I, Adam Chekour, hereby submit this original work as part of the requirements for the degree of Doctor of Education in Curriculum & Instruction.

It is entitled:
The Effectiveness of MyMathLab (MML) Learning System on Developmental Math Instruction

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The Effectiveness of MyMathLab (MML) Learning System on Developmental Math Instruction

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By

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Abstract

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 and traditional instruction supplemented with computer-assisted instruction. In addition, gender differences in mathematical performance were also investigated. The quasi-experimental study was conducted in 7 different Developmental Math classes at a large, public, Midwestern university.

An independent groups T-test was used to compare the mean difference between pretest and posttest mathematics scores of students enrolled in conventional instruction and MyMathLab integrated instruction. Students enrolled in MyMathLab sections made significant gains over students enrolled in conventional sections. Same test confirmed that there was also a significant difference in the posttest scores of females and males, with females outperforming males in both modes of instruction.

Implications from this research study suggest that institutions should offer developmental mathematics courses in a variety of formats (other than traditional format), 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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I discovered that completing a doctorate is not an easy task. To do this while teaching full schedule adds another level of complexity, which requires maintaining a steady balance between my professional duties and student responsibilities.

Joining, experiencing and completing a doctoral program have been a memorable event in my life. Writing my thesis was a very solitary experience. Those I’ve mentioned above and many other friends, colleagues, and extended family made it possible to persevere. Conducting research and writing this thesis has been the most rewarding experience in my entire studies, and I feel blessed to have succeeded in earning my Doctorate.
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Chapter One: Introduction

Research on mathematics problem solving has largely evolved throughout history from experience-based techniques for problem solving, learning and discovery (Polya, 1957) to linking these techniques to the development of mathematical content (Lester & Kehle, 2003). Exposing students to the course content has often not been enough for them to achieve academic success in mathematics. Implementing a variety of instructional strategies that increase students’ motivation and meaningful learning were also necessary. Only recently, math problem solving has known an infusion of a variety of technology tools and procedures aimed at enhancing students’ meaningful understanding of different math concepts (Lesh, Zawojewski, & Carmona, 2003).

Indeed, research on how mathematics is integrated in different fields (e.g. STEM education), and how professionals in these fields tend to heavily apply mathematical concepts, has dramatically affected the nature of math problem solving. Furthermore, this integration emphasizes the necessity of implementing new and powerful technologies to enable students’ conceptualization, communication, and computation while solving math problems (National Council of Teachers of Mathematics, 2000). These skills certainly provide students with a new perspective on how to approach math problem solving and build a foundation for them to be a successful critical thinker and problem solver within and beyond school (NCTM, 2000).

However, the implementation of technology in the teaching and learning of mathematics has witnessed a slow growth, due to factors such as accessibility to technological tools, students’ and teachers’ beliefs about technology, and lack of general research enlightening the effects of technology on enhancing classroom instruction, mathematical curriculum content, and students’ learning of mathematics (Zbiek, Heid, Blume, and Dick, 2007). Such an issue persists mainly in
K-12 education and developmental mathematics classes at two-year or community colleges (International Technology Education Association, 2006). While there are numerous case studies on specific technologies applied to K-12 math education, there is still a need for a comprehensive synthesis of the findings of these separate case studies. This will inform, substantially, both the practice and the research in math education.

Further, most of the research studies on technology-infused math education emphasizes only the technical aspect of learning mathematics, which involves mathematical activities and procedures that lead to numerical computations, solving equations, using diagrams, and collecting and sorting data (Borwein & Bailey, 2005). Conversely, few research studies address the instrumental use of technology to enhance students’ conceptualization of math activities involving how students understand, communicate, and use mathematical connections, structures, and relationships. Achieving this goal not only changes educators’ and students’ belief about technology, but it also improves students’ skills in learning mathematics (Kulik & Kulik, 1991).

Although problem solving has been a concern of psychologists and education researchers for more than a hundred years, there have been limited research studies on mathematical problem solving and math reasoning involving the use of technology. In addition, few methods have been implemented to study the various concepts of problem solving, such as simulation, computer modeling and experimentation (Maccini et al., 2007). One aspect of computer modeling is the use of Computer Algebra Systems (CAS) such as the MyMathLab application, which has found its way to a variety of math course levels and is currently adopted by numerous academic institutions (Pearson Education, 2005). Initially designed and commercialized by Pearson Education, a worldwide leader in education resourcing, MyMathLab has been, somewhat, a
successful tool in enhancing students’ learning, specifically in developing math problem solving skills (Pearson Education, 2005).

This research is intended to evaluate the success of implementing MyMathLab into the learning process while solving math problems and learning developmental mathematics. The efficacy of CAI using MyMathLab will be compared to traditional, face-to-face instruction of mathematics in developmental classes.

**Problem Statement**

The use of technology integrated math education has been recently growing at a steady rate. While there is a considerable amount of research emphasizing the effectiveness and impact of CAI on students’ learning of mathematics, at different K-12 grade levels and within a variety of subjects, there is still a gap in conclusive research that focuses on mathematics developmental classes. Other studies emphasize the advantage of adding other pedagogies to the computer-assisted instruction, such as constructivist activities, group activities and personal interaction of developmental students with their instructor.

Various questions can be raised in this regard: Does an addition of technology such as MyMathLab enhance the learning and teaching of developmental math courses? Or, does traditional (face-to-face) instruction, by itself, produce better results in math performance among students? Also, is math performance in both modes of instruction (computer-assisted and conventional) affected by gender? To try to answer these questions, this research study contrasts a traditional mode against a hybrid mode (using MyMathLab) of instruction, in addition to examining gender differences in both modes.
Research Questions and Hypotheses

1. In the light of the above gap, the main research questions examined were: Does computer-assisted instruction such as MyMathLab (MML) enhance the learning of developmental mathematics, or is traditional instruction more effective for these students?

2. Is there any difference in the math achievement between males and females in developmental math class?

The corresponding null hypotheses this study were as follows:

1. There is no significant difference in the mathematics performance of students in a developmental mathematics course using the following instructional modes:
   i. Traditional instruction (TI).
   ii. Computer-assisted instruction (CAI), which is a traditional instruction supplemented by MyMathLab learning system.

2. There is no significant difference in the mathematics achievement between males and females in developmental mathematics classes.

Purpose of the Study

Many students who register for college math classes need to consistently prepare themselves to meet the expectations for college academic and career success. Traditional methods of instruction especially when not accompanied with effective pedagogies, usually fail to assist students in acquiring these necessary skills for success in developmental math courses and for the twenty-first century workforce. Therefore, schools are seeking alternative approaches to enhance the learning and the teaching of developmental mathematics, and to enable students to acquire necessary skills for college math success.
The purpose of this study was to investigate the value of computer-assisted instruction using MyMathLab as a possible new alternative for delivering math instruction, and to compare this strategy to the traditional mode of instruction. In addition, the study examined the moderating effect of gender differences on math achievement in Developmental mathematics classes at a large Midwestern university.

**Significance of the Study**

High school graduates often come unprepared to college math courses and therefore struggle in meeting math course expectations (National Center for Educational Statistics, 2003b). Despite the continuous intervention efforts of different institutions, only 10% of these students graduate, and only 40% of these students who are in developmental math programs graduate with a bachelor’s degree (Brittenham, et al. 2003).

Whether the developmental math classes will lead students to attend four-year institutions, with more emphasis on college algebra and statistics (NCES, 2003b), or to qualification for a meaningful job, colleges and universities are concerned with a low passing rate not even exceeding 24% at some colleges (Trenholm, 2006). Therefore there is urgency in developing programs and strategies that aim at student retention and provide a meaningful learning experience to students, one that emphasizes understanding of math concepts, promotes active constructivist learning, and allows for transfer to real world applications. Instructors of developmental mathematics are implementing different supplemental tools to traditional instruction known to be limited in effective resources and pedagogies. The broadened use of computer technology in education today has led math instructors to implement computer tools to benefit students’ learning of mathematics (NCES, 2003b). The National Council of Teachers of Mathematics (NCTM, 2000) calls for using computer technology as a means to enhance math
teaching and learning in and out of classrooms. In addition, in a study conducted by the National Center for Educational Statistics (2003b), 31% of the 3230 US surveyed colleges (during the fall of 2000) revealed a frequent use of computers by students for their instructional needs in on-campus remedial math education.

With a fast increase of computer technology, a variety of software, hardware and media tools has found its way into developmental mathematics to offer a rich learning experience to students while they are learning mathematics. Most of the software used in developmental mathematics has been developed by textbook publishers to either supplement classroom instruction with tutorial and algorithmically generated problems, or to provide a thorough presentation of concepts with interactive multimedia (Kinney & Robersrtton, 2003). In addition to the advantage of receiving immediate feedback, students can also self-pace and revisit their assignments until mastery (Hannafin & Foshay, 2008), although there is a schedule for completion of lessons. They can also benefit from accessing a variety of built-in resources such as videos, guided practice problems, and online tutoring. Teachers can also build individualized study plans, quizzes and tests immediately graded by the software and tailored to a specific unit and learning objectives.

Providing instructors with detailed data on students’ progress is a valuable feature to course overall assessment (Cotton, 2001). Within this perspective, this study aims at investigating the effect of computer-assisted instruction on the mathematical learning of students in developmental classes, using the MyMathLab learning system. The results of this study can inform institutions in investing their resources wisely on computer-assisted instruction with potential impact on students’ mathematical achievement. The study also suggests future research to decipher key student characteristics that are associated with higher developmental math
achievement, within different delivery formats, and simultaneously, improve the experience of computer-assisted learning of mathematics in developmental courses.

**Glossary of Terms**

*Developmental Mathematics:* A set of math courses and programs designed for the purpose of supporting underprepared students in terms of providing them with the necessary skills and knowledge that are essential to succeeding in college-level math courses.

*Computer-assisted instruction (CAI):* Instruction delivered through a computer as a supplement to traditional teacher-directed instruction. This mode of instruction includes tutorials, drill-and-practice, graded assignments, other online activities. Other references to CAI include *computer-based instruction* (CBI) and *computer-mediated instruction* (CMI).

*Traditional instruction:* Instruction delivered by a teacher dispensing knowledge and demonstrating skills using lectures, sometimes integrated with discussion and group work. Other terminology for this mode of instruction includes face-to-face instruction and conventional instruction.

*Computer learning systems:* A Software kit provided by textbook publishers as a complement to the textbook. This kit includes a variety of features such as online interactive assignments (homework, quizzes, tests and study plans), tutorial resources, video mini-lectures, interactive discussion threads, and online tutoring.

*Mathematics achievement:* In this study, the mathematics achievement is defined as the score on the posttest, which is measured by the university’s math placement test.

*Math Placement Test:* A computer-based test designed to identify the student’s level of preparation and prerequisite skills level, necessary to be qualified for an appropriate math course or level.
Chapter Two: Theoretical Framework and Review of Literature

The purpose of this review of literature is twofold. First, it investigates how technology is used in math instruction and curriculum development, to come up with a better approach to technology use, which would benefit students’ both technical and conceptual learning of mathematics within a technology-integrated setting. Second, it examines students’ technical and conceptual learning of mathematics within a technology integrated environment, in order to build a solid body of research on technology integration in math education, so that researchers, educators, and policy makers can consider alternative perspectives on the technical and conceptual use of technology in mathematics education.

I begin with a discussion of early research studies highlighting major issues in the learning and teaching of mathematics, especially within math problem solving. In the subsequent section, I describe the distinction between traditional face-to-face instruction and computer-assist mathematics (either as a hybrid or as online method of delivery), and how that affects students’ learning of math problem solving. In both sections, questions are raised and issues are identified about the gaps in research on technology infusion into math education. In addition, this review provides a productive framework to fill in the existing gaps in the literature, and guide future research directions.

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.

**Theoretical Framework**

There are two major theories that provide the framework for analyzing the data and guiding the discussion in this study. The first theory is constructivism grounded in eminent work
of Dewey (1958) and Vygotsky (1978). The main premise of constructivism is the learner’s ability to internally construct an understanding of mathematical concepts and connect them through important relationships. This constructivist learning usually conditionalizes knowledge through experience, exploration, thinking, and reflection (Dewey, 1958). In addition, this experiential learning often takes place within an interactive environment, which promotes understanding through life experiences, or can be mediated by an educator, who usually guides this discovery process.

The second theory is grounded in the nature of technology use, which categorizes technology into instrumental and substantive (Trenholm, 2006). According to Zbiek, et al., 2007), the instrumental view of technology is a legacy of Aristotle, who posited that technological products have no meaning in and of themselves and that technology receives its justification from serving human life. Indeed, technology use in mathematics will have no meaning if it doesn’t promote or supplement the learning process of students. At the same time, the use of technology needs to maintain the right balance and fit the right purpose, by allowing a deeper-level of logical and critical thinking.

The substantive view of technology is based on the view that “technology is becoming autonomous, is going beyond human control, and operates and evolves according to its own logic and norms” (Chen, 2011, p. 57). This theory recognizes that the learner’s experience is mediated by and structured through technology. Indeed, students and technology become embodied in an experientially semi-symbiotic unity, where the technology mediates what and how mathematics is experienced and learned. In this process, the technology becomes appropriated to the learning activity as an integral part of students’ thinking, causing an interweaving of instrumental and
Issues in math teaching and learning

While students are required to acquire the ability to compute, problems solve, and put mathematical concepts and skills into practice, to compete with the demands of a fast growing and technology saturated world, there are still several increased challenges facing the learning and teaching of mathematics. The United States Department of Education indicates that U.S. students are performing below their counterparts in other developed countries (USDOE, 2008). In addition, the National Assessment of Educational Progress (2006) claims that only two percent of U.S. students manage to attain advanced levels of math achievement by grade 12.

Woodward (2004) contends that changing policies and standards in mathematics are among possible solutions for the decline of student performance in mathematics. Indeed, the National Council of Teachers of Mathematics (NCTM) initiated reform efforts to improve students’ achievement in mathematics through revising math curricula and core standards. This revision process focused primarily on a thorough and a deeper pedagogical content knowledge of conceptual understanding (NCTM, 2000). The focus highlighted a significant shift from the rote memorization of computational facts and procedures used in math problem solving to practical situations, where students are given opportunities for critical thinking and problem solving.

Another issue pertaining to students’ performance is the lack of effective instructional approaches and metacognitive strategies, which aim at enhancing and scaffolding the mastery of abstract concepts in mathematics (National Math Advisory Panel, 2008). According to Maccini and Gagnon (2002), authentic mathematics instruction should include the following recommended instructional practices:
1. Differentiated instruction

2. Metacognitive strategies and instructional routines

3. Progress monitoring and formative assessment procedures

4. Computer-assisted instruction and Universal Design (p. 13)

In another study, Bouck (2009) claims there are two fundamental constraints hindering the improvement of K-12 mathematic education. The first one lies in the fact that mathematics teachers spend valuable energy and time in designing instructional activities, which are seldom conductive to students’ exploration and construction of their own understanding of mathematical concepts. The second constraint is that mathematics instructors are resistant to a change in their teaching strategies. Indeed, Bouck claims that the current teaching of mathematics is mainly characterized by universal formal and symbolic presentations of mathematical rules or procedures, based on a mere textbook presentation rather than a synthesis of encompassing mathematical relations.

In a subsequent study, Kilpatrick (2010) maintains that the most fundamental task facing mathematics instructors is to promote mathematics conceptual meaning among their learners. This approach supports the Piagetian position that postulates the existence of mathematical objects as synonymous with meaning, which later become mental entities that unfold over time to allow for connection and transfer of knowledge (Piaget, 1991).

In a different study on the use of constructivism in math activities, Lerman (2003) argues that conceptual knowledge cannot be transferred automatically from teacher to learner, but it should be built and molded by the learner under the guidance of the instructor, and on the basis of prior knowledge and experience. According to Lerman, this constructivist representation of
one’s reality and meaning enables learners to seek the meaning in the structure, organization, and relationships between different math subjects.

Within the same perspective, Santos (2007) contends that mathematics learners achieve better outcomes in problem solving when they assimilate mathematical concepts to the collection of their intrinsic satisfying models. The absence of these intrinsic models makes mathematical problem solving painfully difficult, even when concepts are simulated. This is due to a lack of insights, which mystically shed the light on and facilitate the process of problem solving.

In her study on scaffolding problem solving, Muis (2004) claims that the socialization of problem solving through discussion is essential to the success of this process. This socialization suggests a shift in the focus of activities led by the instructor to activities lead by the students, but understood and facilitated by the former (Kim, 2011). This provides the instructor with a context to be more sensitive to students’ mathematical experience, in addition to developing meaningful mathematical conversations conductive to concepts’ assimilation, organization, extension and transfer.

Within the same construct, Magiera and Zawojewski (2011) contend that the lack of meaningful mathematical discussions is frequently observed in mathematics classrooms. Students tend to work independently on math tasks and activities, without benefiting from the opportunities to communicate and interact with their peers. The socialization aspect of these mathematical conversations is fundamental to critical thinking, problem solving and evolving as a mathematician. Therefore, math instructors need to perpetuate these behaviors and make them a common place in the mathematics classrooms.

Recently, a continued emphasis was made on mathematics and science integration to improve teachers’ knowledge in both mathematics and science. According to Stinson, Harkness,
Meyer & Stallworth (2009), math integrated instruction enables students to better understand problem solving strategies as they are applied to more practical situations. Instructors also benefit from math integration by experiencing greater student involvement and contribution to the design of effective math curricula (Stinson, Harkness, Meyer, & Stallworth, 2009).

Finally, within the same perspective, Schoenfeld (2007) maintains that mathematics instructors should possess two kinds of competencies, subject matter knowledge and general pedagogical skills, in order to achieve satisfactory and efficient teaching. The intertwining of these two competencies constitutes teachers’ belief and affects towards mathematics and mathematical activities, which also affects students’ potentials for learning mathematics (Schoenfeld, 2007). Therefore, it is important to identify and implement professional development components that are specific and instrumental for pre-service preparation, in-service development, and professional identity in the field of mathematics education (Sfard, 2006).

**Developmental Mathematics**

**The concept 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 & 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 schools. 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.

**Necessity of 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, 1999). 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, 2007).

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 & 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 Inc., 2005). According to Robert McCabe (2000), former president of the League for Innovation in the Community College 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 (2001) study of community colleges in Virginia reported pass rates from 29% to 64%. McCabe’s (2000) work also showed that less than half of community college students enrolled in remedial courses successfully completed those courses. 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 (1999), 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, and 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 (Stigler & Hiebert, 1999). 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 could take a developmental course and most allowed students to enroll in college-level courses in other subject areas at the same time. The National Center for Educational Statistics (2003b) survey of over 3,000 colleges provides a national perspective. 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%).

Traits 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, 2003). 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, 2003). Some have been humiliated by a teacher or parent (Hammerman and Goldberg, 2003). 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 (1999) examined 18 studies and summarized the demographic, social, and personal characteristics of community college students. 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 (1999), former president of the National Association of Developmental Education, college students have become increasingly diverse in ethnic background. 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, 2002; Casazza, 1999). Developmental educators contend that
these students deserve an opportunity to be successful in college and that developmental education can provide that opportunity.

**Modes of Instruction**

Exposing students to the course content is often not enough for them to achieve academic success in mathematics. Implementing a variety of instructional strategies that increase students’ motivation and meaningful learning are also necessary.

While there are numerous pedagogies used in teaching mathematics, this literature review will shed light on those with a focus on learning through computer-assisted instruction (CAI), in hybrid format. The efficacy of CAI will be compared to traditional, face-to-face instruction of mathematics in developmental classes.

**Traditional Instruction**

Traditional instruction is teacher-centered and includes various components, including facilitation of lecture material, teacher modeling of concepts, thinking aloud, and guided practice and drill, followed by teacher correction and feedback (Kinney and Robertson, 2003). In this direct mode of instruction, the teacher takes the role of an expert who decides what and how material is to be learned (Brown, 2003; Kinney and Robertson, 2003). A study by Grasha (1994), which examined the teaching styles of 381 faculty members at 200 U.S universities, showed that 60% were adopting a teacher-centered mode of instruction. This often happens as a perpetuation of the same instructional method that these faculty members were taught or felt some comfort with. Therefore, students at the developmental mathematics level are still receiving the traditional method of instruction (Armington, 2003; Kinney & Kinney, 2003; Miles, 2000).

Traditional methods of mathematics instruction present some disadvantages due to teachers’ focus on content and standards more than on students’ needs (Brown, 2003). According
to Mahmood (2006), direct instruction is comparable to the teacher being the “sage on the stage, but not guide on the side” (p.25). Brothen and Wambach (2000) found no major significance in learning mathematics when lecturing alone is chosen as a mode of delivering math instruction in developmental classrooms. This was causing high dropout rates at Southwest Texas State University, where it reached almost 50% in Introductory Algebra (Armington, 2003).

In most colleges and universities, in order to enhance learning, the traditional instruction of developmental mathematics has been supplemented with some technological tools such as whiteboard, chalkboard, overhead projectors, PowerPoint, or graphing calculators (Armington, 2003). Other pedagogies, such as peer collaboration, tutoring, and math computer labs (Kinney, 2001), together with group learning activities (Wright, Wright, & Lamb, 2002) have found their way into math classrooms that previously relied solely on traditional modes of instruction.

All of these pedagogies and instructional tools help students construct their own learning, increase their confidence in solving math problems, and decrease their math phobia, which results in higher math performance (Hall and Pontoon, 2005). Despite the variety of these pedagogical tools, a qualitative study by Kinney (2001), which used student surveys, focus groups, and questionnaires, claimed that students were still attached to the traditional “way” of teaching as it provides them with more human interaction and opportunities to ask questions and receive frequent teacher feedback.

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, 2001; Perez, 1998; Roueche & Kirk, 1974), computer labs (Kinney, 2001; Miles, 2000), group learning activities (Felder and Brent, 1996; Wright, Wright, & Lamb, 2002),
class discussions, peer study groups and Supplemental Instruction (Perez, 1998). 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, 2003; Felder & Brent, 1996). 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, 1998). 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, & 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, 1998; Hall & Pontoon, 2005; Higbee & Thomas, 1999; Roueche & Kirk, 1974).

**Computer-assisted Instruction**

A common mode of math instruction in developmental classes is the hybrid mode, also known as computer-assisted mode of instruction, in which traditional face-to-face instruction is supplemented by online instruction. This computer-enriched pedagogy, which includes both teacher-centered and student-centered instruction, provides online tutorial and practice material, together with assessment tests and multimedia materials (Kinney & Robertson, 2003). It is designed to only supplement face-to-face instruction. Today, many textbook publishers compete
in providing the best computer software to supplement their math textbooks, especially in developmental mathematics (Kinney & Robertson, 2003). This provides instructors with an opportunity to assign online homework, quizzes or exams, in addition to supplementing a variety of text and media tutorials to re-emphasize the covered material during the face-to-face instruction (Olusi, 2008).

The previously cited qualitative study by Mahmood (2006) on the efficacy of online interactive tutorials and guided practice in students’ learning of math concepts revealed that students become more engaged and more participatory in the learning process. A study by Hannfin and Foshay (2008) that surveyed 236 student-users of math web instructional material found that providing individualized study guides and regulated review plans were the features that students found most appealing. This again increases students’ participation and gives them a reason to compete for a better score. The frequency of testing and feedback are among the significant pedagogies of computer-assisted instruction of mathematics, as confirmed by the National Association of Developmental Education (Boylan, 2002). The media tools available online enable students to better visualize math contents and experience their various applications, including manipulation of different parameters that contribute to the solution (Mahmood, 2006).

From these studies, one can conclude that there is strong evidence that computer-assisted traditional math instruction exposes students to combined modes of instruction, both face-to-face and online, and offers a variety of tools and features to promote students’ understanding of math topics. In addition, computer-assisted instruction helps students correct their misconceptions and increases their motivation and contribution to the learning process.

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, & White, 1999; Felder & Brent, 1996; Higbee & Thomas, 1999; Kinney & Robertson, 2003; Miles, 2000; Perez, 1998; Roueche & 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 & 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 Pew Internet and American Life Project (2002), 20%
of today’s college students began using the computer between 5 and 8 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 that provides 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, and 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 10% 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 & 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 & 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.

**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 & 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 & Kulik, 1991; Olusi, 2008).

Interactive tutorials include guided practice problems, which encourage students to be actively engaged with the learning process (Mahmood, 2006; Merisotis & Phipps, 2000). Software can provide a student with an individualized study plan based on his scores on homework and quizzes (Cotton, 2001; Hannafin & 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, 2001; Hannafin & Foshay, 2008; Merisotis & Phipps, 2000). 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 & Klicka, 1998).
Computers as instructors have several advantages over human instructors. The computer has infinite patience but a human does not (Cotton, 1991; Kulik & Kulik, 1991; Mahmood, 2006). The student can revisit the same topic numerous times until he has mastered the concept and developed confidence (Brothen & Wambach, 2000). 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, 1991; Mahmood, 2006). 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, 1991). 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 & Wambach, 2006). 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 (1979), developmental mathematics students need to see the instructor work problems. Instructors are able to observe 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.

*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, & Kulik, 1985; Kulik & Kulik, 1986; Kulik, Kulik, & 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 & 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 & 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 large (0.552); the mean effect size for math was small to moderate (0.291), and the mean effect size for college was large (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, & 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 & 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.

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.

A recent study of low-achieving high school students found positive effects for computer-assisted instruction. Computer-based instruction (CBI) was associated with improved passing rates on a state competency exam (Hannafin & Foshay, 2008).

A Massachusetts high school designed a remediation strategy that assigned 10th grade students at risk for failing the exam to a computer-based math course (Hannafin & Foshay, 2008) (add citation).
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 10th 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 underachieving 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 & 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 & 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) among student using Blackboard 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 & 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 & 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, although students in lecture classes were significantly more likely to withdraw than students in computer-mediated classes.

In a 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 (Teal, 2008). 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. This placement test was developed by the College Board, and is used at 62 percent of community colleges (College Board, 2003). 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 (2004) comparing student learning in traditional classrooms and computer-assisted classrooms in Beginning and Intermediate Algebra at a rural community college in Texas). 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. 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 solely 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 3 hours of classroom instruction and 3 hours of laboratory per week. The percentage of students passing the courses increased an average of 12% within 2 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 (2005) published descriptive data from an assortment of two-year and four-year colleges indicating an increase in success rates (A, B, C grades), 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. 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; as compared to lecture only (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. All of the above studies were independent of the for-profit corporations that conducted them.

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 & Wambach, 2000; Brown, 2003; Kinney & 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 & Brent, 1996; Grasha, 1994).

**Gender Difference in Math 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, & 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, & 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, & Williams, 2008). Effect sizes for gender differences were consistently small at 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 2005 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 & Wendler, 1991) and in a four-year business college (Odell & Schumacher, 1998). Ding, Song & 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 & Wendler), and higher high school class rank (Odell & Schumacher, 1998).

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 (2005) study concluded that males and females have equal access to computers. 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. Of students who took the AP computer science exam in 2002, 86% were male. 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 & 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.

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, & 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 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 & 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**

The above studies reveal that traditional modes of instruction are less effective than a combined (hybrid) approach. The latter approach is more balanced and exposes students to a combination of both methods. This is especially essential to developmental math classes, where students often lack motivation, maturity and time management skills.

Substantial professional developmental programs need to be designed around teaching, training and the sharing of experiences throughout blended instruction. Objectives should aim at effectively matching the needs of students, instructors, and the course curriculum in a blended format of instruction (Barabash, 2003). Further research on e-learning and internet use in developmental math classes is also warranted, as software and hardware tools are evolving exponentially, which affects the conceptualization and implementation of effective technologies and pedagogies that enhance students’ learning and instructors’ delivery of math content.

As reported, there are several critical factors that are significant to the success of blended format instruction (National Center for Academic Transformation, 2005). These factors include student motivation, self-efficacy, self-discipline, self-direction, and time management. Nevertheless, when used properly, computers can create an environment of effective interaction, active participation, constructive feedback, and significant learning outcomes (Roschelle, Pea, Hoadley, Gordin, & Means, 2000).
Furthermore, colleges and universities need to establish assessment and screening tools that determine the appropriate mode of instruction and environment to best meet students’ needs. Educators must implement effective learning strategies that are aligned with academic objectives and are conductive to meaningful learning.

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. 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, 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 two modes of instruction at a large, four-year university.
Chapter Three: Methodology and Procedures

Overview of the Study

The use of technology integrated math education has been recently growing at a steady rate. While there is a considerable amount of research emphasizing the effectiveness and impact of CAI (such as MyMathLab) on students learning of mathematics, at different K-12 grade levels, and within a variety of subjects, there is still a gap in conclusive research that focuses on math developmental classes. Other studies emphasize the advantage of adding other pedagogies to the computer-assisted instruction, such as constructivist activities, group activities and personal interaction of developmental students with their instructor.

This study aims at investigating the value of computer-assisted instruction using MyMathLab, as a possible new alternative for delivering math instruction, and comparing this strategy to the traditional mode of instruction. In addition, the study examines the moderating effect of gender differences on math achievement in Developmental mathematics classes at a Midwestern university.

Research Design and Sampling

This is a quasi-experimental study that uses a non-randomized pretest-posttest design. Students will self-register to class, with no disruption of their schedules. The target population consists of several developmental math classes selected from a Midwestern university, which will provide the sampling convenience. One of each paired classes received traditional instruction (control group), and the other received traditional instruction supplemented with the MyMathLab computer learning system (treatment group). Both groups were subjected to a pre-test and a post-test. The pre-test was a math placement test students generally take to be placed in a certain math course level, while the post-test (also consisting of math placement test) was given
as a review test to the course’s final exam. Instruction of both groups was coordinated with the
content of the textbook. In this study, samples might not represent the real college population,
but generalizability was attempted through sampling different courses and their sections, yet
presenting similar characteristics of developmental classes.

The independent variable of this study is the mode of instruction, with the entrance math
placement test as the pre-test. The dependent variable is the student’s math performance, as
measured by the math department placement test scores at both pretest and posttest, in all
courses. Before the beginning of fall term 2014, both control and experimental groups took a
pretest as an academic requirement to register to any developmental mathematics course. A week
after the start of the course, all students completed an online questionnaire, the purpose of which
was to gather descriptive data to establish similarities of both groups. Students were placed in
developmental mathematics class based on their math placement test scores (pretest). Therefore,
all students were expected to have mathematics achievement within the same range of scores.
Since students self-registered for the classes, they couldn’t be placed by the college into a section
with a particular mode of instruction. However, students were having access to information
about which sections will use computer-assisted instruction and which will use traditional
instruction from their developmental mathematics instructors, their advisors, the developmental
math website, and the tutoring center. The instruction was delivered for 16 weeks, and during the
last week, all students took a version of the placement test prepared and reviewed by the math
department faculty. Data will be compiled regarding instructional method, and pretest and
posttest scores. The questionnaire results will be gathered to serve as information on students’
demographics.
An analysis of variance was conducted using both T-test and ANOVA. The independent variable (IV) was the method of instruction, and the dependent variable (DV) was the math performance measured by the math placement test (at both the pretest and posttest). This analysis was intended to check the first null hypothesis that states: There is no significant difference in the mathematics performance of students in a developmental mathematics course using traditional instruction and computer assisted instruction (traditional instruction supplemented by MyMathLab learning system).

The second null hypothesis stated that there is no significant difference in the mathematical performance of developmental mathematics students by gender. A second analysis of variance using both T-test and ANOVA was conducted with gender as the independent variable and the posttest as the dependent variable. The interaction of method and gender was also be analyzed. Both groups were taught by full-time instructors who have demonstrated competence in teaching developmental mathematics students and in teaching in both delivery formats (face-to-face and hybrid).

This study has been granted approval by the Institutional Review Board (IRB). Students did know they were participating in a research study, and therefore their participation might have deliberately or subtly influenced the outcome of the study.

**Questionnaire**

The responses to the questionnaire were expected to reveal some similarities, consistent with national studies, which report that 56% of undergraduate students in 2000 were female (NCES, 2005), and 55% of community college remedial students were female (Saxon and Boylan, 1999).

The responses to the questionnaire revealed some noticeable similarities between students
in the traditional and traditional with computer assisted instruction classes. Students of both groups were more likely to have the same age, to be white, to have few years since their last math course, and to have positive attitudes toward math and computers. Three-hundred-seventy-one students had taken their last math class one or two years ago.

Overall most students had been in college two to four quarters. All of the students were full-time students, taking at least 12 credit hours.

Thirty-five percent of the traditional students, and 28% of the traditional + CAI students, reported having a negative or very negative attitude toward math. Nearly all students (352 of the 371) used computers for both academic purposes and other reasons, such as email, social networking, and shopping. Seventy-one percent of the traditional students, and 59% of the traditional + CAI 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 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). While, 95% of the students were of traditional college age (less than or equal to 23). Overall, 74% of the students were white, 14% were African American, 4% were Hispanic, and 8% were other ethnicities.

Instrumentation

The construct of mathematics achievement was operationally defined as scores on the developmental mathematics placement test (see Appendix E), at both the pretest and the posttest. This is the departmental placement test given to all students in developmental mathematics. Validity of this test is the extent to which it measures mathematics achievement. The test is a
collection of test exam items created by the developmental mathematics faculty and matched with the developmental mathematics course objectives in proportion to the emphasis given to each topic during the semester. This provides face validity. The test questions are reviewed and critiqued by a team of Department of Mathematics faculty members. This provides content validity. Reliability of the placement test is the extent to which scores are free of random error, that is, the extent to which the exam yields consistent results. Ideally, the reliability coefficient should be close to one. Cronbach’s Alpha, or coefficient alpha, for the final exam is 0.915 as calculated using SPSS, based on scores from a sample of 100 exams from eight instructors from previous semesters. 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 (see Appendix E) consists of 30 questions from the placement test, representing major course objectives of developmental mathematics. The placement test as the pretest was taken by all students as an academic requirement to test into the course. The test usually requires 2 hours to be completed. The placement test as the posttest consisted of 30 questions again and was given few days before the final exam, as part of the course requirements, within a 120-minute exam period. The pretest serves to inform the students that they did indeed need to take the course and gives them a preview of topics that are usually studied in developmental mathematics. Cronbach’s alpha for the pretest was also 0.915.

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 were controlled where possible. An analysis of variance was conducted on the pretest and posttest scores, and the questionnaire data established the similarity of the groups before treatment.

Attitudes of the subjects toward mathematics or technology may affect the outcome of an experiment (Ary et al. 2002). In this study the effect of attitudes was controlled by not telling the subjects they will be participating in a study. Many developmental mathematics students, whether they participated in the study or not, completed a questionnaire (see Appendix A), and all have taken the mandatory pretest and posttest. Extraneous variables were controlled where possible.

All groups had the same course objectives, same schedule, same tests, and the same 16 weeks of instruction. Each instructor was teaching in both modes of instruction. Attrition might have been a threat as more students with low scores withdrew from one group than the others.

**Reliability and Validity**

This research design has provided partial control of threats to internal validity. It also provided the 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 has assisted 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 college of a Midwestern university that offer residential, hybrid, and distance learning courses. The results would likely generalize to community colleges because the academic
preparation of the students at this college is as diverse as a community college. Community colleges value 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.

**Data Collection**

Pretest and posttest scores for each participant were collected. SPSS software was used to run descriptive statistics on the data. The sample size, mean, and standard deviation were tabulated by method of instruction and gender (see Table 1, Appendix D). Before conducting the analysis of variance, data were first screened for missing data and outliers. Scores were omitted for students who did not complete either the pretest or posttest and for any other outliers.

An analysis of variance (ANOVA) was conducted to determine if there are significant differences in mathematical performance between the two methods of instruction. ANOVA 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). ANOVA increases the sensitivity of the F test by removing the unwanted variance associated with the error term, thereby producing a larger F-statistic. The subjects’ math performance before the study should be related to their math performance after the study. The math performance was measured using scores of math placement test on both the pretest and the posttest. ANOVA 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, 2005).
Chapter Four: Data Analysis

Narrative of Findings

Appendix A, Table 1 shows the distribution of the 371 participants as per method of instruction and gender. A total of 371 students took the pretest: 187 from the traditional (control) and 184 from the integrated traditional/MML (intervention); the same number of students took the posttest. Of this group, 146 were male and 255 were female. Therefore, 79 male and 108 female students were enrolled in the control group, and 83 male versus 101 female students were enrolled in the intervention group (Appendix A, Table 1). Of the total 172 participants, 162 (44%) were male and 209 (56%) were female, with an almost even split between traditional instruction and traditional instruction supplemented with MyMathLab learning system.

Assumption Checks

As both t-test and ANOVA were implemented in this study, with two independent variables (mode of instruction and gender) at two levels each (traditional versus hybrid instruction and male versus female), several assumptions must be met. The first assumption involves the instrumentation scale of measurement: data collected for the dependent variable should be continuous or ordinal. The instrument used for reporting test scores in this study meets this assumption.

The second assumption, random sampling, was impossible to satisfy given that students self-registered to classes; however, paired sections were compared to determine similarity of demographics and pretest scores. The third assumption pertains to testing for normality using skewness and kurtosis values (D’Agostino. et. al., 1990). This test was conducted on the dependent variable posttest (MPTPOST), for both subgroups (traditional versus hybrid and male versus female). Both Kolmogorov-Smirnov and Shapiro-Wilk tests (Appendix A, Tables 2&3)
infer a normal distribution for the dependent variable MPTPOST in each method of instruction (p < .05). This is confirmed by the Q-Q Plots (Appendix B, Figures 1-4), where the value for each score is plotted against the expected value from the normal distribution. The reasonably straight line for both male and female plots suggests a normal distribution for the MPTPOST dependent variable. Similar results are shown when examining gender, thus indicating a normal distribution.

The fourth assumption is that of adequate sample size. Each group (traditional versus hybrid, and male versus female) has more than 30 cases and is therefore sufficient for the analysis.

**Hypothesis I**

Hypothesis 1 asks whether there is a significant difference in the performance of students in developmental math classes based on type of instruction. To begin the analysis, an independent groups t-test was conducted to determine whether there was a significant difference between the pretest means of the control group versus the intervention group. Results indicated no significant difference between groups (p = .003) (Appendix A, Table 4). The mean pretest score for students registered for traditional instruction was 69.87 (SD 29.23). The mean pretest score for traditional+MML students was 72.31 (SD 29.94). The total mean score was 71. (SD 29.67). Because there was no significant difference in mean pretest scores between the control and intervention groups, analysis of the difference in pretest and posttest scores between both groups could proceed without the need to adjust for pretest values. Results (Appendix A, Table 5) also indicate that the mean posttest score for the control group was 96.02 (SD 30.13), while the mean posttest score the intervention group was 126.72 (SD 28.08). The total mean score was 112.66 (SD 29.56). Unlike the difference between group means on the pretest, these results show...
a significant difference between group means (p = .001), with the intervention group gaining 54.41 points on the posttest versus a gain of 26.15 points for the control group.

An independent groups t-test was conducted to compare the mean difference in pretest and posttest scores between the control and intervention groups. Results revealed a significant difference between groups (p = .001), with the intervention group scoring significantly higher. Based on the above results, Null Hypothesis 1 was rejected.

**Hypothesis II**

Hypothesis II examines the question of whether there is a significant difference in achievement between males and females in developmental math classes.

Of 371 students who completed the pretest and posttest, 162 were males and 209 females. As indicated in Appendix A, Table 6, the mean posttest score for males was 65.33 (SD 21.72), while the mean posttest score for females was 68.86 (SD 21.19). For all 371 participants, the mean posttest score was 66.26 (SD 21.41). An independent group t-test was conducted to determine whether there was a significant difference between the mean posttest scores of males and females. According to Appendix A, Table 7, results indicated that females scored significantly higher than males (p = .028) on the posttest. Therefore, null hypothesis 2 was rejected.

Of further interest was whether the type of instruction was of particular benefit to one gender or the other. For this reason, the interaction between mode of instruction and gender was examined through an analysis of variance, as summarized in (Appendix A, Table 8). Results indicated that, first, there was a significant main effect of mode of instruction on posttest performance, F (1, 368) = 30.78, p = .002. Second, there was also a significant main effect of gender on posttest performance, F (1, 368) = 7.67, p = .041. However, there was no significant
interaction between the mode of instruction and gender on the posttest performance, F(2, 368) = 52.01, p = .166. This can be explained by the slight difference in mean values between both genders, which renders the interaction effect to be non-significant. This actually means that the effect of mode of instruction on math performance scores was not different for male participants versus females.

**Study Results**

The major finding of this study was the superiority of instruction that integrated MyMathLab over traditional instruction in college developmental math classes. Students in the integrated sections scored 30.7 points higher on the posttest than students in the traditional sections, although both groups had comparable pretests scores. This is not only a significant difference, but one with practical implications. The posttest scores of the sections that integrated MyMathLab indicate that the students are now prepared to enter regular college math courses, while the students who participated in the traditional sections continue to need more developmental math courses. Based on the results of this study, colleges should move to incorporate MyMathLab into their developmental math courses.

A secondary finding that is of interest to instructors of developmental math courses is the performance of females in this study. Regardless of method of instruction, females scored higher than males at posttest. These results indicate the females have bridged the gender gap in terms of performance in mathematics, at least at this level.
Chapter Five: Discussion and Conclusion

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 two different modes of instruction in developmental mathematics: traditional and hybrid (integrating MML). The study was conducted in introductory and intermediate algebra classes at a large, Midwestern university. Based on this study, students within hybrid mode of instruction (traditional instruction supplemented with MML) outperformed their counterparts, receiving traditional mode of instruction in developmental mathematics. In addition, females outperformed males in both instructional modes.

Discussion of Findings

The major finding of this study was the superiority of instruction that integrated MyMathLab over traditional instruction in college developmental math classes. Students in the integrated sections scored 30.7 points higher on the posttest than students in the traditional sections, although both groups had comparable pretests scores. This is not only a significant difference, but one with practical implications. The posttest scores of the sections that integrated MyMathLab indicate that the students are now prepared to enter regular college math courses, while the students who participated in the traditional sections continue to need more developmental math courses. Based on the results of this study, colleges should move to incorporate MyMathLab into their developmental math courses.
A secondary finding that is of interest to instructors of developmental math courses is the performance of females in this study. Regardless of method of instruction, females scored higher than males at posttest. These results indicate the females have bridged the gender gap in terms of performance in mathematics, at least at this level.

**Limitations of the Study**

The results of this study are limited by several factors. This study was conducted at a large university, using introductory and intermediate Algebra courses delivered through two modes of instruction: traditional classroom instruction and traditional instruction supplemented with computer-assisted instruction. The results may not generalize to another foundational developmental mathematics course, such as pre-algebra, beginning algebra or college 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 online course. Of the 13 full-time instructors at the university, only 7 were teaching the course sections used in this study because they were the only ones teaching in both modes of instruction being investigated. The number of students in this study was limited to those enrolled in both introductory and intermediate algebra for the autumn and spring 2014 semesters in the sections taught by the seven instructors. The computer software was limited to the system that the developmental math program had already adopted, MyMathLab.

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 obviously, the same math placement test. The same seven instructors taught one class each of traditional instruction and traditional supplemented with MyMathLab. Both were full-time instructors with doctorate degrees in mathematics and master’s degrees in both math sciences and education, with
extensive experience in 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 a variety of resources MYMathLab offers, such as tutorials, study plans and video mini-lecture. This study accounts only for differences in student mathematics performance as measured by the difference in math placement test (at the pretest and posttest), 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 of the Study

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 better from a lecture supplemented with computer-assisted instruction, rather than from a lecture alone.

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.

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).

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 & 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 often lack study skills, organizational skills, and motivation (Armington, 2003); courses with an online component should include lessons and discussion boards on learning strategies (Kinney & Robertson, 2003; Trenholm, 2006; Wadsworth, Husman, Duggan, & 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 & Harding, 2005; Jacobson, 2006; Smith & 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 also 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.

**Recommendations for Future 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. No paragraph break
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 either traditional instruction or traditional instruction supplemented with computer-assisted 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 a hybrid 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.
Conclusion

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 better with computer-assisted instruction (such as MyMathLab learning system) than with traditional mode of instruction. The mere presence of computers does not improve student learning, unless used carefully. Students have an interest in using technology for a variety of purposes including academics. Computers still 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. Furthermore, female students may learn more than males in a developmental mathematics course integrating and emphasizing technology use.
References


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(Eds.), Beyond constructivism: Models and modeling perspectives on mathematics problem solving, learning, and teaching (pp. 501-518). Mahwah, NJ: Lawrence Erlbaum Associates.


Pólya, G. (1957). *How to solve it; a new aspect of mathematical method.* Garden City, NY:
Doubleday.


Appendix A.  Tables

Table 1.

**Distribution of Sample by Method of Instruction and Gender**

<table>
<thead>
<tr>
<th>Method</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>79</td>
<td>108</td>
<td>187</td>
</tr>
<tr>
<td>Traditional + MML</td>
<td>83</td>
<td>101</td>
<td>184</td>
</tr>
<tr>
<td>Total</td>
<td>162</td>
<td>209</td>
<td>371</td>
</tr>
</tbody>
</table>

Table 2.

**Kolmogorov-Smirnov and Shapiro-Wilk Tests of Normality of Posttest by Mode of Instruction**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Kolmogorov-Smirnov</th>
<th>Shapiro-Wilk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Statistic</td>
<td>df</td>
</tr>
<tr>
<td>Traditional</td>
<td>.078</td>
<td>187</td>
</tr>
<tr>
<td>Traditional + MML</td>
<td>.068</td>
<td>184</td>
</tr>
</tbody>
</table>
### Table 3.

**Kolmogorov-Smirnov and Shapiro-Wilk Tests of Normality of Posttest by Gender**

<table>
<thead>
<tr>
<th>Gender</th>
<th>Kolmogorov-Smirnov</th>
<th>Shapiro-Wilk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Statistic</td>
<td>df</td>
</tr>
<tr>
<td>Male</td>
<td>.064</td>
<td>146</td>
</tr>
<tr>
<td>Female</td>
<td>.059</td>
<td>225</td>
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</table>

### Table 4.

**Independent Samples T-test Results of the Post-test by Mode of Instruction**

<table>
<thead>
<tr>
<th>Mode of Instruction</th>
<th>Levene’s Test</th>
<th>T-test for Equality of Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>Sig.</td>
</tr>
<tr>
<td>Equal Var. Assumed</td>
<td>53.98</td>
<td>.003</td>
</tr>
<tr>
<td>Equal Var. Not Assumed</td>
<td>-5.54</td>
<td>.001</td>
</tr>
</tbody>
</table>
**Table 5.**

*Descriptive Statistics by Method of Instruction*

<table>
<thead>
<tr>
<th>Method</th>
<th>$N$</th>
<th>Pretest Mean</th>
<th>Pretest SD</th>
<th>Posttest Mean</th>
<th>Posttest SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>187</td>
<td>69.87</td>
<td>29.23</td>
<td>96.02</td>
<td>30.13</td>
</tr>
<tr>
<td>Traditional + MML</td>
<td>184</td>
<td>72.31</td>
<td>29.94</td>
<td>126.72</td>
<td>28.08</td>
</tr>
<tr>
<td>Total</td>
<td>371</td>
<td>71.35</td>
<td>29.67</td>
<td>112.66</td>
<td>29.56</td>
</tr>
</tbody>
</table>

**Table 6.**

*Descriptive Statistics by Gender*

<table>
<thead>
<tr>
<th>Gender</th>
<th>$N$</th>
<th>Pretest Mean</th>
<th>Pretest SD</th>
<th>Posttest Mean</th>
<th>Posttest SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>162</td>
<td>56.71</td>
<td>23.51</td>
<td>65.33</td>
<td>21.72</td>
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<tr>
<td>Female</td>
<td>209</td>
<td>58.25</td>
<td>24.56</td>
<td>68.86</td>
<td>21.19</td>
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<tr>
<td>Total</td>
<td>371</td>
<td>57.64</td>
<td>24.13</td>
<td>66.26</td>
<td>21.41</td>
</tr>
</tbody>
</table>
### Table 7.

**Independent Samples T-test Results of the Post-test by Gender**

<table>
<thead>
<tr>
<th>Gender</th>
<th>Levene’s Test</th>
<th>T-test for Equality of Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>For Equality of Variances</td>
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</tr>
<tr>
<td>Equal Var. Assumed</td>
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<td>.041</td>
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<tr>
<td></td>
<td>-1.111</td>
<td>369</td>
</tr>
<tr>
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</tr>
<tr>
<td></td>
<td>-2.5266</td>
<td>2.2748</td>
</tr>
<tr>
<td>Equal Var. Not Assumed</td>
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<tr>
<td></td>
<td>.028</td>
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</tr>
</tbody>
</table>

### Table 8.

**Interaction Between Mode of Instruction (Section) and Gender (Sex)**

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III SS.</th>
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<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
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<td>7182.70</td>
<td>17.02</td>
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<tr>
<td>Intercept</td>
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<td>1</td>
<td>207129.58</td>
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<td>Section</td>
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<td>12987.69</td>
<td>30.78</td>
<td>.002</td>
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<tr>
<td>Section * Sex</td>
<td>346.19</td>
<td>2</td>
<td>346.19</td>
<td>52.01</td>
<td>.166</td>
</tr>
<tr>
<td>Error</td>
<td>155271.13</td>
<td>368</td>
<td>421.93</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1779251.00</td>
<td>371</td>
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<td>Corrected Total</td>
<td>169636.53</td>
<td>370</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Appendix B. Figures

Figure 1.

Q-Q Plot of Normality of Posttest by Mode of Instruction (Control Group)
Figure 2.

Q-Q Plot of Normality of Posttest by Mode of Instruction (Intervention Group)
Figure 3.

Q-Q Plot of Normality of Posttest by Gender (Males)
Figure 4.

*Q-Q Plot of Normality of Posttest by Gender (Females)*

Normal Q-Q Plot of MPTPOST

for SEX = 2.0

Observed Value

Expected Normal