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Community College Student Achievement in Web Based Software-Enhanced Developmental Mathematics Courses

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Community College Student Achievement in Web Based Software-Enhanced
Developmental Mathematics Courses.

Community College Student Achievement in Web Based Software-Enhanced
Developmental Mathematics Courses.

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Education in Higher Education

by

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Abstract

The purpose of this causal-comparative study was to compare the performance of students receiving web based software-enhanced instruction with the performance of students receiving lecture only instruction in terms of retention rates, success rates, test grades, and final exam scores for developmental mathematics courses at Ozarks Technical Community College. The researcher randomly selected 250 participants from the population of students experiencing software-enhanced instruction during the 2012-2013 academic year and 250 participants from the population of students experiencing lecture only instruction during the 2010-2011 academic year. Several demographic variables were compared to control for intervening variables. The sample data was tested against population records to address validity concerns. The researcher formed four conclusions: (a) course retention rates were not impacted after redesigning the developmental math courses; (b) success rates increased after the implementation of software-enhanced instruction; however, the improved rate may not have been fully attributed to the redesign; (c) the effects on unit exam scores were mixed with lower scores on the first test and higher scores on the second and third exams; (d) software-enhanced instruction did not significantly improve final exam scores.

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CHAPTER ONE

Introduction

In the twentieth century, discoveries through scientific inquiry, engineering applications, and technological advancement drove the world's economy. Reflecting on life in the early 1900s causes appreciation for the work saving conveniences that are now everyday experiences. We wonder what life will be like in 100 years. Along with contemplating the future, we question the preparedness of our nation's youth. Will they be able to lead in future innovation and discovery? If American students are not keeping pace in math and science, will we be able to participate in research and discovery of science, technology, engineering and mathematics (STEM) fields at the global level? National studies have explored this issue for many years and the findings continue to be troubling.

One of the first national studies was *A Nation at Risk*. In 1983, *A Nation at Risk* began the discussion about the United States' leadership in STEM fields through its critical evaluation of elementary and secondary schools. Several major problems were summarized into three concerning trends. The rise in remedial education at the collegiate level was one of these trends and is still a major problem thirty years later.

In 2014, the National Conference of State Legislatures estimated that 28% to 40% of all first time undergraduates enrolled in at least one developmental course (NCSL, 2014). Nearly 75% of entering community college freshmen were underprepared for college level coursework. Over 3 million students enroll in developmental courses in our nation's community colleges each year (Noel-Levits, 2008). With such a large number of students lacking the skills and knowledge necessary to complete college level coursework, addressing the needs of these underprepared students may be one of the biggest challenges of community colleges.

The problem is compounded with low retention and pass rates of students enrolled in remediation courses. Consequently, these courses become a roadblock to completing a college degree or technical certificate. As evidence of this, Gerlaugh, Thompson, Boylan, and Davis (2007) conducted a national study on student success in developmental mathematics. Using a passing rate of “C or better,” they found that only 58% of students were completing their remedial math classes. Even though low, the results from this study reflected higher rates than what were experienced at Ozarks Technical Community College (OTC).

Statement of the Problem

In 2010, the developmental mathematics program at OTC consisted of two courses, pre-algebra and basic algebra. These classes had a combined “C or better” rate of 53% during the 2010-2011 academic year. However, this percentage did not accurately reflect the pass rate of their students. At OTC, students were required to score a “B or better” in their developmental mathematics courses before enrolling in the subsequent math class. Consequently, only 39% of students passed their developmental mathematics that year.

To address these low success rates, the OTC mathematics department decided to supplement traditional lecture-based instruction with computer-aided instruction in their developmental math courses. Several methods of computer integration into math classrooms were researched. The department adopted a software-enhanced model of instruction that utilized 50% of the class time for computer teaching and 50% of the time for traditional lectures and assessments. Assessment and Learning in Knowledge Spaces (ALEKS) software was selected for the software-enhanced component because of its ability to integrate with the textbook used at the time, and its accessibility to students through the internet.

The math faculty conducted a limited pilot program using the ALEKS software in the fall 2010 semester and found many positive outcomes for both students and faculty members. Students appreciated the immediate feedback provided by the ALEKS program and showed improved attitudes toward math. The faculty members were able to offer individualized instruction on relevant objectives because the software directed students to the topics that needed extra practice. Because of the successful pilot, the department began using the software in all pre-algebra and basic algebra courses in the fall 2011 academic semester.

This study explored the impact of web-based software on student performance in developmental mathematics courses at OTC by comparing the retention rates, success rates, test grades, and final exam scores of students enrolled in web based software-enhanced developmental courses with students enrolled in lecture-based instruction courses.

Significance of the Study

This study is important for a number of reasons. Four of those reasons are discussed below.

First, one of the college's strategic initiatives was to "improve the success and progression of developmental education students through attainment of their educational goals" by the year 2020. Many areas of the college were focused on how they could help improve the disappointingly low performance of developmental students at the time of this study. OTC administrators aligned financial resources and space allocations to achieve this strategic initiative by creating a centralized area to offer the developmental mathematics courses. Several computer labs were built and traditional classrooms were converted to computer labs. OTC mathematics faculty members adapted the curriculum, course schedules, content objectives and final exams to

a computer-enhanced concept of teaching the course. The results of this study helped both groups assess the effectiveness of their efforts.

Second, this study added to the body of work that explores the impact of adaptive software in developmental mathematics classrooms. The software used to teach mathematics continues to evolve. In the last decade, there has been a tremendous increase in its quality. Current programs, such as ALEKS, are able to tailor the instruction to the students' understanding of concepts using assessments imbedded into modules.

Third, this study compared the student performance on unit exams in the course. By comparing unit test results and final exam problems, this study attempted to discover which algebra topics students comprehend better when presented in a web-based software-enhanced classroom as opposed to a lecture only environment.

Finally, in a small way, this study contributed to the body of knowledge about redesigned remedial mathematics courses. Other colleges and universities can use these results as they develop alternative ways of instruction to improve student success in their remediation programs.

Purpose of the Study

The purpose of this study was to compare the performance of students receiving web based software-enhanced instruction with the performance of students receiving lecture only instruction for developmental mathematics courses at Ozarks Technical Community College in Springfield, MO. Retention rates, success rates, unit test grades, and final exam scores were used to measure performance in these courses.

Alternative Hypotheses

The researcher made the following four hypotheses to compare the performance of students in these two methods of instruction.

1. Developmental mathematics courses utilizing web based software-enhanced instruction at OTC will have higher course retention rates than courses using lecture-based methods of instruction at OTC.
2. Developmental mathematics courses utilizing web based software-enhanced instruction at OTC will have higher success rates than courses using lecture-based methods of instruction at OTC.
3. Students in web based software-enhanced developmental mathematics at OTC will have higher unit test grades than students in lecture-based developmental mathematics courses at OTC.
4. Students in web based software-enhanced developmental mathematics at OTC will have higher final exam scores than students in lecture-based developmental mathematics courses at OTC.

Definition of Terms

To clarify key terms in this study, the following definitions are provided.

1. *Developmental mathematics courses.* These are mathematics courses designed to remediate students for further study in college level mathematics (Armington, 2003). The developmental mathematics program at Ozarks Technical Community College consists of two courses, pre-algebra (MTH 040) and basic algebra (MTH 050) courses.
2. *Adaptive web based software.* In this study, the term refers to software accessed by the internet that provides tutorial instruction to students through text-based and video explanations. The software tracks individualized mastery of skills and concepts by

learning objective. In 2011, Ozarks Technical Community College selected the Assessment and Learning in Knowledge Spaces (ALEKS) software.

3. *Software-enhanced courses.* These are courses that allocate 50% of the instructional time for web-based computer instruction and use the remaining 50% of instructional time for traditional instruction and assessment of course objectives.
4. *Retention rate.* This is a percentage measure of the rate at which students persist through the semester. In this study, the percentage was calculated by dividing the number of students who received a grade at the end of the semester by the number of students enrolled on the census date at the beginning of the semester. OTC's census date is on the Friday of the fourth week of the semester. The complement of this percentage describes the withdrawal rate of students in developmental math courses at OTC.
5. *Success rate.* This is a percentage measure of the rate at which students successfully completed the course and satisfied the prerequisites of the next math course. At OTC, institutional policy states an A or B grade in developmental mathematics is required for a student to progress to the next mathematics course in their program of study. For this study, this percentage was calculated by dividing the number of students who earned an A or B grade in the course by the number of students who were retained for the duration of the semester. Students who withdrew from the course were not included in this statistic.
6. *Performance.* For this study, student performance was measured through the quantifiable data of retention rates, success rates, unit test grades, and final exam scores.

7. *Common objectives.* This term refers to mathematics objectives that were taught in both the lecture-based courses and the software enhanced courses at OTC during the years under investigation. Appendix A contains the list of common objectives used.

Delimitations of the Study

Two delimitations provided focus to this study. They are discussed in the following section.

First, this study only compared the results of students enrolled in basic algebra courses. OTC had two levels of developmental math at the time of this study. Even though the enhancement model occurred in both pre-algebra and basic algebra classes, confounding variables prevented the researcher from collecting data on the pre-algebra students.

Second, the study was delimited to the 2010 to 2013 academic years. Prior to these semesters, OTC did not have an attendance policy that adversely affected the students' grades or enrollment. In the fall of 2010, OTC began enforcing attendance through administrative withdrawals for students who missed more than 20% of the class meetings. By selecting the sample of students from these years, the researcher was able to control for the effects of the mandatory attendance policy.

Limitations of the Study

Two limitations of the study resulted from the sampling methods used to answer the research hypotheses. These are discussed in the following section.

The random sample came from the population of students who had experienced the traditional method of instruction or the web based software-enhanced method of instruction at Ozarks Technical Community College. As a result, the researcher was unable to generalize the conclusions of this study to a population other than the one studied.

This study focused on student achievement of the common objectives in basic algebra courses at Ozarks Technical Community College. These objectives were limited to the topics taught during both years of investigation at OTC. Since basic algebra content varies from school to school, and is determined by the needs of individual mathematics departments, this limits the generalizability of the results. See appendix A for a list of the common objectives taught at OTC during the years of investigation.

Summary

This chapter began by discussing the importance of research and development in STEM related fields. More importantly, a question was raised about the preparedness of students in the United States to participate in those future discoveries. This is not a new concern and these conversations have continued over 30 years.

Next, the chapter briefly described the current magnitude of the problem. Not only do too many students need remediation, too many are failing. The administration and faculty at OTC recognized the problem at their school and designed a program to supplement the course with computer-enhanced instruction.

The next sections provided focus and structure for this study. The purpose of the study, significance of the study, and the research hypothesis were identified. To avoid confusion, several definitions were provided. Finally, the delimitations and limitations of this study were discussed.

The remaining chapters of this paper provide a deeper description of the current state of developmental math education and an evaluation of the program at OTC. In chapter two, a review of the literature identifies several strategies and best practices that were used at other colleges. Research on these programs are reported along with a discussion of their findings.

Chapter three describes the methodology used in this study and verifies the validity of the sample selection. Chapter four presents the researcher's findings on OTC's program. Finally, chapter five will answer the research hypotheses listed in this chapter and relate these findings to previous studies. The paper concludes with recommendations for improving further study and improving practice and research.

CHAPTER TWO

REVIEW OF THE LITERATURE

Introduction

The purpose of this study was to compare the performance of basic algebra students in classes using a software-enhanced method of instruction to the performance of students in traditional lecture-based classrooms at Ozarks Technical Community College in Springfield, MO. Student retention rates, success rates, unit test grades, and final exam scores were used to measure performance. This review of the literature seeks to provide an analysis and synthesis of relevant research that addressed the problem of underprepared community college mathematics students. To accomplish this, the chapter outlines the steps used to locate relevant research, briefly describes the state of developmental education, identifies a few reasons why so many students place into remediation courses, explains why developmental math education is a roadblock to success, and summarizes successful developmental education redesign efforts.

Steps Used to Locate Relevant Research

To locate relevant literature on developmental students, key words such as *remedial math, basic algebra, remediation, developmental education, community college, higher education, computer and software* were used in various search engines of electronic databases.

As an indication of the amount of information available at the time of this study, a search on the University of Arkansas's ProQuest database with key words *community college and developmental math education* yielded over 2 million articles. When the list was narrowed to scholarly journal articles published since 2005, this search resulted in 37,000 findings. Adding *basic algebra and computer or software* to the search fields narrowed this to just under 300 articles. Abstracts of these articles were scanned for relevance and 97 articles were selected for

further review. The same terms in the university's ProQuest Dissertations and Theses search engine yielded 292 dissertations with 29 of them within the same date restrictions. An evaluation of the dissertation abstracts yielded 14 studies relevant to the current research.

Next, the search terms *developmental math and community college* were used on the scholar.google.com website. Over 19,000 websites, articles, publications, and papers were located for the same date restrictions. The addition of *basic algebra and computer or software* to the search terms lowered the number of results to 16,000. The first 75 hits were scanned for relevance. Overlap existed with the information found through the university database searches. The scholar.google.com website added an additional 39 websites, articles, publications to this evaluation of the existing literature.

The State of Developmental Education

Developmental mathematics is part of a larger developmental education effort. Before focusing on the issues of developmental math, it is important to discuss the larger topic of developmental education programs. With this in mind, this section briefly describes the state of developmental education at the time of this study. Estimates of student enrollment and the financial impact are provided. The section concludes with a description of community college developmental math programs.

Nearly all first time undergraduates take a skills assessment in reading, writing, and mathematics prior to registration. Their score on the placement exam categorizes them as "ready for college-level coursework" or "require remediation." Most entering community college students will discover they "require remediation" in at least one subject and are directed into developmental programs. Developmental math is the common entry point for many students (Bailey, 2009).

Enrollment in Developmental Courses

Several reports show the number of students enrolled in developmental math courses is quite significant. Roueche et al. (2001) observed, “Higher education, especially community colleges, witnessed a steady increase in the number of underprepared students, thus warranting additional increases in remedial services” (p. 10). A 2006 national study on developmental education by Attewell, Lavin, Domina, and Levey found 58% of community college students took at least one developmental course their first year. Similarly, a 2008 Noel-Levits study showed over 3 million students enroll in developmental courses in our nation’s community colleges each year (Noel-Levits, 2008). A 2009 Achieve the Dream survey found 59% of entering community college freshmen took at least one developmental course (Bailey, 2009). The developmental education problem is not isolated to community colleges. In 2014, the National Conference of State Legislatures estimated as high as 40% of all first time undergraduates enrolled in United States higher education needed at least one developmental education course (NCSL, 2014). The large number of students in remediation courses has created a significant expense.

Cost of Developmental Education

Higher education institutions have invested a growing amount of scarce resources in developmental education. A decade ago, it was believed that approximately one billion dollars was spent annually on developmental education (Kolajo, 2004). Four years later, a report by the Bill and Melinda Gates Foundation estimated higher education spent \$2.31- \$2.89 billion on remedial education (Strong American Schools, 2008). In 2014, the cost of developmental programs had climbed to seven billion dollars (Scott-Clayton, Crosta, & Belfield, 2014). This

trend is unsustainable and these programs divert resources from credit-bearing course work (MDHE, 2013). In addition to the institutional resources devoted to developmental education, students pay a hefty price.

Students invest a significant amount of money and time in these programs. The cost of tuition, books, and fees continues to rise. More importantly, students in developmental programs must forgo potential earnings while they maintain their enrollment in college courses. The cost of these courses adds up. The Alliance for Excellence in Education estimated a loss of earning potential to be approximately \$4 billion nationwide for students in these courses (Alliance for Excellence in Education, 2006).

Due to the growing cost of developmental education to the institution, students, and ultimately taxpayers, state legislators and higher education administrators look for ways to curb this enormous expense. The approaches taken by state legislatures to curtail the resources spent on remediation vary. For example, Texas limited funding for the number of credits toward developmental courses. Missouri considered removing developmental courses from its A+ scholarship program. Tennessee and Utah require students to pay for their developmental courses out of pocket (Bettinger & Long, 2005). State legislators made remediation classes in Florida optional and Connecticut banned colleges from requiring non-credit remedial classes (Community College Spotlight, 2014). More than 30 states either eliminated, or proposed eliminating, developmental education from their four year schools (Mazzeo, 2002). It is believed that remedial services are better suited for the community college mission as it has been a long standing “inescapable obligation” of community colleges (Gleazer, 1968, p.58).

Developmental Mathematics Education in Community Colleges

As often structured, many developmental math programs contain a set of sequential courses. While the series differs between colleges, the path to credit-level mathematics begins with pre-algebra for many students. If successful, they progress through the hierarchical classes of basic algebra and intermediate algebra before they are eligible to take a final transfer-level college mathematics course (Stigler, Gavvin, & Thompson, 2010). In extreme cases, some students may have to pass five levels of semester-long remediation courses before they can enroll in the first college level math course (Bailey & Cho, 2010).

The American Association of Community Colleges (AACC) conducted a national survey to learn about community college practices related to developmental education. The AACC reached four conclusions related to developmental mathematics. First, most colleges required students to complete three levels of developmental mathematics courses before reaching college level mathematics. Second, large urban college districts often required more levels of remediation. Third, students who were placed into developmental education often had to complete a minimum of two years of math before completing the mathematics requirements of their degree. Finally, while variations in developmental programs existed, most remediation was done as semester long classes (Schultz, 2001). According to the National Center for Educational Statistics (NCES), 98% of community colleges offer remediation in at least one subject. Nearly all community colleges offer more than one developmental course in mathematics (NCES, 2003; Golfin, Jordan, Hull, & Ruffin, 2005).

Why Students Enroll in Developmental Mathematics Courses.

This section provides several of the common factors that contribute to the large number of students enrolled in developmental mathematics courses. While there are too many reasons to

list them all, trends do emerge in the literature. To organize this section, these factors were divided into three categories as they relate to developmental math. The first section describes situations that happen to students before they arrive in college. The second section describes what happens when students apply to college. The third section describes what happens during the first semesters of college.

Factors that Occur Before Students Start College

For many students, the path to developmental algebra began long before reaching the college campus. These factors may be a result of students' personal decisions or the choices of the people around them. For many students, these events occurred during their K-12 education. While students, faculty, and colleges may not have had the ability to control these factors, students in these situations often find they are underprepared for college. Three of these factors are discussed in this section.

First, the nature and quality of the students' former education strongly contribute to their academic preparedness. For example, many students do not understand basic mathematical concepts because they were taught mathematics as a series of rules to memorize in their previous math courses (Hiebert et al, 2003). In a 1999 video study conducted by The Trends in International Mathematics and Science Study (TIMSS), the researchers found that American K-12 teaching methods primarily reduced math to a prescriptive repetition of procedures. Understanding the mathematical concepts behind those processes was given little emphasis and the connection of mathematical thinking to mathematical skills was not evident. In contrast, the researchers noted that countries with high achieving TIMSS outcomes presented the mathematical procedures in the context of mathematical concepts. The researchers concluded that this approach improved the students' ability to think mathematically and connect ideas. In

contrast, students do not learn to think mathematically when a teacher divorces the concept from the skills practice (Hiebert et al, 2003). Unfortunately, it is assumed that the K-12 practice discussed above is still very common across the United States and students find they are underprepared for college-level math.

Next, there are a number of factors related to the K-12 environment that result in many high school graduates entering college developmental math programs. Small K-12 school districts may not have enough teachers or students to offer the appropriate courses with the level of rigor to prepare students for college. Additionally, even when schools provide more challenging courses, the graduation requirements are such that many students only take the minimum number of classes required. Other students choose technical math courses such as business math or consumer math instead of college preparatory classes. Finally, curriculum flexibility and advising results in many students taking all their required math courses during their freshman, sophomore, and junior years of high school. As a consequence, students who did not take math their senior year do not perform well on placement exams. Many of these students are registered for developmental math courses their first semester of college (MDHE, 2013). In short, the number of required courses and nature of their rigor leads many high school graduates into college developmental math programs (Hall & Ponton, 2005).

Finally, a significant percent of students placed in developmental math courses are nontraditional students who have been out of school for several years. Some are displaced workers who returned to school to improve their training, skills, or certifications. Others are nontraditional students who are trying to fulfill lifelong educational goals (Le, Rogers & Santos, 2011). Many of these students may have had a strong educational record in the past; however, students who have not had to use this knowledge for several years may need a refresher. As a

consequence, many of these adult learners need to shore up their skills and knowledge in preparation for college level math and therefore enroll in developmental coursework.

Factors that Occur When Students Register for College

This section initially focuses on the procedures of placing students into developmental education by admission counselors and academic advisors. This is followed by a discussion about issues surrounding common placement assessments and the validity of cut-scores. The section concludes with brief comments about other institutional practices that result in many students having to enroll in developmental math programs.

There are a multitude of placement tests used by colleges and universities today. Nationwide, 27 states have policies that require the use of placement assessments for entering college students (Collins, 2008). The most commonly used assessments in community colleges are ACCUPLACER, Assessment of Skills for Successful Entry and Transfer (ASSET), and Computer Adaptive Placement Assessment and Support System (COMPASS) (Bailey, 2009; Collins, 2008; Golfin et al., 2005). The ASSET and COMPASS are both published by ACT; the ACCUPLACER exam is published by College Board. Nearly 1000 institutions use the COMPASS exam, 800 colleges use ACCUPLACER, and 500 colleges use ASSET (Golfin et al., 2005).

Of the three most common placement exams, the ASSET is the only paper and pencil test. The other two are computer-based assessments and use algorithms to form adaptive test questions. The expressed design of the exams is to test students' abilities in numerical skills and algebra concepts.

Ideally the reports generated by the exam should provide the data needed to assess students' knowledge and place them in an appropriate course. However, the majority of questions on

these placement tests are skill-based procedures (Stigler, Gavvin, & Thompson, 2010). The exam assumes that measuring a students' ability to do math is equivalent to a student's comprehension of mathematical concepts. "While the value of placement tests is known, some research has shown that not all assessment tests accurately place students in developmental mathematics courses" (Golfin, et al., 2005, p. 25).

Two recent studies illustrated the problems with the value and accuracy of placement test. In the first of these, Stigler, Gavvin, and Thompson (2010) studied student responses on placement tests at Santa Barbara Community College in Santa Barbara, CA. They attempted to discover what students actually understood about mathematical concepts by evaluating students responses on standardized placement test. They concluded that students underused their reasoning skills, approached the test questions as memorized procedures, and generally engaged in reasoning only when there was no other option. The researchers stated that the computer graded entry assessments may not adequately place students.

In a more recent study, Scott-Clayton, Crosta, and Belfield (2014) evaluated the accuracy of placement tests at two large urban community colleges. The researchers found that placement tests miss-assigned math students more than 25% of the time. They further concluded that severe-under placement was substantially more common than any over-placements. In short, one out of every four developmental math students may not really need remediation (Scott-Clayton et al., 2014).

One factor contributing to this problem is the issue of cut-score validity. Differences exist both within states and between states about the cut-scores used to indicate a student is ready for college level coursework. Some states have established unified scores while other states allow individual institutions to determine their own cut-scores for placement (Golfin, et al.,

2005). In 2000, the American Association of Community Colleges (AACC) conducted a national survey about community college practices related to developmental education. They found that 77% of colleges determined their own cut-scores on placement tests while the other 23% had state mandated placement scores.

Should there be standardized cut-scores? The ACCUPLACER product technical manual reads, “Institutions differ greatly with respect to composition of the student body, faculty, and course content, it is not possible to stipulate specific test cut scores that should be used for placement decisions. Instead, each institution should establish their own cut scores to facilitate placement decisions” (College Board, 2010, p. A-16). Even though the creators of standardized placement exams urge colleges to establish their own cut-scores, differences in cut-scores send inconsistent messages to students and their families. Why can the same placement score indicate a student is ready for college at one institution but indicate remediation is needed at another college?

The problem of placing students in appropriate courses is further illustrated by two statewide studies, one conducted in Texas and the other in Florida. In 2002, Shadish, Cook, and Campbell studied the success of developmental math students in the state of Texas. At that time, Texas colleges and universities used a standardized placement assessment with established cut off scores to identify which students required remediation. For their study, the researchers selected students who required remediation because they scored just below the cut off for college level math and then compared them with students scoring just above the cut off. They found that some students who passed developmental math scored a higher grade in their college level math courses. They also found that passing developmental math did not increase the students’ probability of completing college level math.

In a later study, Calcagno and Long (2008) studied students in Florida whose placement scores were near the cut-scores. Two groups were established by selecting a sample of students who scored just below the established cut-score and another sample of students who scored just above the established cut-score. Students scoring just below the cut-score enrolled in developmental math courses. Students scoring just above the cut-score enrolled in credit-level math courses. The researchers concluded there was not a statistically significant positive relationship between completing developmental math and completing a degree, technical certificate, or transferring to a four-year college.

In both studies, the researchers used regression discontinuity methodology to compare students who tested just below the cut-score for college level math with students who scored just above the cut-off score for college level math. The goal of the studies was to identify students with similar skills and observe the effects of developmental education. Neither study found developmental education made a significant impact on student success. Not only do these studies raise questions about the value of developmental education, they also illustrate the need to establish a valid and reliable way of placing students into appropriate courses. A single placement score does not provide enough information to accurately differentiate between students who are college ready and students who need remediation.

It is becoming obvious that the reliance on just one placement score contributes to the high number of students enrolled in developmental math courses (What we know, 2012; MDHE, 2013). Many of these students are inaccurately placed because these decisions are based on incomplete or inaccurate data. As pointed out earlier, in 2006 The College Board advised institutions to combine their test results with other information to determine what would be the

most appropriate placement for students. Unfortunately, colleges are still searching for effective multiple measures in placing students into the appropriate math course at the time of this study.

Another problem occurs when students take placement tests without being aware of the consequences of these high stakes tests. As colleges struggle to balance efficient and quick ways to complete students' records in order to register them for classes, students are often rushed through the onboarding process and take the placement tests without any preparation. Consequently, they score below their proficiency level and find themselves enrolled in a sequence of unnecessary developmental math courses.

Even if a college established valid cut-scores and did a good job emphasizing the importance of placement tests, some students are still misplaced. Some advisors fail to follow college policies or use loop holes in admission procedures to help students avoid the developmental courses (Perin & Charron, 2006; Calcagno, 2007). In a 2009 study by Bailey, 21% of students with developmental math placement scores had not enrolled in a developmental math course within three years of starting classes. Either these students were allowed to register in college-level math courses or they voluntarily postponed their graduation for several years. Delaying enrollment or allowing students to enroll in courses for which they are not prepared only compounds the problem.

Finally, diversity of the community college student body contributes to the need for remedial education. Boylan pointed out in 2002, "As student bodies became more diverse, they included more students who were less prepared academically" (Boylan, 2002, p. 2). Recruiting students with diverse backgrounds usually results in students with diverse educational needs. Student differences in ethnicity, socio-economic status, age, physical ability, military

experiences and educational background usually increase the percentage needing developmental education.

Factors that Occur While Students are in College

This section discusses factors that contribute to the high failure rate of students who place into developmental algebra courses. These factors include student characteristics such as maturity, responsibility, motivation, and perseverance. This section also examines the impact of poor study habits as a contributing factor. Many combinations of these issues can keep students swirling in their developmental coursework and never progressing to their college-level math course. As a result, they continue to enroll in developmental education programs once they arrive on the college campuses.

It is well documented that affective qualities such as maturity, perseverance, resilience, self-control, and confidence are just as important as college-content skills (Pascarella & Terenzini, 2005; Boylan, 2002; Blum, 2007; Thomas & Higbee, 2000; Waycaster, 2001). Downing (2011) described these qualities as “fuel that can propel us into the cycle of success” (p. 21). Students who embody these affective qualities demonstrate persistence and a strong self-esteem. They find success by seeking out additional help and are undeterred by challenges or failures (Silva & White, 2013). Downing (2011) goes on to describe the positive effects of responsibility, motivation and discipline. Students who possess these qualities were more likely to show persistence and achieve their educational goals. In contrast, students without these affective qualities exhibit poor self-acceptance and self-esteem. They often stop-out or drop-out of their courses and blame others for their failures to protect their “fragile self-image” (Downing, 2011, p. 21).

Another reason many students fail to succeed in developmental education courses is because they lack several essential study habits and skills (Kuehn, 2003). For example, some students are unable to identify the important and unimportant information in lectures and textbooks. They view textbook cues such as bolding and italics as distractors rather than aids to identify essential concepts of the material. In addition, many developmental students take fewer notes during classroom lectures, independent practice and studying. Finally, they misused answer keys and solutions manuals that could help them determine if they understand the material. As a result, students often believe they have mastered the topics when they actually have very little conceptual understanding of the content.

In summary, there are many reasons students are enrolled in developmental math classes. Some students arrive on college campuses underprepared because of their prior K-12 education or the amount of time since their last math class. Colleges rely on placement tests that lack clear cut-scores and assign many students into remediation courses. Students do not understand the importance of placement tests and are misadvised into the wrong courses. Finally, students' study habits and affective qualities such as maturity, responsibility and motivation contribute to the problem. Unfortunately, the combination of several of these factors can prevent students from succeeding once placed into remediation courses. As a result, students eventually stop-out, drop-out or fail-out of college.

Developmental Math Education as a Roadblock to Success

This section describes the problems students experience as they try to progress through their developmental math programs which often results in them repeating the courses. This section illustrates how the traditional developmental math programs have become a roadblock to success.

A significant number of students placed into developmental math do not complete the required course sequence. Several issues contribute to this problem. First, as pointed out earlier, some students never begin the coursework. Bailey, Jeong, and Cho (2010) found that 28% of students placed into remediation chose not to enroll. Second, many students either stop-out or fail-out at several points along the way. Bailey's 2009 research found that 70% of students either failed the coursework, withdrew, or did not return to complete the next math course. Third, some students who have successfully passed developmental courses choose not to register for the next sequential course. Bailey's 2009 study also found 10% of the students did not continue to the next course even though they passed their earlier developmental math course. Finally, former success in developmental math does not guarantee a passing grade in subsequent math courses. About half of successful developmental students go on to complete their college level math course. Sadly, the combination of all the stop-out points and fail-out points along the sequence of courses results in only 16% of the entering cohort of developmental students ever finishing their gateway credit math requirements (Bailey, Jeong, Cho, 2010).

The reasons so many students find developmental education a roadblock vary widely (Bailey, Jeong, Cho, 2010; Hammerman and Goldberg, 2003; Goldrick-rab, 2007, Trenholm, 2006). Three of the most commonly cited reasons are described below.

First, the sequence of course work is too long. For many students, time is the enemy to completing their degree. The factors contributing to their college success evolve with each passing semester. Changes in students' financial, relationship and personal situations all influence their ability to remain in school. Lengthy course sequences create more opportunities for problems in students' personal lives to deter them from their educational goals (Bailey, Jeong, Cho, 2010).

Second, the current methods used to teach developmental mathematics are not working. As explained earlier, many students do not understand the basic concepts of mathematics because the subject was presented as a series of rules (Hiebert, et al., 2003). All too often, many college developmental math instructors teach the objectives in the same manner. Unfortunately, the “skill-and-drill” method of instruction is still the dominant way of teaching mathematics in American higher education (Goldrick-Rab, 2007). The students didn’t understand the concept through “skill and drill” practice introduced in elementary school, then middle school, and again in high school. These pedagogical methods failed the student several times before. College instructors should not be surprised when developmental math students struggle with topics such as fractions when they continue to use the same strategies that didn’t work in K-12 education. As a result, students who are unsuccessful in K-12 continue to be unsuccessful with their developmental educational experience (Trenholm, 2006).

Finally, the type of required mathematics may be wrong. The entire sequence of developmental math coursework is built around preparing students to take a college-level algebra class. In turn, the college-level algebra course is designed to prepare students for further study in advanced mathematics or math related subjects. Only a small proportion of students have this educational goal. Few students find relevance in the mathematics they are required to learn. For many students, a course in statistics or quantitative analysis may provide a more meaningful college level math experience. By making these changes, the gateway mathematics course could align with the students’ course of study (MDHE, 2013).

As shown above, the current ways we teach developmental mathematics and the nature of the courses are preventing many students from achieving their educational goals. Even though some studies paint a bleak picture of developmental education, research is pointing to promising

changes. Leading scholars in the study of developmental education have constructed practical guides to help colleges mitigate the negative results of ineffective policies.

Boylan (2002) collaborated with the National Center for Developmental Education (NCDE) and the Continuous Quality Improvement Network (CQIN), to construct a practitioner's manual titled, *What Works: Research-Based Best Practices in Developmental Education*. Key findings in this book emphasized the need to make developmental education an institutional priority. As Boylan (2002) stated "Developmental education does not work well when it is random, nonsystematic effort carried out by uncoordinated units spread across the institutional flow chart" (p. 7). In contrast, effective developmental education programs are a coordinated effort between faculty, administrators, and staff. They are integrated into the organizational, administrative, instructional, counseling, advising, and tutoring activities of the school.

Similarly, Roueche and Roueche (1999) summarized research relating to policies and practice in their book: *High Stakes, High Performance-Making Remedial Education Work*. They analyzed the efforts of selected community colleges that demonstrated significant improvements for developmental students. They concluded that colleges must be willing to conduct a self-analysis to determine their strengths and weaknesses as they survey and examine promising efforts by other colleges.

Models of successful developmental education programs vary greatly from school to school. Boylan and Saxon (2006) reviewed many of these programs and determined that "some institutions gave it a priority and put serious effort into doing it well" (p. 37). The next section identifies some of the programs at colleges who are "doing it well."

Best Practices in Developmental Education

This section provides an overview of thirteen representative best practices designed to improve developmental math education in community colleges. The best practices were subdivided into the following four categories: (a) strategies to help students avoid developmental education, (b) non-classroom support for developmental education students, (c) course scheduling variations for developmental education students, (d) classroom practices to improve student outcomes. Many of these strategies were developed at community colleges participating in the Achieving the Dream initiative. For this review of the literature, several publications from the Achieving the Dream organization were provided by Dr. James Hammons, Professor of Higher Education Leadership at the University of Arkansas and Leadership Coach for Achieving the Dream. These publications became a valuable asset to this section. Again, this section is not intended to be an exhaustive list of all best practices in developmental math found in the literature, but an illustration of several emerging innovative strategies.

Strategies to Help Students Avoid Developmental Education

Ideally, every high school graduate in the United States would have the skills and knowledge necessary to be successful in college. The following strategies were designed to increase the percent of student who begin their higher education studies in college-level courses. These strategies help students identify, and shore up, any deficient skills prior to enrolling in college. Three of the best practices related to this goal are described below.

1. Early intervention strategies. Early intervention is a best practice to help students prepare for college and bypass developmental math programs. In 2008, Florida state legislatures mandated that college placement tests be available to high school juniors. Any students who were not identified as “college ready” were given remediation opportunities before graduating

high school. In an attempt to prepare students for college, the Florida Department of Education approved additional high school courses in reading, mathematics, and writing. These courses counted as elective credits toward high school graduation. Students who successfully completed the courses with a C or better were exempt from developmental education in Florida's colleges for two years from the date of completing the course. Using these strategies, Florida decreased the number of first-time freshmen students enrolled in developmental courses (Collins, 2008). Because of these results, and others similar to it, a 2012 report summarizing the Developmental Education Initiative by Achieving the Dream encouraged colleges to administer a placement assessment to high school juniors and seniors. Early intervention allows students to correct deficiencies before graduating (What we know, 2012; MDHE, 2013).

2. Curriculum alignment between K-12 and higher education. Better alignment of curriculum between K-12 schools and higher education is another best practice, as exemplified in Missouri. Collaboration between K-12 educators and higher education was emphasized in a 2013 Missouri government report titled, "Principles of Best Practices in Remedial Education." Working together, colleges and high schools decreased the number of students assigned to remediation and provided focus to students who actually needed developmental services (MDHE, 2013). When high school programs aligned their curriculum to college-readiness expectations, students more readily transitioned into college coursework. Students knew they were college ready when their high school exit assessments correlated with college entry assessments.

3. Pretest and retest. Pretesting and retesting programs are another best practice to help students avoid developmental courses. Summer bridge programs, boot camps, and preparation courses can dramatically decrease the number of students who eventually enroll in semester long

remediation programs. These programs occur before the students begin their college education. Three community colleges that have explored the impact of pretest and retest programs are described below.

El Paso Community College implemented a pretesting and retesting approach to placing students. First, students took the placement test. Second, students reviewed placement exam materials and content through computer-based modules. Third, specialists referred students to support networks for non-academic issues. Fourth, students were retested to determine their placement. With these changes, El Paso Community College has increased the number of students testing “college ready” and reduced the number of students placing into multiple levels of developmental coursework (What we know, 2012).

Guilford Technical Community College (GTCC) in North Carolina also adopted a pretest and retest program for its students. GTCC faculty created an online test preparation program that included practice test questions and reviews. Using the online software, the college was able to dramatically increase the number of students participating in the program. Over 2000 students completed the review and 40% placed at least one math course higher than the pretests originally indicated (What we know, 2012).

Houston Community College in Houston, TX modified the pretest then retest approach to placing students into developmental math. This college’s program placed marginally developmental students into a four-week long lab course with individualized instruction. Upon completing the four-week practice course, students were retested and placed into a "Second Start 12-week semester" course. The college reported that 50% of the math students retested into at least one level higher in the math course sequence (What we know, 2012).

These programs utilized an exam as a pretest to identify deficiencies in skills and knowledge. A modular-based course helped the underprepared students brush up on prerequisite skills in a week-long accelerated pace. Students then retested to determine a more accurate placement. Colleges that participated in the Developmental Education Initiative found that some students in these programs were “advancing multiple levels of remediation or bypassing it altogether” (What we know, 2012, p. 12).

In summary, remediation prior to starting college has great potential to help students avoid developmental education all together. As seen in the previous examples, pretests and retests can provide opportunities for quick remediation and improve students’ academic skills. Aligning the curriculum and assessing high school juniors and seniors can also dramatically decrease the number of students entering college with academic deficiencies. These strategies allow students to fill the gaps in their understanding before beginning their first semester in college.

Non-classroom Support for Developmental Education Students

Some colleges have increased support for their developmental students outside the classroom by investing resources in academic assistance and advising (McCabe, 2003; Roueche & Roueche, 1999; McClenney, 2005). Unfortunately, students most in need of these services fail to utilize them. Successful programs have designed creative ways to combat this challenge. This section presents three examples of best practices in non-classroom support to help students succeed in developmental courses.

4. Building connections. Programs designed to build connections between developmental students and external support services is a best practice. One example of this type of programming started in 2008 at South Texas College in McAllen, TX. It was named “Beacon

Mentoring.” Prior to the start of the semester, the college recruited and trained volunteer mentors from student services departments within the college. These employees agreed to serve as classroom mentors in addition to their regular duties. Each mentor was assigned to one of the 41 participating math classes. The mentor visited the classes and served three key roles. First, mentors communicated important information about counseling, academic advising, financial aid advising, academic support services, and registration information by visiting the class during class time. Second, the mentors acted as the students’ go-to person throughout the semester for student services questions. Finally, mentors and faculty members collaborated to support students who were at risk of failing before they dropped out of class. The program was evaluated through an experimental design which formed three major findings. First, “Beacon Mentoring” increased the number of students utilizing the college’s tutoring center. Second, “Beacon Mentoring” led to a statistically significant decrease in withdrawal rates; however, it did not change the pass rates of the courses. Third, there was no change in the percent of students that enrolled in the following semester (Visher, Butcher, & Cerna, 2010).

5. Intrusive advising. Intrusive advising is another non-classroom best practice to support developmental students. Intrusive advising is an advising practice that does not wait for the students to seek assistance. These programs reach out to students through mandatory meetings and provide early interventions in order to guide them to academic support networks and career services departments. As an example, Zane State College in Zanesville, Ohio recognized the importance of intrusive academic advising for its most at-risk students. Advisors utilized personal phone calls, mandatory meetings, e-mails, and Facebook as ways to provide ongoing information about tutoring, workshops, and services. Intrusive advising, combined with

other initiatives at Zane State College, increased retention rates over 10% (Matter of Degrees, 2013).

6. Improve college readiness. Successful programs realize that college readiness is more than academic preparedness. Students need courses in study skills and academic preparation (Pascarella & Terenzini, 2005; Boylan, 2002). Faculty, staff, support services, and student services all play a role in the success of these students. For example, Valencia College in Orlando, Florida integrated success skills into each developmental course in order to improve student habits in at least one of the following categories: reading, goal setting, study skills, motivation, and critical thinking (What we know, 2012). Implementing strategies to address study habits and affective student qualities is another best practice.

In summary, these best practices illustrate three key ideas. First, successful programs are more than discipline specific education. Interdepartmental efforts provide a comprehensive approach to serving the diverse needs of developmental students. Second, college readiness encompasses many of the behaviors and affective qualities of successful individuals. “Maturity, self-discipline, perseverance and habits of mind such as problem solving, the ability to observe, listen, and speak” (MDHE, 2013, para 7.1) all contribute to student success. Finally, colleges should provide comprehensive student services such as advising, counseling, support, and tutoring to help their developmental students succeed.

Course Scheduling Variations for Developmental Education Students

Better outcomes occur when a student progresses through the course sequence in a reasonable time frame. For example, once students complete a basic algebra course they should register for the intermediate algebra course as soon as possible. Advising is key to helping students make informed choices about course pairings, types of courses offerings, degree plans,

and career paths. Many states and community colleges are working to close the gap that often leads students to “stop out” of their math sequence (Collins, 2008). This section describes innovative variants on course scheduling that have shown improved outcomes for developmental students.

7. Continuous enrollment. Continuous enrollment is a recommended best practice for students facing multiple required courses in a developmental mathematics program. Continuous enrollment allows students to work at their own pace through course content and modules. Thus, some students complete multiple courses in one semester while other students take longer than a semester to complete a single course. At the start of the next semester, students move forward with their learning. Students who complete the developmental sequence are able to transition into credit coursework. Students who need more time in remediation continue to make forward progress instead of restarting at the beginning of the course.

An example of a continuous enrollment program is ModMath at Tarrant County College in Fort Worth, Texas. This modular approach to teaching developmental math replaced the college’s three 16-week long developmental math courses with nine modules, each lasting 5-weeks long. After taking a placement assessment to determine which of the 9 modules they must complete, students work at their own pace. This practice accelerates them through the program. “By dividing the curriculum into modules, ModMath allows students to leave and return (or fail and return) without losing as much ground as they would in semester-length courses” (Fong & Visher, 2013, p. 3). Several colleges have adopted these modular approaches to developmental course offerings and have seen a 10% increase in student success rates (What we know, 2012).

8. Learning communities. In contrast to the flexible schedules of continuous enrollment, some colleges have had success with rigid scheduling programs for their developmental students.

Cohort scheduling through the use of use of learning communities is one common option. Learning communities group students together with similar courses so that “students are required to share the experience of learning. They participate in cooperative learning activities that call for them to be interdependent learners” (Tinto, 1997, p. 602). The faculty members of these courses function as a team to foster interdisciplinary learning through connecting concepts and class discussions. Learning communities have shown positive outcomes on student success in college level courses for many years (Scrivener et al, 2008; Bailey & Alfonso, 2005; Grubb, 2001).

A recent successful adoption of cohort scheduling through learning communities occurred at Kingsborough Community College in New York. At this school, freshmen were grouped by enrollment in three courses. Developmental students took their remedial course, a college-level course, and a college success course all together. Because of their common schedules, students formed stronger friendships that supported their learning through shared accountability. Students who participated in the program were more likely pass the gateway skills assessment to enroll in college-level coursework (Matter of Degrees, 2013; NCSL, 2014).

9. Co-remediation. Co-remediation is another best practice identified in the literature. Co-remediation is the practice of placing marginally developmental students into courses that remediate within the content of the gateway courses. The goal is to shorten students’ time to graduation and improve completion rates. When students are given the opportunity and appropriate support, studies have shown that students who score just below the cut off scores can be successful in college-level coursework (Calcagno & Long, 2008; Shadish, Cook, & Campbell, 2002).

The Community College of Baltimore (CCB) offers an example of a successful co-remediation program. CCB placed borderline remedial students into college-level courses, then provided extra support in the form of an additional study hour course taught by the same instructor. A study of this program conducted by the Community College Research Center found that students in the co-remediation model were more likely to pass the first two college-level courses than the students who were not in the program (NCSL, 2014).

10. Mathematics pathways. Mathematics pathways is another example of a best practice. The American Association of Community Colleges defined pathways as an “education experience that is built around and through an area of study” (AACC, 2014, p. 11). Math pathways provide differentiated gateway courses designed to teach the mathematical skills necessary for the students’ programs of study. Instead of relying on a traditional college algebra course as the default general education mathematics requirement, pathways align course objectives and curriculum around designated degree and career goals. Moving away from traditional gateway mathematics requirements has the ability to solve many of developmental education's problems.

The Dana Center at the University of Texas-Austin, in cooperation with the Carnegie Foundation for the Advancement of Teaching, developed two such pathways: Statway and Quantway. Both are year-long math programs that have successfully brought students through their developmental course work and credit level math with much higher success rates than the traditional sequence of courses (Silva & White, 2013). These courses integrate developmental math with college level math. The course content centers on real-world problems and the teachers focus on helping students become successful learners. The program produced amazing results in its first year. In fall 2011, 51% of the 1077 students in the program had earned college

level math credit (Silva & White, 2013). Typically, only 6% of development students have earned college level math credit at the end of their first year (Calcagno & Long, 2008).

In summary, this section presented course scheduling variations that may have great potential for increasing developmental education students' success. Self-paced courses allow for continuous enrollment so students do not lose ground after the end of a traditional academic term. Cohort scheduling through learning communities offer peer support networks. Finally, new strategies of co-remediation and mathematics pathways may allow students to skip remediation courses altogether.

Classroom practices to improve student outcomes

This final section on best practices in developmental education describes three examples of how faculty members can promote student success in their classrooms by providing opportunities for peer-to-peer collaboration and tutoring.

11. Collaborative learning. Collaborative learning has been identified as a successful variant on traditional instructional practices. First introduced in elementary and secondary schools, collaborative learning has been expanding into college and university classrooms (Tinto, 1997). The American Mathematical Association of Two Year Colleges (AMATYC) identified collaborative learning as a key component to helping students learn and retain information (AMATYC, 2006). In 2006, AMATYC published the document, "Beyond Crossroads: Implementing Mathematics Standards in the First Two Years of College." It defined collaborative learning as "an unstructured process in which participants define problems, develop procedures, and produce socially constructed knowledge" (p.53). It identified collaborative activities as a strategy to promote interactive learning and improve both oral and written communication skills. To accomplish these goals, the AMATYC organization suggested faculty

members utilize internet activities, engage in research projects, facilitate informal study groups, encourage students to work in pairs, and establish group reviews before tests (AMATYC, 2006). This form of classroom instruction typically improves student interest and student-to-student peer learning (Tinto, 1997; Roueche & Roueche, 1999; AMATYC, 2006).

12. Supplemental instruction. Supplemental Instruction (SI) is a widely used best practice in higher education. In 2002, Boylan concluded that SI “is probably the most well documented intervention available for improving the academic performance of underprepared students (p. 75).” SI programs use highly successful students as peer tutors after completing a gateway course. The tutors provide structured study sessions for students currently taking the class and meet two or three times a week. Student leaders of SI regularly communicate with the faculty members about important course concepts and learning strategies. The U.S. Department of Education identified it as an exemplary educational program in 1981. While it is not a new idea, new trends in SI continue to evolve.

An example of a successful SI program was developed at Austin Community College in Austin, TX. The college piloted supplemental instruction in its math and chemistry departments during the 2007-2008 academic year. Pilot courses designed with SI support had nearly 20% higher completion rates than courses without SI. The school continued to scale the model. In the 2011-2012 year, SI courses had completion rates 15% higher than non-SI courses. Because of the successful longitudinal results of SI, the school has committed to scaling the SI model into 20% of its gateway courses (Matter of degrees, 2013).

13. Video-Based supplemental instruction. Video-Based Supplemental Instruction (VSI) is a variant on traditional supplemental instruction. In VSI, students view videotaped recordings of the instructor’s lectures. Students are able to pause the video, rewind, and ask

questions as they work through the material at their own pace. VSI and “flipped” classrooms use technology to provide instruction through videos viewed outside of class (MDHE, 2013). Martin and Blanc (2001) reported that VSI reduced the percentage of withdrawals while increasing the percentage of passing grades for varsity athletes.

In summary, faculty members who adopted these classroom best practice improved student success in remedial courses. Collaborative learning encouraged peer-to-peer learning. Supplemental instruction provided extra support. Video-based supplemental used technology to increase opportunities for students to learn the material.

This section reviewed thirteen best practices in developmental education by dividing them into four categories. The first group of strategies was designed to decrease the number of students being placed into developmental education. The second group of best practices described ways that student services personnel and advisors contribute to student success. The third set of ideas showed how variations in course scheduling could individualize student learning. The final section identified three strategies for faculty members to implement in their classrooms.

The Use of Computer-Aided Instruction

Many colleges and universities have added computer-aided instructional techniques into their developmental math courses. This method of classroom instruction has gained momentum in higher education as a way to improve student success rates. The findings of several of these studies are discussed in the final section of this literature review.

There is a large amount of research on the role of technology in the classroom and its use as an instructional tool. To focus this literature review, primary consideration was given to studies that compared student performance in traditional lecture-based courses with student

performance in computer-aided courses specific to developmental algebra. This section discusses the impact of computer-aided instruction on student attitudes, retention, success rates, and test scores in developmental algebra courses.

Institutions vary greatly in their approach to using computer-aided instruction in math classes. Some colleges use the software as a homework management tool while allowing the classroom to operate as a lecture-based course. Students complete the homework via a web-based program related to the daily instruction. On the other extreme, students learn by computer instruction in open computer labs staffed by a math specialist. In this approach, students work at their own pace to complete as many modules as they can during the academic term. Sometimes they are allowed to complete multiple courses in one semester. Other math departments require students to attend the computer-based math class during traditionally scheduled class meeting times. Some departments allow flexibility in student schedules but requiring a certain amount of time to be spent in the computer lab without requiring daily class meetings. (Twigg, 2011; What we know, 2012).

Student Attitudes in Computer-aided Courses.

A number of studies have examined the impact of computer-aided instructional practices on student confidence and attitude toward math. The results of five of these studies are discussed below.

The first of these studies was conducted using a sample of data collected from three Texas colleges and universities. Taylor (2008) evaluated the effects of software instruction on college and university freshmen in developmental math courses. Her study compared student outcomes in traditional lecture-based courses and computer-based courses. She found that students in the traditional lecture-based courses scored higher on the tests than the students who

received computer instruction; however, their anxiety levels were also higher. Participants in the computer courses self-identified lower anxiety and higher confidence on a mathematics anxiety rating scale.

A second study at Valencia Community College used trained advisors to place students into traditional classes or software instruction introductory algebra courses. The students' learning style determined their placement. While the results of the study found no significant difference in final exam scores, the findings suggested that students in the software instruction courses self-identified an increase in confidence and attitude toward math (Kinney, 2001).

Another study was conducted at a small Midwest university in South Dakota. Stillson and Alsup (2003) designed a correlation study to evaluate the use of ALEKS software in teaching basic algebra. To gain a deeper understanding of their research questions, Stillson and Alsup performed follow up interviews with the participants. Students in the courses indicated they appreciated the immediate feedback provided by the software, the repetition of problems, and the ability to work at their own pace. Students using the software self-identified with learning more in the ALEKS enhanced course than what they had learned in previous attempts at math courses (Stillson and Alsup, 2003).

In the fourth study, Canfield (2001) researched the effects of web-based software on student attitudes at National-Louis University in Chicago. Canfield questioned thirty participants using a five-point survey in a pre-test and post-test methodology. The researcher concluded that students felt the online program made a less stressful environment. In addition, the software gave students only the problems they were ready to learn. As a result, the students believed they learned more and appreciated the immediate feedback.

The final study of this section was conducted by Bishop (2010) at a community college in southern Mississippi. She examined the effects on students' attitudes of a sample of 112 students. Her participants self-selected into traditional lecture-based algebra courses and computer-based algebra courses. Both groups learned the same objectives during 75 minute class meetings. Pretest and posttest data were collected using the Attitudes Toward Mathematics Inventory (ATMI). She concluded that students in the traditional lecture courses had significantly higher positive attitudes toward math when compared to the computer-based courses.

The majority of these studies indicate that student attitudes in math appear to improve with the integration of computer instruction in the classroom. The software's ability to provide immediate feedback on accuracy, coupled with its ability to adapt the topic to a student's current understanding, seemed to create a less stressful learning environment. Students were more confident in their mathematical abilities and believed they learned more. Interestingly, the students in the computer-based classrooms had better attitudes toward math even though the control group outperformed them on the tests in some of the studies.

These findings are consistent with a meta-analysis of computer instruction completed in the 1990s. Associates at the University of Michigan conducted a meta-analysis to combine the results of 254 studies by comparing the outcomes of students in computer instructed classes and traditional classes. The analysis summarized the findings of research on students ranging from kindergarten to adult learners in a variety of subjects using computer-based instruction. The researchers concluded that the computers were primarily useful for drill and practice, and students showed positive attitudes toward computers and learning. The researchers also determined that less time was needed for instruction in computer-based courses (Kulick and

Kulick, 1991). Their conclusions, however, were not overwhelmingly in favor of computer-based instruction. The measured outcomes on student attitudes and learning in the computer-based instruction courses were higher for K-12 students than for adult learners. Kulick and Kulick suggested that software developers were better at writing programs to teach the basic skills of elementary mathematics than in developing programs to teach advanced concepts of higher level math.

Current research continues to support Kulick and Kulick's 1991 conclusions about the effects of computers on student attitude. Since then, developers have created programs such as ALEKS and MyMathLab to teach the more advanced topics of higher level mathematics. Both ALEKS and MyMathLab are mathematics software programs, accessed by the internet, and used by many departments to manage student homework and learning. The programs algorithmically generate problems while using text explanations and video tutorials to help students learn the material. They have been the subject of a few studies on computer instruction in the classroom in recent years (Ha, A. 2014; Kodippilli & Senaratne, 2008; Burch & Kuo, 2010; Vezmar, 2011).

Retention and success in computer-aided courses

Student retention rates and success rates from five studies are compared in this section. These studies were selected because of their focus on redesigned developmental math education courses.

In the first study, Ha (2014) researched the effect of MyMathLab on student achievement of basic algebra students at a mid-sized suburban community college in northern Texas. He compared withdrawal rates and success rates of these students in their future intermediate algebra, contemporary math, or college algebra courses. His sample consisted of 326 students with 161 students enrolled in a traditional lecture-based classroom and 165 students enrolled in a

course supplemented with the MyMathLab program. The longitudinal study lasted from 2008 to 2013. He found no significant impact of the used of software on the measures of student retention and success in the MyMathLab supplemented courses.

In another study, Kodippilli and Senaratne (2008) used MyMathLab to explore the effects of computer-aided instruction on final course averages and pass rates for students at Fayetteville State University. The researchers randomly selected intact classes to participate as the control group and treatment groups. The control group followed a traditional math classroom by completing textbook assignments through paper and pencil homework. The treatment group completed homework assignments through the use of the online software MyMathLab. They concluded that the pass rates were significantly higher in the courses using MyMathLab, but the final course averages were not statistically different.

In the third study, Brocato (2009) conducted a multi-semester review of student performance at a small community college in southern Mississippi. Retention and success data were collected over seven semesters of algebra courses taught using traditional lecture-based instruction and compared with data collected over six semesters on student retention and success in computer-aided instruction. She found a significant increase in the end-of-course grades and in withdrawal rates during the computer-aided semesters.

In the fourth study, Kinney and Robertson (2003) researched the effects of computer-based courses on developmental math students' retention rates at the University of Minnesota. Developmental students were allowed to choose between traditional lecture courses and software enhanced courses. Placement exams and information about the two methods of instruction helped students self-select their participation in the treatment or control groups. The lecture classes followed the traditional method of content delivery. During class time, students worked

independently and collaboratively while the instructor provided guided practice. In the software enhanced courses, classes met with their instructor during established times in a computer lab. During the class meetings, students interacted with each other and the instructor; however, they worked through the material at their own pace. Attendance and scheduled assessment dates were mandatory in both forms of instruction. The researchers determined that students in software-enhanced courses were more likely to persist (Kinney and Robertson, 2003).

The final study of this section revisits Stillson and Alsup's (2003) correlation study at a small Midwest university in South Dakota that was introduced earlier. As described in the previous section, Stillson and Alsup evaluated software in teaching basic algebra through the use of ALEKS software. Students in the courses indicated they appreciated the immediate feedback provided by the computer, the repetition of problems, and the ability to work at their own pace. However, findings showed that the computer-based courses had higher withdraw rates and failure rates.

The findings in these studies indicated mixed results for student success and retention in computer based algebra courses. In some cases, the researchers concluded the computer-aided instruction was more effective than traditional instruction. In other studies, the researchers did not find a statistically significant difference between the treatment and control groups. Some reported findings showed a positive relationship existed between student success and computer-aided instruction strategies; however, the research methodology limited the generalizability of the conclusions. None of the studies were able to provide a clear picture of the cause and effect relationship between student success and instructional method. (Brothen and Wambach, 2000; McSweeney, 2003, Nguyen, 2002; Olusi, 2008). In short, even though attitudes appeared to

improve with the use of computer-aided instruction, this did not always translate to increased retention and success rates.

Student exam scores in computer-aided algebra courses

Many math faculty members determine end-of-course grades through a series of unit exams and final exams. Test scores have been the dependent variable in numerous studies on the effects of computer-aided instruction. Eight of these studies are presented in this literature review because of their similarities to the current study.

Mahmood (2006) conducted a study at a historically black institution in Texas. The researcher established two classes as the control group and utilized traditional methods of instruction only. Two classes were the treatment group and utilized software to enhance instruction. The researcher compared the differences in student scores from pre-tests and post-tests. Students in the computer-aided instruction classes had significantly higher scores on the post-test than the students in traditional courses. The researcher concluded that students in the computer-aided instruction classroom outperformed the control group on the Texas Higher Education Assessment practice test.

Burch and Kuo (2010) studied the effects of software-based homework assignments on exam scores at Indiana University of Pennsylvania. Over the course of two semesters the researchers collected data on a control group of students who used traditional textbook homework assignments. The next semester, the researchers used MyMathLab for homework assignments. The data showed improved unit test scores during the MyMathLab semester. However, the improved final exam scores were not statistically significant.

A few correlation studies have found a relationship between computer-based coursework and higher test scores. In one of these, Vezmar (2011) researched the effects of MyMathLab in

the developmental math classes at Delaware Technical and Community College. She collected student achievement data on 178 students who completed their developmental math course. The study measured homework grades in MyMathLab, time spent using the software, final exam grades, and end-of-course grades. She found a strong relationship between student scores in MyMathLab and scores on the departmental final exam. Students who scored higher than 75% on the MyMathLab assignments had statistically significant increases in final exam scores (Vezmar, 2011).

Stillson and Alsup's (2003) correlation study at a small Midwest university in South Dakota also examined the relationship between student exam scores and the use of ALEKS software in teaching basic algebra. They found a positive relationship between the amount of time a student spent in ALEKS and higher test scores.

In an attempt to establish causal relationships, some researchers have utilized experimental designs or quasi-experimental designs to study the effects of various instructional methods on student test scores. Four of these studies are described below.

Teal (2008) used ACCUPLACER and test scores as the dependent variables in a quasi-experimental design at a suburban community college in the mid-Atlantic region. This study included 152 students who self-selected into either a computer-aided course or a traditional instruction course. Participating faculty members agreed to teach one class using traditional instructional methods and another class using computer-aided instruction. The researcher concluded there was not a statistically significant difference in test scores between the two groups of students. However, the computer-aided courses had higher retention rates than the courses utilizing traditional instruction.

Spradlin and Ackerman (2010) conducted a quasi-experimental study at a large, private, eastern university. The control group consisted of two classes receiving traditional lecture-based instruction; the treatment group was two classes that experienced computer-aided instruction. Learning outside of the classroom was the primary difference between the two groups. Students in the traditional classrooms received textbook homework assignments. Students in the computer-aided classrooms completed assignments through a computer learning system. The researchers concluded there was not a statistically significant difference in the posttest scores between the two groups.

Reagan (2004) compared student learning outcomes in traditional lecture-based developmental math classes to student learning outcomes in computer-assisted classes at a rural community college located in south-central United States. Eleven sections of developmental math were studied. Five of the sections were taught using traditional instructional methods. The other six sections were taught using computers while the teacher acted as a facilitator. The ACCUPLACER exam was used as the pretest and posttest assessment instrument. The researcher concluded that there was not a significant difference in the students' exam scores between lecture-based instruction and computer-assisted instruction. However, she did determine that 71% of the variation in the scores was related to reading ability instead of mastery of mathematical concepts.

The final study was done at the University of Minnesota by Kinney and Robertson (2003). The researchers compared the difference in final exam scores between computer-aided courses and traditional lecture classes. In the computer-aided courses, students worked through the material at their own pace. In the lecture classes, students learned through typical methods of

group-based content delivery. The researchers found no significant differences in the final exam scores or pass rates for the two groups.

In summary, the impact of computer-aided instruction on exam scores in developmental math classes has had mixed results. A few of the studies attributed improved test scores to the use of computers while other studies concluded there was no difference. Problems resulting from research design limited the generalizability of some studies or limited the researchers' ability to conclude a cause and effect relationship existed.

The lack of conclusive evidence to support computer-aided instructions has led experts in developmental education to form three recommendations. First, colleges need to understand the context of reform, and the role of technology in those reform efforts. Second, they must understand the appropriateness of computer instructional practices and create a plan without "reinventing the wheel." Finally, the reform efforts and student learning should be accompanied with multiple assessments (Cowen, 2008). Okojie, Olinzonck, and Boulder (2006) concluded "Technology should not be treated as a separate entity but should be considered as an integral part of instructional delivery" (p. 67).

Chapter Summary

This chapter began by restating the purpose of this study and describing measures for student success. This was followed by a section on the steps used to locate relevant research. Initial searches on developmental math education yielded too many articles and publications to organize. Adding date restrictions, peer review restrictions, and a focus on basic algebra with computers or software yielded a more manageable amount of literature for this review. A description of related dissertations and web-based resources was also provided.

The second section of the chapter discussed the state of developmental education. This section began with data about the number of college students in remediation courses and was followed with information on the growing costs of these programs. Over the last ten years, the cost of developmental education programs has grown exponentially. The price tag of college remediation reached seven billion dollars in 2014 (Scott-Clayton et al., 2014). The section concluded with a short discussion on action plans taken by state legislatures and college administrators to manage these growing costs.

The third section of the chapter discussed common practices of community colleges in providing developmental education. Four of them were examined. First, most colleges required students to complete three levels of math courses before allowing them to enroll in their gateway credit-math course. Second, the developmental math sequence at large urban districts often required more sequential courses. Third, most students in developmental programs needed a minimum of two years to complete the math requirements of their degree plans. Finally, most developmental math courses were typically offered in full semester-long courses.

The fourth section reported several of the factors that cause students to enroll in remediation programs. Some of these contributing factors occurred before the students ever started college. Problems that occurred during their K-12 education or the amount of time between high school and beginning college coursework were briefly discussed. Next, the section described problems with institutional practices in determining student placement. These included several issues that occur during the onboarding process that place many students in developmental math courses. For many students, these courses may not have even been necessary. Finally, the section described the important role of affective student qualities such as motivation and attitude. Students lacking a combination of these qualities often find themselves

enrolled in developmental math courses. The section concluded by suggesting that current predictive analytics do not indicate success for many of the students who place into developmental education courses.

The fifth section explained how developmental math education is a roadblock to success for many students. Students tend to stop-out, fail-out, or withdraw from their community college education during their developmental math courses. Generally, fewer than 25% of students who began in developmental math will graduate eight years after their first semester. In some cases, fewer than 16% of the entering cohort of developmental students ever finish their gateway math requirements (Bailey, Jeong & Cho, 2010; Silva & White, 2013). Students who begin their college coursework in developmental programs have much lower persistence rates from semester to semester and lower degree completion rates when compared to students labeled “ready for college-level coursework” (MDHE, 2013).

The sixth section of this literature review focused on thirteen best practices in developmental programs. These practices were grouped under four categories. The first group described programs that helped students avoid developmental education by shoring up deficiencies prior to beginning college courses. These interventions were implemented during the students’ junior and senior year of high school or as boot-camps prior to the college’s first day of classes. The second category consisted of examples showing how some colleges invested in support for the students outside the classroom. Advising, mentoring and tutoring were the focus of many of these strategies. The third group of best practices described programs designed to provide more flexibility when students entered, and completed, developmental math courses. These scheduling variations focused on individualized learning goals in developmental

coursework. The fourth group of best practices described strategies that faculty members could implement in their classrooms.

The final section of this chapter discussed the use of computers in developmental education programs. It focused on studies that compared student performance in traditional lecture-based courses with student performance in computer-aided courses. Student attitudes, success rates, retention rates, and test scores in developmental math courses were common dependent variables in these studies. In general, the use of computers improved student attitudes but had mixed results on retention rates. Several studies found improved success rates and exam scores. Most studies concluded final exam scores were unchanged after the introduction of a computer-aided instructional model.

Even with the large number of studies on successful developmental education programs, there were noticeable gaps in the research. For example, only a few studies partitioned developmental students into smaller subpopulations. Goldrick-Rab (2007) noted “there is little research on the variation of effectiveness of remedial education based on student characteristics such as family background, race, or full-time or part-time enrollment status” (p. 12). Similarly, few studies have considered the differences between traditional-aged developmental students and non-traditional aged students. These two groups of students may have very different needs. Finally, at the time of this writing, it appears there is a significant lack of experimental studies based on randomization with controlled variables. Without this research, it is difficult to conclude what efforts at developmental education reform are truly having a positive impact for the students.

In the fall of 2011 Ozarks Technical Community College changed the instructional methods used in its development math courses. The purpose of this study was to compare the

performance of students in OTC's developmental math program after redesigning the course to include computer-enhanced instruction. The next chapter describes the setting of the study, selection of the sample, and outlines the methodology used for this research.

CHAPTER THREE

METHODOLOGY

This chapter provides a description of the methodology used to address the purpose statement and answer the hypotheses provided in chapter one. A detailed analysis of the selected sample and threats to validity are also included.

Introduction

This research explored student performance in computer-aided instruction in developmental mathematics courses at Ozarks Technical Community College in Springfield, MO. Student performance was measured by retention rates, success rates, unit exam scores, and final exam scores. The following four research hypotheses guided this study.

1. Developmental mathematics courses utilizing web based software-enhanced instruction at OTC will have higher course retention rates than courses using lecture-based methods of instruction at OTC.
2. Developmental mathematics courses utilizing web based software-enhanced instruction at OTC will have higher success rates than courses using lecture-based methods of instruction at OTC.
3. Students in web based software-enhanced developmental mathematics at OTC will have higher unit test grades than students in lecture-based developmental mathematics courses at OTC.
4. Students in web based software-enhanced developmental mathematics at OTC will have higher final exam scores than students in lecture-based developmental mathematics courses at OTC.

Selection of the Research Design

The causal-comparative research design described by Gay, Mills and Airasain (2009) was selected to conduct this study. This methodology explores potential relationships *ex post facto*, Latin for “after the fact,” and is explained in this section.

Gay, Mills and Airasain (2009) identified causal-comparative studies as non-experimental descriptive research used to conduct a systematic inquiry into preexisting conditions. In this research methodology, “studies typically involve two (or more) groups of participants and one dependent variable. Causal-comparative studies focus on the differences between groups” (p. 218). This methodology was chosen because the study compared the independent variable of instructional strategy to the dependent variable of student performance after the developmental courses were redesigned. All students registered prior to fall 2011 received a lecture-based instructional method. All students registered after fall 2011 received computer-enhanced instruction. The researcher was unable to sample the students during the same semesters because OTC did not concurrently offer the courses in the two instructional formats. Data for this study were collected after the semesters were completed.

This study used inferential statistics to analyze the data. Proportion z-tests were used to explore differences in retention rates and success rates. Population data were collected and reported when available. T-tests were used to examine the differences in mean grades on unit exams and final exams. The findings of these tests are described in chapter four.

Setting for the study

This section describes the setting for the study and provides a brief history of Ozarks Technical Community College.

OTC was formed in 1990 when the residents of Springfield, MO, and thirteen additional school district, voted to create an open admissions two-year college. The college's original focus was on technical education and thus offered a two year Associate of Applied Science degree and one year certificates in 16 different programs. In the fall of 1991, OTC enrolled 1198 students in credit courses at its facilities near the center of town (OTC catalog, 2014).

New programs were developed and existing programs were revised as the college adapted to the needs of the community. A two year general education transfer degree, Associate of Arts, was created in 1994. The school received its first accreditation through the Higher Learning Commission of the North Central Association of Colleges and Schools in 1996 (OTC catalog, 2014). Over 8,000 students enrolled in classes at OTC within 10 years of its inaugural semester (OTC statistics, 2014).

The college expanded its facilities with the growing enrollment. From 1997 through 2002, four new buildings were constructed on the Springfield campus and renovations were made to the existing buildings. Beautification of the campus was supported through donations to the college and a pedestrian mall was created. During these years, the college also expanded to surrounding communities.

Education centers and campuses were established in Lebanon, Branson, Ozark, and Waynesville. In 2007, the Ozark education center moved into new facilities and became the Richwood Valley Campus. In the fall of 2013 the college transitioned into Ozarks Technical Community College System and opened the Table Rock Campus, formerly the Branson Education Center. These extensions of the college reached nearly 100 miles east and 50 miles south of Springfield, MO.

As the college moved toward becoming a system of campuses, the governance structure also evolved. Each campus location had a president along with deans and directors for academic and student services areas of the college. Education centers had a director to oversee the daily operations at that location. Administrative decisions for the college were primarily made at the Springfield campus which housed the majority of system administrative offices. Likewise, curriculum decisions within departments were often made at the Springfield campus. System wide, administrators and faculty members regularly convened at the Springfield campus for meetings. The culture of collaboration among the locations was key for the mathematics department's transition to a computer-enhanced model for its developmental math courses.

The transition required extensive planning and resources. In the spring of 2010, the math faculty members began regular meetings to brainstorm ideas for their developmental program. The department chair, director of the tutoring center, and department faculty members traveled to other colleges to explore best practices in developmental education. These meetings were instrumental in the creation of the OTC's mandatory attendance policy and the course redesign. After the successful pilot, several faculty members and the department chair began the process of adapting the course schedules, course curriculum, and final exams to meet a computer-enhanced model of instruction.

OTC uses a large number of adjunct instructors. During the study, per-course instructors taught nearly 85% of the school's developmental math classes. Training them was key to the implementation. After the college identified full-time developmental math instructors for the Springfield Campus and hired a new developmental math instructor for the Richwood Valley Campus, these people helped the department chair provide ALEKS training seminars for the

adjunct instructors during the summer of 2011. By the fall of 2011, all developmental math classes were taught with a computer enhanced model of instruction.

At the time of this study, the Ozarks Technical Community College System consisted of three full-service campuses and two education centers. Enrollment exceeded 15,000 students.

Identification of the Population

The target population for this research was all students enrolled in basic algebra classes at OTC. This section describes how the population was narrowed to conduct this study.

As stated in chapter one, this research was delimited to the 2010-2013 academic years because of a mandatory attendance policy implemented in 2010. At that time, OTC began enforcing attendance through administrative withdrawals for students who missed more than 20% of their class meetings. To control for the effects of this new attendance policy, the study's population was delimited to 2010-2013, resulting in a duplicated head count of 11,666 students enrolled in basic algebra classes in the 2010-2013 academic years. Repeat students were counted each semester they registered for the course.

The target population was further delimited to instructors who taught using both methods of instruction. Only students enrolled in classes where the faculty member taught during the 2010-2011 year as a lecture only format and then taught using software-enhanced instruction during the 2012-2013 academic year were considered for the sample selection. This helped the researcher control for instructor differences and further narrowed the subpopulation to 10,414 students.

Selection of the Sample

A sample was selected because the subpopulation was too large for the researcher to study all students taking basic algebra during the years of investigation. Approval was obtained

through the Institutional Review Boards for both Ozarks Technical Community College and the University of Arkansas. The provost of OTC provided a letter of support. The following section describes the steps taken to determine the samples chosen for this study.

Rosters from the basic algebra classes were downloaded into spreadsheets for the 2010-2011 academic year and the 2012-2013 academic year. The 2011 to 2012 academic year was intentionally omitted to minimize the number of students who repeated the course and thereby had received instruction through both methods.

A stratified random sample of 500 students was drawn from the rosters using the random number generator function in Microsoft Excel. The researcher selected 250 students from lecture-based instruction semesters and 250 from the computer-enhanced instruction semesters.

Since the use of samples can introduce intervening variables that may compromise the validity of any conclusions in a causal-comparative study, the next section explains the actions taken to ensure the samples were alike in all aspects except the method of instruction.

Comparison of Demographic Variables for the Samples

The researcher compared several demographic variables through the use of SPSS grad pack 22.0 and Microsoft Excel software. The demographic variables under consideration were age, gender, ethnicity, enrollment status, first generation, and math placement. The following section lists the findings of these comparisons.

Age was the first demographic variable compared. The results of the sample data collection are shown in Table 1. The mean age and standard deviation for the two sample groups were similar. The researcher concluded that there was not a significant difference in the mean age of the students in the lecture-based instructional method ($M=24.83$, $SD=7.79$) and software-enhanced instructional method ($M=24.80$, $SD=7.55$) samples; $t(498)=0.0437$, $p =0.9654$.

Table 1

Age (in years) Separated by Instructional Method During the Lecture-Based 2010-2011 and Software-Enhanced 2012-2013 Academic Years at OTC.

Instructional Method	n	Mean	SD
Lecture-Based 2010-2011	250	24.83	7.79
Software-Enhanced 2012-2013	250	24.80	7.55

Note. n = sample size, SD = Standard Deviation

Gender and ethnicity were the second and third demographic variables analyzed. A slightly higher proportion of males were randomly selected in the sample of lecture-based semesters. However, computation for statistical difference in the two proportions for men showed there was not a significant difference in the percentage of men in the lecture-based instructional method (42.8%) when compared to the percentage of men in software-enhanced instructional method (39.2%) in the two samples; $z=0.8183$, $p=0.4124$. Thus, there was not enough evidence to state the proportion of men between the two methods of instruction was different. Similarly, there was not enough evidence to suggest the proportion of women differed between the two methods of instruction. Table 2 displays these statistics for the two samples.

Table 2

Gender and Ethnicity by Instructional Method During the Lecture-Based 2010-2011 and Software-enhanced 2012-2013 Academic Years at OTC.

Instructional Method	Gender		Ethnicity				
	Male	Female	White	Black	Native American	Asian	Hispanic
Lecture-Based 2010-2011	107 (42.8)	143 (57.2)	223 (89.2)	11 (4.4)	6 (2.4)	5 (2.0)	5 (2.0)
Software-Enhance 2012-2013	98 (39.2)	152 (61.8)	221 (89.4)	15 (6.0)	4 (1.6)	4 (1.6)	6 (2.4)

Note. Percents appear in parentheses. Lecture-based sample size n = 250. Software-enhanced sample size n = 250

Table 2 also shows the ethnicity of the sample groups. These statistics are in line with OTC’s institutional population data which reports ninety percent of its students are white, six percent of the students are of other races, and four percent are of unknown ethnicity (NCES, 2014). Therefore, the researcher concluded that the gender and ethnicity of the subjects in the two samples were similar enough to the general population of students that validity of the conclusions would not be affected by student ethnicity.

The comparison of demographic variables continues with enrollment status and first generation. Unlike many other demographic variables, enrollment status can change during the semester. Students may begin the semester with a full time course load and change to part time

status if they drop a class. To create consistency in counting, enrollment status was determined by the identified intent of the student at the time of registration.

The sample selection resulted in six percent more students registered as full time during the software-enhanced semesters. This difference, however, was not large enough to suggest that the percent of full-time students in the lecture-based semesters was significantly higher than the percent of full-time students during the software-enhanced semesters; $z=-1.6039, p=0.1087$.

The sample data are listed in Table 3.

Table 3
Enrollment Status and First Generation Separated by Instructional Method During the Lecture-Based 2010-2011 and Software-enhanced 2012-2013 Academic Years at OTC.

Instructional Method	Enrollment Status		First Generation	
	Part Time	Full Time	No	Yes
Lecture-Based 2010-2011	64 (25.6)	186 (74.4)	226 (90.4)	24 (9.6)
Software-Enhanced 2012-2013	49 (19.6)	201 (80.4)	227 (90.8)	23 (9.2)

Note. Percents appear in parenthesis. Lecture-based sample size $n = 250$. Software-enhanced sample size $n = 250$

In addition to enrollment status, Table 3 listed the percent of self- identified first generation students. The percent of first generation students was nearly identical between the two groups and the researcher decided this variable would not compromise the conclusions of this study.

The final demographic variable compared in this study was placement. At OTC, students typically place into basic algebra using one of three metrics. For new students, either their ACT score or the COMPASS exam score determined placement. Many returning students placed into basic algebra because they completed pre-algebra. Like basic algebra, A or B grades were necessary for students to successfully complete pre-algebra. Table 4 shows the placement data for the two samples.

Table 4
Sample Statistics for Student Placement Separated by Method of Instruction During the Lecture-Based 2010-2011 and Software-Enhanced 2012-2013 Academic Years at OTC.

Instructional Method	Placement Method		
	ACT	COMPASS	Prerequisite Course
Lecture-Based 2010-2011	74 (29.6)	134 (53.6)	42 (16.8)*
Software-Enhanced 2012-2013	66 (26.4)	115 (46.0)	69 (27.6)*

Note. Percents appear in parenthesis. Lecture-based sample size $n = 250$. Software-enhanced sample size $n = 250$. * $z = -2.905$, $p = .0037$

There was not a significant difference in the percent of ACT placement in the lecture-based instructional method (29.6%) when compared to the percent of ACT placement in the software-enhanced classes (26.4%) in the two samples; $z = 0.7968$, $p = .4255$. Similarly, there was not a significant difference in the percent of COMPASS placement in the lecture-based

instructional method (53.6%) when compared to the percent of COMPASS placement in the software-enhanced classes (46.0%) in the two samples; $z=1.699$, $p=.0892$.

Unlike the ACT and COMPASS placement, there was a large difference in the percentage of students who took the pre-algebra class in the two samples. Nearly 11% more of the sample completed the pre-algebra course in the software-enhanced semesters. This suggested a higher percentage of the population took the prerequisite course during the software-enhanced semesters. This difference could have an impact on the conclusions of the hypothesis tests. The prerequisite course was designed to remediate students in their deficiencies in order to help them succeed in their next math classes. It is possible that some of the higher success rates during the software-enhanced semesters were the result of the remediation in pre-algebra.

To summarize, these comparisons suggested that there were very few differences between the two sample groups on the demographic variables of age, gender, ethnicity, enrollment status, first generation, and math placement. Thus, the researcher concluded the two samples would provide useful information to collect further data.

Data Collection Procedures

The research hypotheses of this study were explored through several assessments of student performance. This section describes the process used to collect the data on the sample of students.

Retention and Success rates

The first two hypotheses addressed retention rates and success rates. The Office of Institutional Research at OTC was able to provide population data. The data, however, included all sections of basic algebra. The sample drawn for the study came from a subpopulation of

instructors who taught using both methods of instruction. Both population data and sample data were collected and compared.

As stated earlier, the retention rate was a percentage measure of the rate at which students persisted through the semester. It was calculated by dividing the number of students who received a grade at the end of the semester by the number of students enrolled on the census date at the beginning of the semester. OTC's census date was the Friday of the fourth week of the semester. The complement of this percentage described the withdrawal rate of students in developmental math courses at OTC.

The success rate was also a percentage measure. It described the rate at which students successfully completed the course and satisfied the prerequisites of the next math course. This percentage was calculated by dividing the number of students who earned an A or B grade in the course by the number of students who were retained for the duration of the semester. Students who withdrew from the course were not included in this statistic.

Exam Scores

Student success on exams was the focus of the third and fourth hypotheses. These data were collected from instructor gradebooks and student-completed final exams.

At the end of each semester, instructors submitted a copy of their gradebooks to division secretaries who archived them electronically. Gradebooks included unit exam scores, final exam scores, and homework scores. The researcher obtained access to the electronic copies of the gradebooks and recorded the scores.

The accuracy of the gradebook scores was trusted for several reasons. The mathematics department of OTC takes careful steps to mitigate the effects of instructor differences by providing all instructors with common schedules, common homework assignments, and core

final exams. Instructors submit their unit exams to the designated “course lead instructor” who provides feedback on the level of rigor, breadth of objectives, and point distributions prior to having students take the test. This ensures that each unit exam matches the departmental expectations.

In the fall 2011 semester, the department changed its approach to a few of the course objectives. During the traditional method of instruction semesters, “factoring polynomial expressions” and “solving polynomial equations by factoring” were mastery objectives for the course. On the other hand, these same objectives changed to introductory topics during the software-enhanced semesters. The objective of “solving systems of equations” during the traditional method of instruction semesters was replaced by expanded coverage of “applications of linear equation in two variables,” “solving literal equations for a specified variable,” and “applications of slopes”. As a result, only three of the four tests had one-to-one correspondence to course objectives prior to the redesign efforts. The investigator used the student exam scores from instructor gradebooks for these tests only.

The adjustment to course objectives also changed some of the problems on the departmental core final exam. Raw final exam scores from instructor gradebooks did not provide useful data and the final exams were rescored for this study. The researcher used the OTC math department rubric to grade the final exams on the common objectives identified in Appendix A. The rubric is shown in Table 5.

Table 5
Scoring Guide for Problems on the Final Exams. Points Earned Quantified the Level of Mastery.

Criteria	Points Earned
Correct answer is given and most of the appropriate steps are clearly stated.	6
Incorrect answer due to one minor computational mistake.	5
Incorrect answer is given and most steps are stated but contain minor computational mistakes and possible one conceptual error. -or- Correct answer is given, but few, if any of the appropriate steps are stated.	4
Incorrect answer is given, and most of the steps are stated but contain two procedural/conceptual errors.	3
Incorrect answer is given, and most of the steps are stated but contain more than two procedural/conceptual errors.	2
Incorrect answer is given with some steps stated; however, most steps indicate a lack of conceptual understanding -or- Incorrect answer with few steps stated.	1
Other	0

The researcher collected student completed final exams from the instructors at the end of each semester. Earlier versions of the final exam included a stronger emphasis on “factoring polynomial expressions” and “solving polynomial equations by factoring”. Appendix A shows the objectives assessed on the final exam during the lecture-based semesters and the computer-enhanced semesters. The researcher compared the student-completed final exams on common objectives that were present for both methods of instruction. This also controlled for any differences in the emphasis of the problem types.

Threats to Validity

Threats to internal validity can compromise a researcher’s statements about cause and effect relationships. Threats to external validity limit the ability to generalize the result of a study to another context (Creswell, 2008). This section addresses several internal and external threats to validity.

The first threat to internal validity is *selection*. This threat occurs when differences in people introduce unintended bias that may influence the outcomes of the study. A researcher’s identified relationships may be the result of a confounding variable instead of the independent variable being studied (Creswell, 2008). A rigorous attempt was made to ensure the sample groups were similar in all aspects except for the method of instruction in this study. The groups were compared on several demographic variables and found very little differences between the samples. The percent of students who took the prerequisite course was the only variable that was statistically different. This variable may have influenced the performance of students in the computer-enhanced semesters and may have a minor impact on the validity of this study.

The inability to manipulate the independent variable can pose a threat to validity. It is a frequent problem in educational research designs (Cresswell, 2008). Often, random assignments

would disrupt the learning environment or are impossible. While the selection of students from each grouping variable was randomized, the students themselves were not randomly assigned to the groups. OTC did not offer both modes of instruction during the same semester. Therefore, the participation in the control group or the treatment group was solely a factor of the semester the student chose to take their developmental mathematics course. Additionally, this study was conducted *ex post facto*. The causal-comparative approach to research uses pre-existing conditions. Therefore, the lack of randomization of the independent variable may pose a threat.

Cresswell (2008) identified *instrumentation* as another potential threat to validity.

Instrumentation is a concern when the assessments used to measure the dependent variable change over time. To mitigate the effects of this threat to validity, Creswell (2008) emphasized the importance of establishing a standardized procedure throughout the experiment.

Instrumentation proved to be a significant threat to the validity of this study. The researcher limited the effects of this threat by only collecting data on the exams that covered the same material. Likewise, rigorous steps were taken to minimize the effects of these changes on the final exam scores.

The goal of the causal-comparative design is to uncover possible relationships for further study. It is possible that confounding variables influenced the dependent variables used to measure student performance. For example, personal issues affect students' ability to remain enrolled in school and be successful. These external factors may be positive and provide additional support to increase success. On the other hand, problems beyond the classroom may lead to student failure or withdrawal from the course. In short, some students would be successful regardless of the method of instruction. These confounding variables were beyond the scope of this study and not assessed.

While the conclusions from this research may not demonstrate a cause and effect relationship, causal-comparative studies often identify variables worthy of experimental study or identify the probable outcome of such studies (Gay, Mills, & Airasain, 2009).

Chapter Summary

This chapter provided an overview of the research design and described the location for the study. The target population was too large, so this chapter outlined the steps taken to select the sample. Finally, this chapter compared several demographic variables of the samples to ensure the groups were alike and addressed additional validity concerns. Chapter four will present the findings of the research on student performance.

CHAPTER FOUR

RESULTS

This chapter presents the findings of this study. First, an overview of the study summarizes the purpose statement, the selection of participants, and the data collection procedures. Next, the research hypotheses are answered and inferential statistics and data are presented in tables. Finally, a summary of the findings concludes this chapter.

Overview of the Study

The purpose of this causal-comparative study was to compare the performance of students receiving web based software-enhanced instruction with the performance of students receiving lecture only instruction in terms of retention rates, success rates, test grades, and final exam scores for developmental mathematics courses at Ozarks Technical Community College in Springfield, MO.

The researcher randomly selected 250 subjects from the population of students experiencing software-enhanced instruction during the 2012-2013 academic year and 250 subjects from the population of students experiencing lecture only instruction during the 2010-2011 academic year. Several demographic variables were compared to test for intervening variables. The researcher determined there was little difference between the two sample groups in terms of average age, gender, ethnicity, enrollment status, first generation, and math placement. Chapter Three contained a detailed description of these comparisons.

Data for the research hypotheses were collected *ex post facto* by reviewing institutional records, instructor gradebooks, and student completed final exams. Retention rate and success rates were obtained from institutional population records and for the sample. Scores for unit

exams were collected by accessing electronic copies of instructor gradebooks. Final exams grades were determined from student completed tests rescored by the researcher.

Presentation of the Data

This section presents the findings of the four research hypotheses listed in Chapter One. All statistical tests were conducted with an alpha level of .05; therefore, any *p*-value less than .05 was determined to be significant.

Hypothesis One

The first hypothesis focused on the retention rates of students in the basic algebra classes. It claimed that developmental mathematics courses using web based software-enhanced instruction would have higher course retention rates than courses using lecture-based methods of instruction at OTC.

At the time of this study, the college's Office of Institutional Research annually reported the retention rates of students in developmental math courses. These data were made available to the mathematics department and the researcher. Retention rates were calculated by dividing the number of students who received a grade at the end of the semester by the number of students enrolled on the census date at the beginning of the semester. The complement of this percentage was the withdrawal rate of students in developmental math OTC.

Table 6 shows the retention rates and withdrawal rates for the population of students enrolled in basic algebra along with the sample statistics during the 2010-2011 and the 2012-2013 academic years.

Table 6

Sample Statistics and Population Data for Retention Rates of Basic Algebra Students Separated by Instructional Method During the Lecture-Based 2010-2011 and Software-Enhanced 2012-2013 Academic Years at OTC

Instructional Method	Sample Statistics			Population Data		
	n	Retention Rate	Withdraw Rate	N	Retention Rate	Withdraw Rate
Lecture-Based 2010-2011	250	202 (80.8)	48 (19.2)	3674	2803 (76.3)	871 (23.7)
Software-Enhanced 2012-2013	250	207 (82.8)	43 (17.2)	3812	2936 (77.0)	876 (23.0)

Note. Percents appear in parenthesis. n = Sample size. N = Population size.

The sample statistics and population data showed only small improvements in retention rates. In the sample, two percent more of the software-enhanced students were retained when compared to the lecture-based sample group. Population records indicated a much smaller improvement in retention rates. The researcher concluded this difference was not large enough to suggest the retention rates in the software-enhanced semesters were higher than the retention rates in the lecture-based semesters; $z=0.5795$, $p=.2811$. The next hypothesis explored the success of these students retained through the semester.

Hypothesis Two

The second hypothesis claimed that developmental mathematics courses utilizing web based software-enhanced instruction would have higher success rates than courses using lecture-based methods of instruction. At the time of the study, OTC students needed an A or B grade at

the end of the semester to progress to their next math course. The success rate was determined by dividing the number of students who earned an A or B grade at the end of the semester by the number of students who were retained for the duration of the semester. The complement of this percentage is the failure rate which was calculated using C,D,F grades. Students who withdrew from the course were not included in this percentage.

Success percentages were another statistic reported by OTC’s office of institutional research and the population data were provided to the researcher. Success rates in both the sample and the population records increased by nearly 12 percent after the redesign. Table 7 displays the findings.

Table 7
Population Data and Sample Statistics for Success Rates and Failure Rates of Basic Algebra Students Separated by Instructional Method During the Lecture-Based 2010-2011 and Software-Enhanced 2012-2013 Academic Years at OTC.

Instructional Method	Sample Statistics			Population Data		
	n	Success Rate	Fail Rate	N	Success Rate	Fail Rate
Lecture-Based 2010-2011	202	109 (54.0)	93 (46.0)	2803	1366 (48.7)	1437 (51.3)
Software-Enhanced 2012-2013	207	139 (67.1)	68 (32.9)	2936	1769 (60.3)	1167 (39.7)

Note. Percents appear in parenthesis. n = Sample size. N = Population size.

A comparison of the sample data was conducted using an alpha = .05 level of significance. The researcher concluded that there was enough evidence to suggest that the

success rates for computer-enhanced basic algebra classes was significantly higher than the success rates of lecture-based basic algebra classes at OTC; $z=3.5058$, $p=.0002$. In terms of the population of students, over 300 more students were successful after the redesign to software-enhanced instruction.

To answer the first two hypotheses, the researcher was able to obtain sample and population data. However, OTC's Office of Institutional Research does not collect data from instructor gradebooks. Therefore, the final two hypotheses were answered with the sample data only.

Hypothesis Three

The third hypothesis of this study addressed student success on the unit exams and claimed students in web based software-enhanced developmental mathematics would have higher unit test grades than students in lecture-based developmental mathematics courses at OTC.

At the time of this study, OTC basic algebra courses were partitioned into three units. Instructors gave exams as the culminating assessment for each unit. To answer this hypothesis, the researcher compared the results of each unit exam for the lecture-based academic year with the results for the software-enhanced academic year. The data for the unit exams are listed in tables 8 through 11.

In the first unit of basic algebra, students learned the concepts of solving linear equations and inequalities in one variable. Students practiced the topics of the order of operations, distributive property, and combining like terms. They used the properties of equality to clear fractions, clear decimals, and solve literal equations. Finally, students learned to apply these

skills and concepts in the context of inequalities and used interval notation to write their solutions. Table 8 shows the mean and standard deviation for the first unit test.

Table 8
Unit One Test Scores for Basic Algebra Students Separated by Instructional Method During the Lecture-Based 2010-2011 and Software-Enhanced 2012-2013 Academic Years at OTC.

Instructional Method	n	Mean	SD
Lecture-Based 2010-2011	211	83.95%	14.98%
Software-Enhanced 2012-2013	213	81.09%	13.93%

Note. n = sample size, SD = Standard Deviation

A random sample of 250 students was selected from each instructional method for this study; however, not all subjects had a score for the first unit test. This exam occurred during the 5th week of the semester. By this time, nearly 15% of the sample of students in each group had dropped the course.

Contrary to the original hypothesis, students in the software-enhanced courses had a lower unit one test average when compared to students in the lecture-based courses. Furthermore, statistical tests determined that the difference in scores was significantly lower; $t = -2.042, p = .0209$. There was enough evidence to generalize that students scored lower on the first unit test in the software-enhanced classes when compared to the first unit test in the lecture-based courses.

In the second unit of basic algebra, students learned the concepts of analyzing and graphing linear equations in two variables. Students plotted points on the Cartesian coordinate system, identified intercepts of graphs, and named ordered pairs from a graph. Next, they learned to use the Cartesian plane to represent the solutions to an equation in two variables and used the intercept method and the slope-intercept method to graph. Students evaluated the slope of a line and used the formula for finding slope. Students practiced the concept of writing the equation that satisfies a given set of conditions and used these ideas to solve application problems of linear models. Finally, the course applied the topics of slope and intercepts into contextual applications.

The second unit exam occurred near the 10th week of the semester. Only three additional sample students withdrew between the first and second unit exams. Summary data for the unit two exam are found in Table 9.

Table 9
Unit Two Test Scores for Basic Algebra Students Separated by Instructional Method During the Lecture-Based 2010-2011 and Software-Enhanced 2012-2013 Academic Years at OTC.

Instructional Method	n	Mean	SD
Lecture-Based 2010-2011	210	74.86%	17.56%
Software-Enhanced 2012-2013	211	78.0%	18.43%

Note. n = sample size, SD = Standard Deviation

On this exam, the original hypothesis appeared to be correct. The sample of students scored a higher average in the software-enhanced classes when compared to the lecture-based sample of students. The difference in scores was large enough to be statistically significant; $t=1.790, p=.0371$. From these results, there was enough evidence to suggest that the average student score during the software-enhanced semesters was higher on the exam over analyzing and graphing linear equations in two variables.

To finish this hypothesis test, the researcher compared the unit three test scores. The mean and standard deviation for each instruction method are shown in Table 10.

Table 10
Unit Three Test Scores for Basic Algebra Students Separated by Instructional Method During the Lecture-Based 2010-2011 and Software-Enhanced 2012-2013 Academic Years at OTC.

Instructional Method	n	Mean	SD
Lecture-Based 2010-2011	205	74.40%	18.98%
Software-Enhanced 2012-2013	209	78.93%	18.36%

Note. n = sample size, SD = Standard Deviation

The third unit in the basic algebra courses at OTC covered operations with polynomials and exponents. Students practiced simplifying multivariate algebraic expressions with integer exponents. They simplified algebraic expressions using multiple properties of exponents in a single problem. Students extended their understanding of exponents in the context of polynomials. This unit also focused on combining polynomials using the operations of addition, subtraction, multiplication and division. The unit ended with an introduction to the methods of factoring polynomial expressions. The unit three exam was administered during the 15th week of

the semester. At this point, 83% of the students in the original sample were still enrolled in their class. The original hypothesis claimed that students would score better in the software-enhanced classes. The sample statistics for the third unit test also supported this claim and a comparison of the data was conducted using inferential statistics. The researcher determined there was statistically significant evidence to suggest that the students' scores for unit test three were higher in the software-enhanced semesters when compared to the students in the lecture-based courses; $t=2.4676, p=.0070$.

In summary, the third hypothesis of this study had three components. Test scores were collected from instructor gradebooks and compared for each unit test. Statistical tests were conducted individually because students withdrew from the class as the semester progressed. As a result, the sample size decreased with each exam. Table 11 shows the findings of the three parts to this hypothesis.

Table 11
Unit Exam Results for Basic Algebra Students Separated by Instructional Method during the Lecture-Based 2010-2011 and Software-Enhanced 2012-2013 Academic Years at OTC for Each Unit Test.

Exam	Lecture-Based 2010-2011	Software-Enhanced 2012-2013	<i>t</i>	<i>df</i>
Unit Test One	83.95 (14.98)	81.09 (13.93)	-2.042*	417
Unit Test Two	74.86 (17.56)	78.00 (18.83)	1.790*	418
Unit Test Three	74.40 (18.98)	78.93 (18.36)	2.468**	411

Note. Standard Deviation appears in parenthesis, *= $p < .05$, ** = $p < .01$

A comparison of the three unit test averages showed that scores rebounded after an initial drop on the first unit test. Even though the first unit test average was significantly lower, the second and third unit tests were significantly higher. Overall, it appeared that student exam scores improved slightly after the redesign.

Hypothesis 4

The final hypothesis of this study claimed that students in web based software-enhanced developmental mathematics at OTC would have higher final exam scores than students in lecture-based developmental mathematics. Of the original sample selected for this study, nearly 72% of the lecture-based students completed the final exam and 79% of the computer-enhanced students completed the final exam. These grades were converted to percentages and the summary statistics are provided in the following table.

Table 12
Final Exam Scores for Basic Algebra Students Separated by Instructional Method During the Lecture-Based 2010-2011 and Software-Enhanced 2012-2013 Academic Years at OTC.

Instructional Method	n	Mean	SD
Lecture-Based 2010-2011	181	68.82%	21.47%
Software-Enhanced 2012-2013	198	69.58%	22.16%

Note. n = sample size, SD = Standard Deviation

To collect these data, the researcher examined student-completed final exams submitted by the instructors at the end of each semester. A few of the assessed topics on the final exam changed after the redesign. Only objectives that were assessed during the lecture-based academic

year and during the software-enhanced semesters were used in the rescoring of the final exams. Appendix A shows the list of the common objectives.

The sample final exam averages were very similar and the difference of the two means was not found to be statistically significant; $t=.3390$, $p=.3674$. The researcher concluded there was not enough evidence to suggest that final exam scores improved with the implementation of software-enhanced instructional methods.

Chapter Summary

The goal of this study was to compare the retention rates, success rates, unit exam scores and final exam scores of the students experiencing traditional lecture-based instruction to students in software-enhanced courses. For each measure of student performance a hypothesis assumed that student performance would improve after the implementation of software-enhanced instruction. Sample statistics were compared with the population data provided by the college's Office of Institutional Research. After reviewing the data, the researcher formed four conclusions: (a) course retention rates were not impacted after redesigning the developmental algebra courses; (b) success rates increased after the implementation of software-enhanced instruction; however, the improved rate may not have been fully attributed to the redesign; (c) the effects on unit exam scores were mixed with lower scores on the first test and higher scores on the second and third exams; (d) software-enhanced instruction did not significantly improve final exam scores. The final chapter of this paper will summarize these findings in the context of existing research, provide recommendations for future studies and offer suggestions for improved practice.

CHAPTER FIVE
FINDINGS, CONCLUSIONS, and RECOMMENDATIONS

Introduction

This chapter provides an overview of the research design, summarizes the findings of the study, and discusses the conclusions of the researcher. In the overview of the study, the purpose statement, setting for the study, and participant information are reviewed. Next, the findings related to the hypotheses are presented. The conclusions section presents the findings of this study in the context of earlier research. Finally, the chapter concludes with recommendations for improved practice, and a list of suggestions for further research.

Overview of the Study

Over half of entering community college students are underprepared for the academic rigor of higher education and assigned to multi-semester developmental education programs each year (NCSL, 2014; Noel-Levits, 2008). Some students benefit from developmental math programs; however, the vast majority either drop-out, stop-out, or fail-out of the coursework. Reports have found only 16% of the entering cohort of developmental students ever finish their gateway math course (Bailey, Jeong, Cho, 2010). Many of these students never receive a degree or certificate because they did not complete their college-level math requirement.

The growing financial cost of developmental education is unsustainable. In the last decade, estimates for the cost of developmental education climbed from one billion dollars in 2004 to over seven billion dollars in 2014 (Kolajo, 2004, Strong American Schools, 2008, Scott-et al., 2014). Students, colleges, and tax payers invest too many resources in light of the poor success rates. Pressures to decrease expenses, while improving the retention and success of

students, have caused many colleges to rethink their approach to remediation (Bettinger and Long, 2004; Trenholm, 2006; Bailey, 2009; Stigler, Givvin, & Thompson, 2010).

Redesigned math courses integrate computer-based learning and are an evolving trend in developmental math. These programs individualize learning, provide only the topics the student is ready to learn, assess students' understanding of current objectives, and test their retention of former learning. Software developers continue to improve the technology to make the programs more effective for students and instructors. Many colleges have adapted their traditional lecture-based classrooms to utilize the current technology to improve learning and assessment of the course objectives.

The implementation of these redesigns varies across institutions. The culture and climate of the organization greatly influence the model that works best at each school. Some courses are highly structured and other classes are self-paced. Some instructors utilize the software as homework management systems. Other professors turn the instruction over to the computer software and view their role as a classroom facilitator. Ultimately, the methods used to teach and assess mathematics are changing.

This causal-comparative study was designed to compare the performance of students receiving web based software-enhanced instruction with the performance of students receiving lecture only instruction in terms of retention rates, success rates, unit test grades, and final exam scores for developmental mathematics courses at Ozarks Technical Community College in Springfield, MO.

Ozarks Technical Community College is a multi-campus two-year college in southwest Missouri. Established in 1990, the college has grown to three full-service campuses and two education centers. At the time of this study, the enrollment exceeded 15,000 students. During

the expansions, the college maintained a unified approach to serving its students through a strong governance structure. Administrative, curricular, and departmental decisions were primarily made at the Springfield campus and disseminated throughout organization.

In 2010, the developmental mathematics program at OTC consisted of two courses, pre-algebra and basic algebra. Only 39% of students passed their developmental mathematics that year. To address these low success rates, the OTC mathematics department considered supplementing traditional lecture-based instruction with web based software-enhanced instruction in their developmental algebra courses. The math faculty conducted a limited pilot program using the ALEKS software in the fall 2010 semester and found many positive outcomes for both students and faculty members. Students appreciated the immediate feedback from the ALEKS program and showed improved attitudes toward math. The faculty members were able to provide individualized instruction on relevant objectives because the software directed students to the topics that needed extra practice. Because of the successful pilot, the department began using the software in all pre-algebra and basic algebra courses in the fall of 2011.

Several methods of computer integration into math classrooms were researched once the department decided to scale the redesign of computer-aided instruction into all of its developmental classes. A software-enhanced model of instruction that utilized 50% of the class time for computer instruction and 50% of the time for traditional lectures and assessments was selected. Assessment and Learning in Knowledge Spaces (ALEKS) software was selected for the computer-aided component of the redesign because of its ability to integrate with the textbook used at the time, and its accessibility to students through the internet.

The causal-comparative research methodology described by Gay, Mills and Airasain (2009) guided this study. This research design examines potential relationships through the

exploration of existing data. It was selected because the traditional lecture-based instruction and software-enhanced instruction developmental math courses were not offered during the same semesters at OTC. The researcher collected and analyzed all data *ex post facto*. Gay, Mills and Airasain (2009) classified causal-comparative studies as non-experimental descriptive research used to conduct a systematic inquiry into preexisting conditions.

Prior to conducting any research, approvals were obtained through the Institutional Review Board for both Ozarks Technical Community College and the University of Arkansas. The provost of Ozarks Technical Community College provided a letter of support.

This study used data from a stratified random sample of 500 students. To determine the sample, the OTC population of developmental math students was delimited to instructors who taught using both instructional methods. This controlled for the effects of instructor differences. A sample of 250 students was randomly selected from the 2010-2011 academic year when the traditional lecture-based method of instruction had been used. The other 250 students were randomly selected from students enrolled during the 2012-2013 academic year. This was the second year the math department used a computer-enhanced approach to teaching mathematics. This study omitted data from the 2011-2012 academic year to control for the effects of repeat students and their exposure to both methods of instruction.

In causal comparative studies, samples must be alike in all aspects except for the variable being studied. To address this issue, several demographic variables were compared. Through statistical analysis and population records, the researcher concluded that any differences in age, gender, ethnicity, enrollment status, first generation, and math placement were not extreme enough to affect the conclusions reached during the hypotheses testing. The statistical analysis of these comparisons were presented in chapter three.

Findings

Four hypotheses were stated prior to beginning the study. Inferential statistics were used to analyze the data and make conclusions regarding these hypotheses. Proportion z-tests explored differences in retention rates and success rates. Population data were collected and reported. T-tests were used to examine the differences in mean grades on unit exams and final exams. A summary of these findings are outlined in this section.

To answer the first two hypotheses, the researcher compared the data from the selected samples and data from the OTC's Office of Institutional Research.

Hypothesis One

The first hypothesis claimed the following: developmental mathematics courses utilizing web based software-enhanced instruction at OTC will have higher course retention rates than courses using lecture-based methods of instruction at OTC.

The data showed only small improvements in retention rates. In the sample, only two percent more of the software-enhanced students were retained when compared to the lecture-based sample group. Population records indicated a much smaller improvement in retention rates. The researcher concluded this difference was not large enough to support the first hypothesis of this study. It appeared the retention rates did not improve with the implementation of software-enhanced instruction at OTC.

Hypothesis Two

The second hypothesis stated: developmental mathematics courses utilizing web based software-enhanced instruction at OTC will have higher success rates than courses using lecture-based methods of instruction at OTC.

The data from this study supported the claim in hypothesis two. In the sample, 13% more students successfully completed the course with a “B” or better grade. In the population of students, nearly 12% more students were successful after the redesign to software-enhanced instruction. This improvement was large enough to be considered statistically significant. The researcher concluded that success rates in OTC’s developmental math courses improved after the implementation of software-enhanced instruction.

The final two hypothesis could only be answered through the sample data collected by the researcher.

Hypothesis Three

The third hypothesis claimed: students in web based software-enhanced developmental mathematics at OTC will have higher unit test grades than students in lecture-based developmental mathematics courses at OTC.

To address the statement in hypothesis three, the researcher compared the results of each unit exam. Test scores were collected from instructor gradebooks and compared using separate statistical tests. Contrary to the original hypothesis, the average score for the first unit test was lower after the courses were redesigned to the software-enhanced model. The second and third test averages rebounded and were higher in the software-enhanced semesters. In each case, the differences in the unit test averages were statistically significant. Overall, the researcher concluded the net unit test averages improved with the implementation of the software-enhanced course redesign.

Hypothesis Four

Hypothesis four stated: students in web based software-enhanced developmental mathematics at OTC will have higher final exam scores than students in lecture-based developmental mathematics courses at OTC.

The final hypothesis compared the student complete final exams rescored by the researcher. Final exam averages were nearly the same for the sample of students experiencing lecture-based instruction and the sample of students in software-enhanced courses. The researcher concluded that there was not enough evidence to support the claim that the final exam scores improved after the redesign.

Conclusions

The following section discusses the results of this study in the context of earlier research. Direct comparisons of this study to any former research was impossible because of limitations, delimitations, setting and research methodology. Some of the earlier research focused on the effects of self-paced programs in large computer labs. Other studies researched the effects of software as a homework management tool. The computer-enhanced project at OTC blended the two extremes in an attempt to balance self-paced practices with traditional instruction. In short, the implementation of computer instruction in developmental math classes varies between institutions. It is possible, however, to identify trends in the impact of computer-aided instruction and this study adds to that understanding. This section organizes the discussion by comparing the current findings with earlier studies on retention, success, unit exam scores, and final exam scores in computer-aided developmental math classrooms.

First, student retention rates in developmental algebra do not improve with the implementation of computer-aided instruction.

The findings on student retention rates in software-enhanced courses at OTC were similar to the majority of findings of earlier studies about the impact of retention rates in computer-aided courses discussed in chapter two. OTC's retention rates did not improve with the implementation of the software-enhanced program. Many earlier studies had similar conclusions (Ha, 2014, Stillson and Alsup, 2003; Brothen and Wambach, 2000; McSweeney, L, 2003, Nguyen, 2002; Olusi, 2008).

In contrast, two former studies found improved retention rates in computer-aided math courses when compared with traditional lecture-based math courses (Teal, 2008; Kinney and Robertson, 2003). Teal's 2008 quasi-experimental study was conducted at a suburban community college in the mid-Atlantic region. This study included 152 students who self-selected into a software-enhanced course or a traditional instruction course. The researcher concluded computer-aided courses had higher retention rates. In Kinney and Robertson's (2003) study, developmental students were allowed to choose between traditional lecture courses and software enhanced courses. Placement exams and information on the two methods of instruction helped students self-select their participation in the treatment or control groups. The researchers determined that students in computer-aided courses were less likely to withdraw.

The conflicting conclusions between these earlier studies and the current study could be a result of differences in sampling methodology. Both Teal's (2008) and Kenney and Robertson's (2003) studies allowed students to self-select their method of instruction. This may have inadvertently introduced additional variables such as motivation, learning styles, and attitudes. In contrast, student participation in the control group or treatment groups of this study was determined by the year they chose to register for their developmental math course. Thus,

students were unable to self-select their method of instruction because the two instructional strategies were not offered during the same semester.

Second, success rates increase significantly in developmental algebra courses when redesigned to use computer-aided instructional strategies.

The findings on success rates may be the most significant result of this study. Prior to the redesign, population records indicated only 49% of students passed their basic algebra course. After the implementation of the software-enhanced methodology, over 60% of students passed their basic algebra course. The percent increase translated to nearly 300 more students successfully completing the course after the redesign.

Earlier studies also found improved success rates. Brocato (2009) conducted a multi-semester review of student performance at a small community college in southern Mississippi. Success data were collected over seven semesters of algebra courses taught using traditional lecture-based instruction and compared with data collected over six semesters on student retention and success in computer-aided instruction. Brocato (2009) found a significant increase in the end-of-course grades in the computer-aided instruction semesters. Kodippilli and Senaratne (2008) also explored the effects of computer-aided instruction on final course averages and pass rates for students at Fayetteville State University. The researchers randomly selected intact classes to participate as the control group and treatment groups. The control group followed a traditional math classroom and the treatment group completed homework assignments through the use of the online software. They concluded that the pass rates were significantly higher in the computer-aided courses. These findings were similar to the conclusions of the current study.

Third, test grades improve in developmental algebra courses when redesigned to use computer-aided instructional strategies.

One former study that closely paralleled the parameters of this study was Mahmood's 2006 research on the effects of integrating computer-assisted instruction with traditional instruction. In this earlier study, students in the computer-aided instruction classroom outperformed the control group with significantly higher test scores than the students in traditional instruction courses (Mahmood, 2006). Like Mahmood's findings, this study also found overall improved test scores after the implementation of computer-aided instruction. At OTC, two of the three unit test averages improved in the software-enhanced semesters. Students average scores increased by nearly 4% on the unit exams after the redesign.

Fourth, final exam averages in developmental algebra do not improve with the implementation of computer instruction.

The findings related to student average scores on the final exam in this study closely aligned with the conclusions of earlier research. Like Kodippilli and Senaratne's (2008) study at Fayetteville State University, students completing software-enhanced basic algebra course had increased success rates even though there was no significant improvement in final exam scores. Likewise, Burch and Kuo (2010) found modest increases in unit exam scores but increases in the final exam grades were not statistically significant. Finally, Kinney and Robertson (2003) did not find improved final exam scores when they compared the test averages of students in software enhanced courses and traditional lecture-based classes. The results of this study were similar to these earlier conclusions. The average final exam scores in developmental algebra did not appear to change after the redesign to computer-enhanced instruction.

In summary, while a large amount of research exists on the use of computers as an instructional tool in the classroom, the effects of adaptive software instruction has shown mixed results. The mixed results are partially due to the variety of implementation strategies and the research methodologies used to evaluate the outcomes. Some research presented in this chapter studied the effects of software used as a homework management tool and did not utilize the computers in the classroom. In the other extreme, some studies explored the effects of self-paced open computer lab math courses where students worked at their own pace. When drawing conclusions about the effectiveness of computer-aided instruction in basic algebra, one should keep these differences in mind. At Ozarks Technical Community College, the math department redesigned these courses to allocate 50% of the instructional time for web-based computer instruction and used the remaining 50% of instructional time for traditional lecture-based instruction and assessment of course objectives.

Recommendations for Improved Practice

While this research did not establish a cause and effect relationship between the method of instruction and student success, this study provides useful data as colleges continue to develop instructional strategies in improve student success. Gay, Mills and Airasian (2009) stated that even though conclusions from causal-comparative research designs may not yield a cause-effect relationship, these studies often suggest variables worthy of further study. From the results of this research, the first six recommendations for improved practice were formed. Three additional recommendations were formed from the review of research and practices similar to this current study. These nine recommendations are enumerated below.

1. Developmental algebra courses should integrate the use of computer-aided instruction strategies. This study found improved success rates in both sample statistics and

- population records. Once the OTC math department adopted a software-enhanced model, the school experienced almost a 12% increase in the number of students who passed the class.
2. To successfully scale new programs, colleges should provide faculty training in the use of computer-aided instructional strategies. Summer seminars were a key component to the implementation of OTC's redesign efforts. Training helped adjunct instructors adapt to the new format to teaching developmental algebra.
 3. Departments should acclimate students to any new techniques of learning math. Many students expect their math class to be like all their other experiences in the math classroom. They are surprised when they walk into a computer lab on the first day of school. OTC students in the software-enhanced semesters scored lower on the first unit test than expected. These same students did better on exams given later in the semester. It is likely the lower scores on the first test were not a result of their learning in ALEKS but rather a reflection of a "learning curve" in adapting to a new way of doing math.
 4. Instructors should utilize the assessment tools provided by the software and adapt their teaching accordingly. A myriad of assessment data are embedded in most internet-based software programs. These allow teachers to closely monitor students' progress. For example, early intervention strategies can be formed for students who are off-track and instructor reports can quickly identify concepts that are difficult for students. Teachers can then pair students in similar stages of learning to create support networks. The analytics provided with the software make it possible to adapt

- the course material to the student's needs in ways not feasible in a traditional classrooms.
5. Assessment measures embedded in the software should be used to calculate end-of-course grades. The typical method of calculating students' end-of-course math grades primarily rely on unit tests and final exam scores. Prior to the redesign, daily practice work had little impact on students' grades at OTC. Previous formulas used to calculate grades created a high stakes environment for passing a class. In contrast, software-based homework assignments were tailored to the students' understanding of math content that algorithmically generated unique problems for each student's homework. Additionally, professors are able to observe the students practice the homework on the software during class time. In summary, daily coursework provided an additional measure of the student's understanding of math and should be used in calculating grades.
 6. The initial assessments in computer-aided algebra courses should be used in college placement practices. Prior to beginning a course, the software assesses the students understanding of the math topics to be learned. This assessment guides the software to construct the course topics for the students to practice. However, this additional measure of students understanding could be used to determine the accuracy of their placements. Students who score high on their initial assessment should be reassigned to a higher course.
 7. Math software should be used to accelerate students through the developmental math curriculum. The traditional length of time required for students to complete multiple semester-long courses often prevent them from completing college level math. Math

- course redesigns have shown success when students work independently through the material and are able to focus their learning on their deficient skills identified by the software. This allows them to complete multiple levels of coursework in one semester.
8. Institutions must do a better job of communicating the importance of placement test to students. Without this knowledge, too many students are underprepared to take the test, they score below their proficiency, and are directed into a sequence of developmental coursework.
 9. Colleges must overcome their reluctance to change. Unfortunately, the best practices coming from rigorous research are seldom implemented at an institutional level and educational reform movements have had limited success at changing the American classroom (Higbee, Arendale and Lundell, 2005; Chung, 2005; Goldrick-Rab, 2007). “All available evidence suggests that classroom practice has changed little in the past 100 years” (Stigler and Hiebert, 2004, p. 12).

Recommendations for Further Study

This study provided evidence to support the claim that success rates and unit test averages improve with the implementation of software-enhanced developmental math programs. In the course of conducting this study, the following list of suggestions for future research was formed.

1. This study examined student achievement in classrooms where time was divided into 50% lecture and 50% computer instruction. Further research could explore this and other distributions of time.

2. Additional research is needed about the relationship between computer-aided instructional strategies and student learning styles. Does the adaptive technology of current software better match the learning styles of developmental math students? Do developmental students find resources such as text and video explanations optimize their learning?
3. Additional research is needed about the relationship between computer-aided instructional strategies and the diversity of the student body. For example, does student achievement differ for traditional aged students when compared to non-traditional aged students in computer-aided developmental algebra classes?
4. Software publishers have integrated a myriad of assessment tools into the software. More studies should be done to examine students' perceived value of these assessment tools.
5. Adaptive software such as ALEKS contains numerous measures of students' understanding of math. Do instructors use them? Do they trust the validity of these assessment tools?
6. Software publishers have added new tools to the instructor dashboard. To what extent are these tools being used? For example, do instructors utilize the early warning messages generated within the program to identify students who are at risk, and if so, does it make a difference?
7. Do colleges and universities utilize the statistical reports generated through the software for departmental or institutional assessment of student learning? Could the reports be used to generate data on departmental and institutional goals?

8. Course retention rates in computer enhanced developmental classes was a common focus in the literature. In all of these studies, retention rates were measured at the end of the semester. This study found the majority of students withdrew prior to the first test in both the traditional lecture-based semesters and software-enhanced semesters. This suggests other factors may be contributing to the withdrawal rates of students in basic algebra courses. Future research could explore this observation.

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Appendix A

Course Objectives Assessed on the Final Exam by Method of Instruction

Course objective	Lecture- Based 2010-2011	Software- Enhanced 2012-2013
Solve linear equations requiring the distribution property	Assessed	Assessed
Solve linear equations containing fractions	Assessed	Assessed
Solve linear inequalities in one variable	Assessed	Assessed
Solve compound inequalities in one variable	Assessed	Assessed
Solve a literal equation for a specified variable	NA	Assessed
Determine the intercepts of a linear equation in two variables	Assessed	Assessed
Graph a linear equation in two variables	Assessed	Assessed
Find the slope and graph of a vertical or horizontal line	Assessed	Assessed
Find the slope of a line when given two points	Assessed	Assessed
Find the slope and y-intercept of a linear equation in two variables	Assessed	Assessed
Graph a linear equation using slope and y-intercept	Assessed	Assessed
Determine if lines are parallel or perpendicular from the equation	Assessed	Assessed
Write the equation of a line when given the slope and a point	Assessed	Assessed
Solve a graphing application by interpreting slope and y-intercept	Assessed	Assessed
Identify and apply slope in the context of an application	NA	Assessed
Simplify exponents in an expression	Assessed	Assessed
Simplify negative exponents in an expression	Assessed	Assessed
Simplify exponents in an expression using multiple properties	Assessed	Assessed
Subtract trinomial expression	Assessed	Assessed
Multiply a binomial and trinomial expression	Assessed	Assessed
Square a binomial expression	Assessed	Assessed
Factor a polynomial by grouping	Assessed	Assessed
Factor a nonmonic trinomial with a greatest common factor	Assessed	Assessed
Factor a trinomial with composite leading coefficient and constant	Assessed	Assessed
Factor a difference of squares	Assessed	Assessed
Factor a sum or difference of cubes	Assessed	NA
Repeated use of difference of squares	Assessed	Assessed
Solve a quadratic equation in factored form and equal to zero	Assessed	NA
Solve a quadratic equation in standard form	Assessed	NA
Solve a quadratic equation in factored form not equal to zero	Assessed	NA
Solve a projectile motion application with quadratic equation	Assessed	NA

Note. NA indicates an objective that was Not Assessed on the final exam during that academic year.

Appendix B
IRB Approval Letter



Office of Research Compliance
Institutional Review Board

April 29, 2014

MEMORANDUM

TO: Andrew Aberle
James Hammons

FROM: Ro Windwalker
IRB Coordinator

RE: New Protocol Approval

IRB Protocol #: 14-04-693

Protocol Title: *Community College Student Achievement in Web Based Software-Enhanced Developmental Mathematics Course*

Review Type: EXEMPT EXPEDITED FULL IRB

Approved Project Period: Start Date: 04/29/2014 Expiration Date: 04/28/2015

Your protocol has been approved by the IRB. Protocols are approved for a maximum period of one year. If you wish to continue the project past the approved project period (see above), you must submit a request, using the form *Continuing Review for IRB Approved Projects*, prior to the expiration date. This form is available from the IRB Coordinator or on the Research Compliance website (<http://vpred.uark.edu/210.php>). As a courtesy, you will be sent a reminder two months in advance of that date. However, failure to receive a reminder does not negate your obligation to make the request in sufficient time for review and approval. Federal regulations prohibit retroactive approval of continuation. Failure to receive approval to continue the project prior to the expiration date will result in Termination of the protocol approval. The IRB Coordinator can give you guidance on submission times.

This protocol has been approved for 500 participants. If you wish to make *any* modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

If you have questions or need any assistance from the IRB, please contact me at 210 Administration Building, 5-2208, or irb@uark.edu.