Algebra and Intermediate Algebra were offered by computer-directed instruction in which students worked at a time of their choosing in a campus computer laboratory with tutors as facilitators. Many students discovered on the first day of class that their course was computer-directed. After a brief introduction, they were given the choice to stay or transfer to a traditional lecture course. Pass rates were low, few students had the motivation and self-discipline to complete the courses, and some students relied primarily on the tutors for instruction instead of using the computer tutorials or the textbook. The courses were redesigned with three hours of classroom instruction and three hours of computer lab per week. Final exam grades were higher in classes with computer-assisted instruction combined with classroom instruction than in the former computer-directed classes. The pass rates improved an average of 12% within two years.

A more recent study conducted by Mahmood (2006) at a historically black community college in Texas revealed higher mathematical performance in classes with traditional instruction supplemented with computer-assisted instruction than traditional instruction alone, which directly disagrees with the current study. The study used the pretest-posttest quasi-experimental design. The pretest and posttest instrument was the practice test for the state-required Texas Higher Education Assessment test. Students in both Fundamental Mathematics and Analytical Mathematics who received traditional instruction supplemented with computer-assisted instruction had significantly higher scores than those who received only traditional instruction.

Colleges and universities offer distance learning courses to serve students who otherwise may not be able to earn a college degree. Online courses provide flexibility for students with families and jobs, giving them choices about where and when to work (Heubeck, 2008). They are well-suited for a student who does not live near a college or university or who has work-related travel. Students cite many reasons why they prefer online instruction, including they control the pace of the learning, they like immediate feedback, the multimedia hold their attention better than a lecture, and they want to avoid another negative classroom experience (Kinney, 2001). Both the percent of higher education institutions offering online distance education courses and the number of students enrolled in these courses has increased dramatically (National Center for Educational Statistics, 2003a).

The design of the current study included an experimental group of two classes of students enrolled in Intermediate Algebra in the online environment. Unfortunately, the pretest mean of the online group was so different from the pretest means of the other two groups that this group was removed from the analysis due to concern that the results may be misleading or faulty. An investigation into why this may have occurred revealed that the pretest for the online students was not identical to the pretest for the residential students. The instructors loaded the pretest for the online classes based on problems selected by the researcher but the researcher was not aware that some of the questions were only available in the computer learning system as multiple-choice and not free-response. If this study is replicated, it will be essential to verify that the pretest is identical for all groups. Online students differed from residential students in other ways in addition to the pretest.

Students enrolled in distance education courses differed demographically from students in residential classes. Prior research shows that distance education students may be older and more often female than on-campus students (Carr, 2000). In a developmental mathematics course in Australia, the average age was 35 years, and 65% of the students were female (Taylor and Mohr, 2001). Students in an online statistics course were older, worked more hours, and were enrolled in fewer credit hours than the students in the equivalent traditional course (Estes, 2002). The current study agrees with prior research that online students are more often older. In the online group, 26% of the students were less than 24 years of age, compared to 95% of the residential students. The percent of females, however, was nearly in the same. Fifty-seven percent of the online students were female, compared to 55% of the residential students.

Online students also differed in how they were instructed and their learning was assessed. Online students received instruction through the computer learning system and the textbook and had no face-to-face contact with the instructor. They had control over how much time they spent on each lesson. Quizzes and tests were given and graded by the software. The instructor controlled how long the quizzes and tests were available but had no control over what resources the students may have used or who was actually taking the tests. On the other hand, students in the traditional classes and traditional + CAI classes received 150 minutes of classroom instruction per week, assuming they attended class each day. The traditional + CAI group could receive additional instruction by working the tutorials in the computer learning system. Since quizzes and tests were given in class, the instructor could forbid the use of unauthorized resources and would know who was taking the tests.

Course completion rates in online courses are substantially lower than in residential courses (Carr, 2000). According to Carr, the two reasons given most often by students for dropping an online course were busy schedules and teachers who did not know how to manage an online course. In an online health education course, the drop rate was 13.5% compared to 7.2% for traditional students (Diaz, 2002). The drop rate in a management information systems course offered online was higher than the traditional course, 7.4% compared to 2.8% (Carey, 2001). The withdrawal rate in an online statistics course was 39.4%, compared to 13.2% in the traditional classes (Estes, 2002). In the current study, 21.4% of the online students did not complete the course and 12.1% of the residential students did not complete the course. Students most often reported that the reasons they did not complete the course were not having sufficient time due to family and work commitments and not being prepared for the course.

Some educators question whether developmental students can be successful in an online course. Hunter Boylan of the National Center for Developmental Education asserted that developmental students lack the independent learning skills, study discipline, time management skills, and motivation that computer-based distance learning requires (Boylan, 2002). Some developmental educators, however, have seen positive results after redesigning online courses that had low pass rates and high withdrawal rates. For example, beginning and intermediate algebra students at a community college in New York were required to attend an orientation session to introduce the technology, complete all homework online, and take exams in a proctored setting (Testone, 2005). The pass rate was 20% higher than the pass rate of students in residential classes who had access to the online tutorials and homework but were not required to use them. A distance learning developmental math course in Australia integrated discussion groups, essays, and journal entries to create a similar experience to the student-teacher interaction that takes place in the traditional classroom (Taylor and Mohr, 2001). Fifty-one percent of students reported a decrease in math anxiety and 90% reported an increase in confidence in their ability to do mathematics in their future studies. An action research project involving eight community colleges in six states identified factors critical to success in an online developmental mathematics course, including courseware that is easy to navigate, technical support for learners and faculty, frequent contact with faculty, professional development for faculty, and learners with motivation, time management, and academic goals (Perez and Foshay, 2002). Educators creating and managing online developmental mathematics courses have a responsibility to their students to learn from this prior research.

The lack of uniform results in the developmental mathematics research on computer-assisted instruction is not surprising because of the great variety of hardware and software, how they are used, other changes that are implemented at the same time, and the attitude of the instructor. The literature suggests several reasons why computer-assisted instruction had statistically significant positive or negative results in some cases and not in others. One reason suggested by Kinney and Robertson (2003) is the proper selection of software. Software designed to supplement classroom instruction is best suited to a teacher-centered mode of instruction and is not the same as software designed to deliver a thorough presentation of the course content, which is best suited for student-centered instruction. Educators who make a choice of software in haste without examining the features thoroughly may make a selection that does not match the course design. Computer learning systems vary in many ways including ease of use, clarity of instructions, quality of multimedia, availability of live tutors, and technical support. The literature reveals that educators are using computer-assisted learning in a variety of ways in developmental mathematics courses. How well computer learning systems are integrated into the curriculum may have an impact on whether learning improves (Barabash, Guberman-Glebov, and Baruch, 2003; Roschelle, Pea, Hoadley, Gordin, and Means, 2000). For example, Bump (2004) and Jacobson (2006) both found weaknesses in the implementation of computer-assisted learning in their studies. Stillson and Alsup (2003) found that a high number of students failed the course because they did not use the learning system. Hannafin and Foshay (2008) noted that the impact of CAI on low-achieving high school students was likely affected by other curriculum changes implemented at the same time. The attitude of the instructor toward computer-assisted instruction, as well as how much assistance was provided to students learning to use the software, may impact the results of a study. In some studies, the researcher was one of the instructors in the study and his or her belief about whether computer-assisted instruction benefited learning may have impacted the instruction and therefore the results (Carey, 2001).

For females to have the same educational and employment opportunities as males, they must be equally well-prepared academically. Gender differences in mathematics concern educators because many of the jobs of the 21st century require mathematical knowledge and skills. Stereotypes that females lack mathematical ability, perform poorly in math courses, and have limited experience with computers persist in society. Research suggests, however, that the large gender gap that once existed in mathematics has been reduced or eliminated (Hyde, Lindberg, Linn, Ellis, and Williams, 2008; National Center for Educational Statistics, 2005). Researchers have investigated gender differences in course grades, test scores, attitudes, motivation, interest, AP exams, class rank, grade point averages, and college majors.

The current study challenges the perception that males have higher achievement in math than females. The mean final exam score of females was significantly higher than the mean final exam score of males in Intermediate Algebra. This is also consistent with prior research that found that females perform better on classroom assessments than males. Studies show that females had higher high school math course grades than males (Ding, Song, and Richardson, 2006; Gallagher, 1998), higher high school grade point averages (Bridgeman and Wendler, 1991), and higher high school class ranks (Odell and Schumacher, 1998). However, males had significantly higher SAT-M scores than females (Bridgeman and Wendler) and were more likely to choose a college major that required math skills, such as engineering, physics, and computer science (National Center for Educational Statistics, 2005). Gallagher (1998) suggested that this evidence that females are performing as well or better than males on classroom assessments but not standardized assessments may be because females have different socialization skills or learning styles that lead to different ways of approaching problems. According to Bridgeman and Wendler (1991), it is possible that females engage in behaviors, such as attending class more regularly and doing more homework, which better prepared them for classroom assessments than males.

A meta-analysis of 82 studies on the impact of computer-based instruction (CBI) at all grade levels did not find sufficient evidence to link effectiveness of CBI to gender (Roblyer, Castine, and King, 1988). A study of seventh and eighth graders' achievement on fraction and decimals tasks (Nguyen, 2002) and another study of third, fourth, and fifth graders' arithmetic achievement (Mevarech and Rich, 1985) also did not find any gender differences between students receiving traditional instruction and traditional instruction supplemented with computer-based instruction. The current study, on the other hand, found a gender difference in favor of females on the final exam scores of Intermediate Algebra students.

The National Center for Educational Statistics report *Trends in Educational Equity of Girls and Women* (2005) concluded that males and females have equal access to computers, thus challenging the perception that females may not have as much access to technology or interest in using technology as males. Price's work at the Open University found no significant difference in women's and men's access to computers and the internet (2006). In addition, women were more likely to complete an online course, twice as likely to pass the course, more academically engage with the course, and more self-confident than men. The current study is consistent with this prior work by finding that females were not at a disadvantage when using computers and the internet for academic purposes but indeed outperformed males in the computer-assisted classes.

Few studies on the impact of computer-assisted instruction on the achievement of developmental mathematics students also investigated gender differences. The current study in Intermediate Algebra found a statistically significant difference between posttest scores of males and posttest scores of females. Females outperformed males in both traditional instruction and traditional instruction supplemented with computer-assisted instruction. This conflicts with two prior studies in developmental mathematics. A study at a historically black community college found no significant gender differences in two developmental mathematics courses (Mahmood, 2006). An earlier study comparing the effectiveness of computer-assisted instruction and traditional instruction for teaching geometry and algebra to African-American students at an urban university found significantly higher posttest scores for males than females (Owens and Waxman, 1994).

One possible explanation for females having a higher mathematical achievement than males in the current study may be related to the gender of the instructor. Based on Waycaster's study in five community colleges in Virginia, teacher gender can influence participation by students. She examined attendance, question asking, and question answering. The results were that participation was higher when the gender of the instructor matched the gender of the student than when the genders were different. Also, the minority gender participated less than the majority gender. The instructors in the current study were both female and the majority of students in each group was female. It is possible, but not known, that the instructors' question asking and answering behavior was consistent with Waycaster's work and females participated more in class, which possibly contributed to higher test scores. Female developmental math instructors, having completed at least a bachelor's degree in mathematics, are likely to believe that females are as capable as males at learning math and are likely to have high expectations for the female students in their classes.

Conclusions

Based on the literature and the findings of the current study, several conclusions can be drawn concerning developmental mathematics and computer-assisted instruction. The results of this study indicate that developmental mathematics students learn equally well with or without computer-assisted instruction. The mere presence of computers does not improve student learning. Students have an interest in using technology for a variety of purposes including academics. Computers have the potential to be useful tools to improve learning. They provide educators the opportunity to create courses in a variety of alternative formats to the traditional lecture in order to address the different learning styles and preferences of students. Quality is essential in any mode of instruction. Females may learn more than males in a developmental mathematics course.

Implications for Practice

Developmental mathematics students are unprepared for college-level mathematics courses and need a learning experience that is different from their learning experiences in middle and high school that resulted in them being placed in a developmental course in college. Since developmental students are very diverse in mathematical background and have a variety of learning styles, no one instructional style will meet the needs of all students. Therefore, colleges and universities should offer developmental mathematics courses in a choice of instructional models. The findings of this study indicate that developmental mathematics students learn equally well in traditional lecture and lecture supplemented with computer-assisted instruction.

Several reasons indicate that colleges and universities should offer developmental mathematics courses with computer-assisted instruction. Standards developed by the American Mathematical Association of Two-Year Colleges (1995) and the National Council of Teachers of Mathematics (2000) call for the use of technology in the classroom to improve student learning. Technological advances have made computers more powerful and less expensive, which has resulted in more students having access to computers. Most college students are inclined to use them for academic purposes in addition to communication and social uses. Eighty-five percent of college students in the Pew Internet and American Life Project (2002) had their own computer and 79% said the computer had a positive impact on their college academic experience. Finally, much of the research indicates that students of all ages and abilities using computer-assisted instruction in a variety of instructional models learn as well or better than those receiving traditional instruction.

Computer-assisted instruction offers students an opportunity to be actively engaged in the learning process, to receive instruction through a variety of multi-media, to choose when and where they learn, to work at their own pace, and to receive immediate and accurate feedback (Brown, 2003; Cotton, 2001; Hannafin and Foshay, 2008; Kinney and Robertson, 2003). Students in the current study and several others (Bump, 2004; Ford and Klicka, 1998; Kinney and Robertson, 2003) reported choosing a math class based on what fit their schedule, not whether the class used a computer. Faculty and advisors should improve the course selection process so that students choose the instructional model that best matches their learning style. Students could complete a questionnaire about learning styles and preferences that would provide feedback on which instructional model is likely to provide a successful experience. This questionnaire could be available online, in advising sessions, from math instructors, and in the learning center. In an online course, before the course begins, the professor should inform students how much time and computer skill will be required to successfully complete the course.

Developmental educators should learn how to use technology effectively to improve student learning. One of the factors identified as critical to success in an online developmental mathematics course was professional development for faculty (Perez and Foshay, 2002). A report based on 176 literature reviews and individual studies found that the achievement of students using computer-based instruction was significantly related to the amount of technology-related training the teachers had received and whether the technology was being used appropriately (Bialo and Sivin-Kachala, 1996). A national study on the effect of technology on fourth and eighth graders' mathematical achievement also concluded that students of teachers who had received professional development in computer use had higher levels of achievement (Wenglinsky, 1998).

Faculty should constantly evaluate computer software because new products continue to be developed and old ones changed. Some software is designed to supplement classroom instruction and some is designed to deliver instruction (Kinney and Robertson, 2003). Instructors need time to evaluate and select software appropriate to the course design. They need to know how to use the technology and how to integrate it in the curriculum in a way that enhances student learning. Since developmental students lack study skills, organizational skills, and motivation (Armington, 2003), courses with an online component should include lessons and discussion boards on learning strategies

(Kinney and Robertson, 2003; Trenholm, 2006; Wadsworth, Husman, Duggan, and Pennington, 2007).

In order for students to receive the maximum benefit from using a computer learning system, faculty should provide instruction in how to use the system. Researchers have discovered a high degree of frustration among students and teachers in communicating with mathematical symbols (Engelbrecht and Harding, 2005; Jacobson, 2006; Smith and Ferguson, 2004; Testone, 1999). Students need to learn how to enter mathematical notation. A student may have the correct answer on paper but the computer will not accept it as correct if the answer is entered improperly. They also need to know how to use the tutorial features and the study plan to improve their learning. Some students attempt the graded assignments without first working the tutorials and become discouraged when they earn low scores. Students should also be taught how to monitor their progress in the course using the grade book.

This study indicates that some developmental mathematics students do learn in a traditional classroom. Although lecture alone has not been effective with developmental students, there is evidence in the literature that enhancing the lecture with such techniques as group work, cooperative learning, class discussions, real-world examples, and peer tutoring has positive results. Educators using the traditional lecture should examine their teaching practice and find ways to enhance the lecture with active learning and relevant examples that will motivate students to learn. Courses could be redesigned with classes meeting four or five days a week. Two or three days could be lecture and the remaining days would be for students to work problems and take quizzes.

Professional developmental should be provided to help developmental educators understand the needs of developmental students (Boylan, 2002). This professional development can be attending developmental education conferences, reading current research, and participating in departmental workshops on relevant topics. Often colleges and universities hire instructors with high school teaching experience or use professors in the traditional mathematics department to teach developmental courses. However, they must learn how developmental students differ from high school students and how they differ from those ready for college-level work. Instructors must be committed to continually improving their instructional practice in order to provide a high-quality education for all students, no matter what method of instruction is being used.

Developmental educators should strive to give all students, whether male or female, equal opportunities to receive a quality education. Instructors should examine whether they treat males and females differently in any way, including asking and answering questions from one gender more than the other, and then make necessary corrections. A peer or supervisor could conduct a classroom observation in which the number and types of interactions are recorded by gender.

Limitations

The results of this study are limited by several factors. This study was conducted at a large university, using Intermediate Algebra courses delivered by two modes of instruction: traditional classroom instruction and traditional instruction supplemented with computer-assisted instruction. The results may not generalize to another developmental mathematics course, such as pre-algebra or beginning algebra. In addition, the results may not apply to a course that uses computer-assisted instruction in a different way, such as a laboratory setting or hybrid course. Of the seven full-time instructors at the university, only two were teaching the course sections used in this study because they were the only ones teaching in all three modes of instruction being investigated. The number of students in this study was limited to those enrolled in Intermediate Algebra for the spring 2009 semester in the sections taught by the two instructors. The computer software was limited to the system that the developmental math program had already adopted, CengageNOW.

As many factors as possible were controlled in the design of the study. Each group used the same course objectives, the same textbook, the same 16-week semester, and the same final exam. The same two instructors taught one class each of traditional instruction, traditional supplemented with computer-assisted instruction, and online instruction in the distance learning format. Both were full-time instructors with bachelor’s degrees in mathematics and master’s degrees in education and with experience teaching developmental students with and without CAI. It is possible that one instructor provided better quality of instruction than the other. One may have given greater emphasis to the importance of the computer component of the course and provided more classroom demonstrations of the tutorials and equation editor. This study accounts only for differences in student mathematics performance as measured by a pretest and does not account for other factors that may possibly influence performance such as gender of instructor, class attendance, extra-curricular activities, parent education, socio-economic status, ethnicity, or math anxiety.

Recommendations for Further Study

The following recommendations for further investigation were based on the findings of this study. To further validate the findings of this research, the study should be replicated with a larger sample and in other developmental mathematics courses. Additional research should be conducted comparing the success rates (percent of A, B, C course grades) in college-level math courses of developmental mathematics students receiving traditional instruction, traditional instruction supplemented with computer-assisted instruction, and online instruction.

The relationship of math anxiety and math performance in different modes of instruction should be examined. A study of students' math anxiety levels at the beginning and end of traditional instruction and computer-assisted instruction is recommended. Discussion board assignments related to best and worst experiences in a math class and lessons on what math anxiety is and how to control it could be added to an online course, then comparisons of the math anxiety level of students in classes with and without these lessons should be conducted.

A study is recommended to investigate any possible learning style or other differences in males and females that may influence their math performance. It is possible females have acquired habits that lead to success in college. An examination of attendance, class participation, and visits to a tutoring center for male and female developmental math students is suggested. A case study would provide an in depth investigation of the behavior of students in a developmental math course which may reveal any differences in male and female behaviors associated with success or failure.

Faculty characteristics were not considered in this study. Research should be done to determine if there is a difference in mathematical performance based on gender of faculty and gender of students. Also recommended is a study on the differences between the mathematical performance of students taught by adjunct faculty and students taught by full-time faculty.

Summary

Concern for the low pass rates in developmental mathematics courses has led educators to explore alternatives to the traditional lecture that has been used for many years in college classrooms. Computers make possible new methods of delivering instruction with the potential to improve learning by providing an active learning environment. The purpose of this study was to compare the mathematical performance of students receiving three different modes of instruction in developmental mathematics. The study was conducted in Intermediate Algebra classes at a large, eastern university. Based on this study, students perform equally well when receiving traditional classroom instruction and traditional classroom instruction supplemented with computer-assisted instruction. In addition, females outperformed males in both instructional modes.

Colleges and universities should offer developmental mathematics courses in a variety of modes of instruction to meet the diverse learning needs of developmental students. Recommendations for further study include replicating the study with a larger sample and in other developmental mathematics courses, investigating math anxiety levels of students in various modes of instruction, and examining performance of students based on faculty gender and student gender. Faculty must improve the curriculum and their instructional practice so that all students in every instructional setting have an opportunity to improve their learning, to pass a developmental mathematics course, and to achieve their educational and career goals.

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Appendix A. *Questionnaire*

1. Number of years since your last math course:

   ☐ Less than one year ☐ One or two years ☐ Three or four years ☐ More than four years

2. Number of semesters you have been in college, including this one:

   ☐ One ☐ Two ☐ Three or four ☐ Five or six ☐ Seven or more

3. Number of credit hours you are registered for this semester:

   ☐ Less than 12 credits ☐ 12 or more

4. Rate your attitude toward math on a scale from 1 to 5. Circle your answer.

   1 = very negative 2 = somewhat negative 3 = neutral 4 = somewhat positive 5 = very positive

5. How have you used computers? Check all that apply.

   ☐ Email ☐ Surfing the web

   ☐ Social networking sites ☐ Games

   ☐ Shopping ☐ Word processing

   ☐ Homework, quizzes, and tests ☐ Math assignments

6. Rate your attitude toward using computers for educational purposes. Circle your answer.

   1 = very negative 2 = somewhat negative 3 = neutral 4 = somewhat positive 5 = very positive

7. Gender : ☐ Male ☐ Female

8. Age: ________ years

9. Check what best describes your ethnicity: □ white □African American □ Hispanic □ Other

10. Are you an International student: □ yes □ no

11. Is this your first distance learning course? □ yes □ no (for DLP sections only)

Appendix B

Characteristics of Participants

Characteristic	Traditional		Traditional + CAI		Online		Overall	
	N	P	N	P	N	P	N	P
Years Since Last Math								
<1	38	74.5	38	76.0	18	51.4	94	69.1
1 or 2	11	21.6	12	24.0	4	11.4	27	19.9
3 or 4	1	2.0	0	0.0	4	11.4	5	3.7
>4	1	2.0	0	0.0	9	25.7	10	7.4
Semesters in College								
1	3	5.9	4	8.0	3	9.1	10	7.5
2	26	51.0	14	28.0	1	3.0	41	30.6
3 or 4	13	25.5	22	44.0	13	39.4	48	35.8
5 or 6	8	15.7	7	14.0	9	27.3	24	17.9
7 or more	1	2.0	3	6.0	7	21.2	11	8.2
Credit Hours								
Part-time	0	0.0	3	6.0	18	51.4	21	15.4
Full-time	51	100.0	47	94.0	17	48.6	115	84.6

Characteristic	Traditional		Traditional + CAI		Online		Overall	
	N	P	N	P	N	P	N	P
Math Attitude								
Very negative	1	2.0	4	8.0	2	5.9	7	5.2
Negative	17	33.3	10	20.0	1	2.9	28	20.7
Neutral	12	23.5	15	30.0	8	23.5	35	25.9
Positive	15	29.4	18	36.0	17	50.0	50	37.0
Very positive	6	11.8	3	6.0	6	17.6	15	11.1
Computer Use								
Other than academic	1	2.0	3	6.0	0	0.0	4	2.9
Academic and other	50	98.0	47	94.0	35	100.0	132	97.1
Computer Attitude								
Very negative	1	2.0	2	4.1	0	0.0	3	2.2
Negative	0	0.0	1	2.0	0	0.0	1	0.7
Neutral	14	27.5	17	34.5	1	2.9	32	23.7
Positive	22	43.1	21	42.9	6	17.1	49	36.3
Very positive	14	27.5	8	16.3	28	80.0	50	37.0
Gender								
Male	21	41.2	24	48.0	15	42.9	60	44.1
Female	30	58.8	26	52.0	20	57.1	76	55.9

Characteristic	Traditional		Traditional + CAI		Online		Overall	
	N	P	N	P	N	P	N	P
Age								
≤ 23	48	94.1	48	96.0	9	25.7	105	77.2
≥ 24	3	5.9	2	4.0	26	74.3	31	22.8
Ethnicity								
White	36	70.6	35	70.0	29	85.3	100	74.1
African American	10	19.6	6	12.0	3	8.8	19	14.1
Hispanic	2	3.9	2	4.0	1	2.9	5	3.7
Other	3	5.9	7	14.0	1	2.9	11	8.1
International								
Yes	5	9.8	6	12.0	0	0.0	11	8.1
No	46	90.2	44	88.0	35	100.0	125	91.9
First Online Course								
Yes					3	8.6	3	8.6
No					32	91.4	32	91.4

Appendix C. *Pretest*

Name ____ Date _________________

These questions are a sample of the topics we will cover in Math 110 *Intermediate Algebra*. Answer each one to the best of your ability to see what you know now about these topics.

1) Solve and write the answer in interval notation:
$-2(x-5) \geq 6(x+7) - 12$

2) Solve: $\dfrac{x+11}{x^2-x-12} + \dfrac{1}{x-4} = \dfrac{4}{x+3}$

3) Simplify. Write the answer without using zero or negative exponents.
$2(x^2 y^{-1})^{-3}$

4) Perform the indicated operation and simplify.
$(3\sqrt{2}+1)(\sqrt{2}-1)$

5) Solve using the quadratic formula.
$3x^2 - 5x = 1$

Appendix D. *Posttest*

1. a. (5 points) Solve: $-2(x-5) \geq 6(x+7)-12$

b. (3 points) Write the solution in *set* notation.

c. (3 points) Write the solution in *interval* notation.

d. (3 points) Graph the solution.

2. (6 points) Solve: $2|x+5|-3=9$

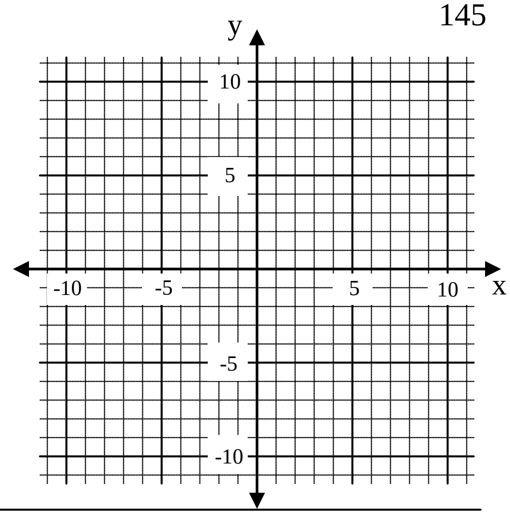
3. (6 points) Solve: $|3x-2|>10$

4. (3 points each) Given $5x-4y=20$

a. Find the *x*-intercept.

b. Find the *y*-intercept.

5. (4 points) Graph. $y = x^3 + 2$



6. a. (3 points) Find the slope of the line containing the points (-2, 5) and (3, -1).

b. (6 points) Write an equation in *standard form* of the line containing the points (1, -5) and (-3, 2).

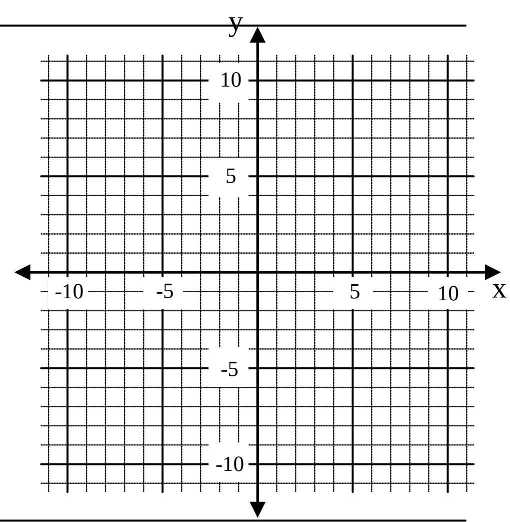
7. For the equation $x + 3y = 6$

a. (2 points) Write in slope-intercept form.

b. (2 points) Find the slope.

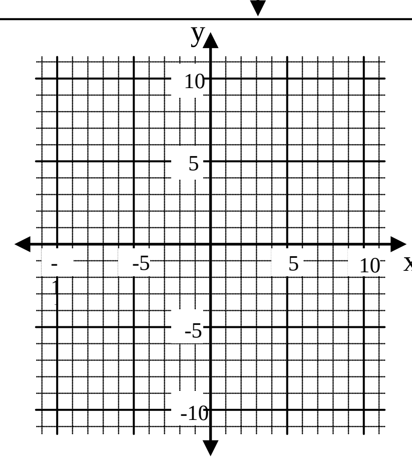
c. (2 points) Find the *y*-intercept.

d. (3 points) Graph the line.



8. a. (3 points) Graph the line $y + 3 = 0$

b. (2 points) What is the slope of the line?



9. (3 points) Subtract the polynomials.

$4x^2 - 3x + 2$ from $2x^2 + 5x - 9$

10. (4 points) Multiply.

$(x+3)(5x^2 + 4x - 1)$

11. (4 points) Factor completely:

$x^3 + 5x^2 - 5x - 25$

12. (6 points) Solve:

$x(2x-7) = 4$

13. (6 points) Divide:

$$\frac{x^3 - 64}{16 - x^2} \div \frac{x^2 + 5x + 6}{x^2 - 3x - 18}$$

14. (6 points) Subtract:

$$\frac{x}{x^2 + 5x + 6} - \frac{2}{x^2 + 3x + 2}$$

15. (6 points) Simplify: $\dfrac{\dfrac{1}{x-2} - \dfrac{3}{x-1}}{\dfrac{2}{x-1} + \dfrac{5}{x-2}}$

16. (3 points each) Use the following rational equation to answer this question.

$$\frac{x-1}{x^2-2x-3}+\frac{x+2}{x^2-9}=\frac{2x+5}{x^2+4x+3}$$

DO NOT SOLVE!!!!!

a. Find the LCD.

b. State the restrictions.

17. (6 points) Solve:

$$\frac{x+11}{x^2-x-12}+\frac{1}{x-4}=\frac{4}{x+3}$$

18. (5 points) Divide: $(y^2-20y+64)\div(y-6)$

19. (4 points) Simplify the expression. Express final results without using zero or negative integers as exponents.

$$2\left(x^2y^{-1}\right)^{-3}$$

20. (3 points each) Simplify the following. Assume all variables represent positive numbers.

a. $\sqrt{49x^6}$

b. $\dfrac{\sqrt[3]{16x^4}}{\sqrt[3]{2x}}$

21. (4 points) Perform the indicated operation and simplify, if possible. Write answers using radical notation.

$\sqrt[4]{8a^6b^3}\ \sqrt[4]{2ab^5}$

22. (4 points each) Perform the indicated operations and simplify, if possible. Write all answers using radical notation.

a. $3\sqrt{45}+7\sqrt{20}-\sqrt{80}$

b. $\left(3\sqrt{2}+1\right)\left(\sqrt{2}-1\right)$

23. (4 points) Rationalize the denominator: $\dfrac{3}{\sqrt{2x^3}}$

24. (6 points) Solve and check: $3+\sqrt[3]{x-4}=5$

25. (3 points) Rewrite with rational exponents and simplify, if possible:

$$\left(\sqrt[4]{x+y}\right)^{12}$$

26. (3 points) Write an equivalent expression using radical notation and simplify, if possible.

$$\left(x^3 y^3\right)^{\frac{1}{4}}$$

27. (a, b 3 points, c 5 points) Perform the indicated operation and simplify. Write each answer in the form a + b*i*.

a. $(8+7i)-(5+3i)$

b. $\sqrt{-9}\sqrt{-25}$

c. $\dfrac{3-4i}{5-i}$

28. (6 points) Solve by completing the square: $x^2 + 6x + 7 = 0$

29. (4 points) Use the discriminant to determine whether the equation has two nonreal complex solutions, one real solution with a multiplicity of two, or two real solutions. **DO NOT SOLVE.**

$$7x^2 = -2x - 1$$

30. (6 points) Solve using the quadratic formula. $3x^2 - 5x = 1$

---

31. (3 points each) Find the domain of each function, write your answers in interval notation.

a. $f(x) = \dfrac{5x}{2x-9}$

b. $f(x) = \sqrt{x+3}$

c. $f(x) = 4x + 5$

---

32. (5 points) Find $\dfrac{f(a+h) - f(a)}{h}$ for the function $f(x) = x^2 - x + 4$

33. (6 points) Solve the system of of equations using any method.

$$x - 4y = 29$$
$$3x + 2y = -11$$

---

34. (4 points) Translate into a system of equations. **DO NOT SOLVE!**
For moving purposes, Mr. Henderson bought 25 boxes for $97.50. There were two kinds of boxes. The large ones cost $7.50 per box and the small ones cost $3 per box. How many boxes of each kind did he buy?